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(Eds.)

Collaborative Systems for Smart Networked Environments

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Preface

The world of the future would comprise many smart environments, transparently enriched with sensors, actuators, and computational elements, where they together provide a complex collaborative context sensitive system. The area of collaborative systems provides an important foundation for emerging smart networked environments, wherein humans, organizations, intelligent agents, and devices can co-exist and collaborate. The main target is enhancing and facilitating the emerging collaborative applications, including security, transportation, construction, sustainability and energy management, education, government, and manufacturing. It is therefore fundamental to understand and model the structure and inter-relationships among entities within the smart environments, as well as to design and develop collaborative systems of systems addressing the functional/non-functional requirements of the targeted applications.

Advanced pervasive computing and interaction possibilities that can be offered by smart environments will enhance the abilities of their occupants and will raise the level of possibilities for their collaboration. Notions such as sensing enterprise, collective awareness, smart cities, and ambient intelligence are just some of the current expressions of these possibilities. Incorporating context awareness in the supporting infrastructures enables more effective forms of collaborative ecosystems. Furthermore, models and mechanisms that are being addressed by research and development in collaborative networks can provide more efficient ways for organizing and dealing with large collections of objects that are interconnected through the Internet.

Among the main research and development challenges in this area, governance, interoperability, emergence, and value creation can be mentioned. Furthermore, any effective solution for smart environments imposes collaboration of multiple stakeholders organized in a mix of dynamic value chain networks. Therefore, new collaborative systems need to be developed under a well-integrated socio-technical perspective. The extensive body of empiric knowledge and the size of the involved research community in collaborative networks provide a basis for leveraging the potential of new concepts and mechanisms in addressing big societal challenges and consolidating the scientific discipline on "collaborative networks." As such, this discipline is strongly multidisciplinary and thus the PRO-VE Working Conference is designed to offer a major opportunity to mix contributions from computer science, manufacturing, engineering, economics, management, and socio-human communities. The selected theme for PRO-VE 2014 focused on the main identified and crucial aspects that empower collaborative networks in support of smart networked environments, and thus contributed to a new generation of systems.

PRO-VE 2014 held in Amsterdam, The Netherlands, was the 15th event in a series of successful conferences, including PRO-VE 1999 (Porto, Portugal), PRO-VE 2000 (Florianopolis, Brazil), PRO-VE 2002 (Sesimbra, Portugal), PRO-VE 2003 (Lugano, Switzerland), PRO-VE 2004 (Toulouse, France), PRO-VE 2005 (Valencia, Spain), PRO-VE 2006 (Helsinki, Finland), PRO-VE2007 (Guimarães, Portugal), PRO-VE 2008 (Poznan, Poland), PRO-VE 2009 (Thessaloniki, Greece), PRO-VE 2010 (St. Etienne, France), PRO-VE 2011 (São Paulo, Brazil), PRO-VE 2012 (Bournemouth, UK), and PRO-VE 2013 (Dresden, Germany).

This book includes selected papers from the PRO-VE 2014 Conference, providing a comprehensive overview of identified challenges and recent advances in various CN domains and their applications, with a particular focus on the following areas in support of smart networked environments.

- Behavior and Coordination
- Product-Service Systems
- Service Orientation in Collaborative Networks
- Engineering and Implementation of Collaborative Networks
- Cyber-Physical Systems
- Business Strategies Alignment
- Innovation Networks
- Sustainability and Trust
- Reference and Conceptual Models
- Collaboration Platforms
- Virtual Reality and Simulation
- Interoperability and Integration
- Performance Management Frameworks
- Performance Management Systems
- Risk Analysis
- Optimization in Collaborative Networks
- Knowledge Management in Networks
- Health and Care networks
- Mobility and Logistics

We would like to thank all the authors, both from academia/research as well as industry, for their contributions. We hope this collection of papers represents a valuable tool for those interested in research advances, emerging applications, and future challenges for R&D in collaborative networks. We also appreciate the dedication of the PRO-VE Program Committee members who helped with the selection of articles and provided valuable and constructive comments to help authors improve the quality of their papers.

July 2014

Luis M. Camarinha-Matos
Hamideh Afsarmanesh

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Table of Contents

Introduction

Behaviour and Coordination

Product-Service Systems

Transition Towards Product-Service Systems

Service Orientation in Collaborative Networks

Engineering and Implementation of Collaborative Networks

Cyber-Physical Systems

Business Strategies Alignment

Innovation Networks

Sustainability and Trust

Reference and Conceptual Models

Collaboration Platforms

Virtual Reality and Simulation

Interoperability and Integration

Performance Management Frameworks

Performance Measurement Systems

Risk Analysis

Optimization in Collaborative Networks

Knowledge Management in Networks

Health and Care Networks

Mobility and Logistics

Erratum

Introduction

Collaborative Systems for Smart Environments: Trends and Challenges

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Abstract. Collaborative systems will form the warp for smart networked environments wherein humans, organizations, intelligent agents, and devices collaborate. The smart environments of near future will be context sensitive systems within which the physical world is richly and transparently interwoven with sensors, actuators, and computational elements that seamlessly embed everyday objects and interconnect them through networks. Modeling, design, and development of collaborative systems in this context will support a large number of emerging applications including security, care and assistance, transportation, construction, sustainability and energy management, education, government, and manufacturing. In this context, a brief survey of trends and challenges is presented.

Keywords: Smart Environments, Collaborative Networks, Cyber-Physical Systems.

1 Introduction

Smart environments represent a fast growing area which is often presented as an evolution of the notion of pervasive or ubiquitous computing, initially suggested by Mark Weiser [1] as "*a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network*". From this notion, smart environments emerge as "*small worlds that are able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment*" [2]. Similar to pervasive computing, in smart environments there is the idea of a physical environment interwoven with a network of devices and systems, sensors and actuators. But now with a more explicit purpose – using technology to improve the life or comfort of its inhabitants.

Examples of smart environments include: closed spaces with relatively well-defined boundaries, such as home, office, or car, and open spaces such as streets, bridges, parking lots, or smart cities [3]. The relevance of this area can be illustrated by the growing number of applications in domains such as health monitoring, elderly care provision, transportation and logistics, entertainment, environment monitoring, smart homes, smart offices, and smart shop floors, etc.

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In technical terms, smart environments result from the convergence of a variety of contributions including sensor networks, pervasive and mobile computing, robotics, miniaturization of hardware components with embedded processing power, reliable wireless network protocols, increased automation associated to everyday devices such as home appliances, natural human-computer interfaces, artificial intelligence, middleware platforms, etc. In fact, this is clearly an area that is leveraged by multi-disciplinary contributions.

When systems involved in smart environments grow and involve large number of entities (hundreds, thousands, or millions), flat organizational structures are not sufficient to support effective management. Therefore we also need to address the organization of such entities in "communities" and "societies" within the "**ecosystems**" of cyber-physical artefacts. Within such organizational structures **collaboration** among artefacts can then support the creation and provision of composed value-added services, by service developers. Such environments and associated services are opening new grounds for business opportunities, which typically require the collaboration of multiple stakeholders, and also challenge the positioning of enterprises in society, leading to new concepts such as **sensing enterprise**. **Collective awareness** then also becomes a necessary property of such systems. Furthermore, some artefacts have a **nomadic** characteristic, i.e. they move between spaces (e.g. gadgets or sensors carried by the human user or by other moving objects), which in turn raises the issues of artefact discovery, acceptance (by the "visited" ecosystem), definition of roles, access policies (addressing security and safety), pro-active promotion of services, and system dynamics. In this context, **data/service interoperability** assumes a fundamental role.

Additionally, people are increasingly surrounded by and depend on a fast growing collection of gadgets and other smart objects in their daily lives. These artefacts in turn have gradually **changed people's habitat** and **extended their sensorial and acting capabilities**. **User acceptability** is therefore the base criterion for the design of any such systems, in the context in which users' expectations increase as the technology evolves. Another important criterion for designing such systems is the **trustworthiness** of the components and the composed systems, which is mainly associated to the notions of **reliability, risk, privacy**, and **security**. Furthermore, with the trend towards more personal data being available through the cloud, monitoring and understanding "what people will accept" in exchange of higher value services, becomes relevant. On the other hand, **smarter decision making** and **higher levels of autonomy** is required from systems, in order to neither "overload" the humans with excess of information, nor requiring constant input, e.g. "pressing buttons" to interact with the cyber-physical world, considering the real-time access to a large number of devices.

In this context, collaborative networks can play a significant role in a number of areas facilitating the design and development of complex smart environments. Although already identified by various authors [2], [3], such collaborative perspective is so far only briefly touched by current developments.

This introductory text aims at giving a brief overview of the area and its challenges, particularly from the collaborative networks perspective, contributing to identify further research directions.

2 Related Areas

A number of different partially overlapping related paradigms have been introduced in recent years, among which the Ambient Intelligence (AmI), Ambient Assisted Living (AAL), and Sensing Enterprises can be named. These paradigms address environments supported through the collaboration among human actors, intelligent agents, and smart devices.

Different aspects of the above paradigms are further addressed by related work in several technology-based areas, including the Cyber Physical Systems (CPS), Internet of Things (IoT), Internet of Events, Sensing Networks, etc.

As an outcome of these research and development directions, a number of advanced areas of application have emerged illustrating substantial impact in improving the quality of life in societies, as exemplified by the Smart Cities, Smart Homes, and a number of Intelligent Infrastructures such as those manifested as Intelligent Transportation Systems and Smart Grid, etc.

2.1 Related Paradigms

Ambient Intelligence (AmI)**:** A paradigm that represents electronic-enhanced environments, which are sensitive and responsive to the presence of people [4], considering their needs, habits, and even emotions. The notion is similar to smart environment, but perhaps with more emphasis on human-computer interaction, context awareness, and provision of intelligent services.

A number of characteristics are usually presented to identify AmI systems, including: context awareness, personalization (tailored to the needs of each individual), acting anticipatory (anticipating the needs of individuals), adaptive (coping with the changing needs of individuals), ubiquitous (integrated in our everyday environments), and transparent (making computers disappear in the background) [4], [5].

Many application examples can be found in the areas of healthcare and elderly care [5], but references in other sectors can also be found [4], [6], e.g. in smart homes, intelligent transportation, rescue / crisis management, education, workplaces, energy management, etc. The convergence between AmI and social computing is attracting growing interest [7], namely with the new interaction facilities offered by mobile computing and wireless networks.

Ambient Assisted Living (AAL)**:** AAL is a paradigm widely used in Europe representing a kind of AmI that provides safe and adapted environments for people with specific needs, allowing them to live more independently [8]. Most developments in AAL are focused on assisting elderly [9], [10], namely to help them live independently in their home environments. Most efforts in the last decade have been focused on transferring the dependence from human assistance to assistive devices [11]. But even earlier works such as the TeleCARE project [12], [13], pointed out the need for a collaborative systems approach to AAL, both at the infrastructure level (collaborating multi-agent systems) and social computing level (virtual communities).

In fact, the realization that a pure technological perspective also has the negative effect of reducing the social connections of the assisted people has triggered other efforts to combine the basic technological assistive aspects with social computing [10]. Furthermore, provision of integrated care and assistance services require the involvement and collaboration of multiple stakeholders. This led to a shift in the AAL developments, from a device and infrastructure focus, to a **care ecosystem** [14], [15]. Such perspective is well represented in the BRAID roadmap for ICT and ageing [16] and recent development initiatives such as the AAL4ALL project [9], [10].

***Sensing enterprise*:** A paradigm introduced by the FInES (Future Internet Enterprise Systems) cluster of projects [17] to refer to an enterprise making decisions by using multi-dimensional information captured through physical and virtual objects in its environment, and providing added value information to enhance its global context awareness. In other words, this notion particularly focuses on enriching enterprises' context awareness through intelligent, interconnected, and interoperable smart components and devices that power enterprise systems, making them responsive to events in real time and aiming at reaching seamless transformation of (raw) data to (tailored) information and (experienced) knowledge [18].

2.2 Related Supporting Technologies

Cyber-Physical Systems (CPS): Engineered systems that are built from and depend upon the synergy of computational and physical components [19]. Numerous projects (e.g. AMADEOS, CASAGRAS2, CONET, GAMBAS, SCUBA, COMPASS, DANSE, DYMASOS, to name a few), have addressed the development of communication middleware systems to support seamless and trustworthy interoperation of heterogeneous subsystems and artefacts, new programming paradigms to support adaptive applications, methods to deal with real-time requirements, and management of devices with critical constraints such as energy, computing and communication capabilities. Many successful developments have been focused on vertical use cases, while those solutions prove to be difficult to generalize and scale up. The cost-effective engineering of larger CPSs, coping with an evolving nature and ensuring added-value to their users, remains a challenge.

***Internet of Things (IoT)*:** A term representing "*a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, and use intelligent interfaces, and are seamlessly integrated into the information network*" [20]. In this context, a "thing" is understood either as a real/physical or digital/virtual entity that exists and moves in space and time and is capable of being identified [21]. Large classes of the objects that are connectable to Internet constitute (smart) sensors and (smart) devices, able to provide status information, thus an important technological enabler for smart environments. IoT is in fact a way to materialize the vision of a technology that becomes invisibly embedded in our natural surroundings, but present themselves whenever we need them.

There has been quite some discussion on the relationship between Cyber-Physical Systems and Internet of Things. For some authors the two terms carry some "geographical bias", being CPS more popular in the USA, while IoT is more prevalent in Europe and Japan. Others refer to CPS as being originated in the embedded systems community, while IoT comes from the area of Internet computing. These are certainly limited perspectives, and other authors try to relate the two concepts in terms of their focus [21], [22]. In any case, there is a growing convergence between the two areas since CPSs are becoming more Internet-based and complex CPSs / complex Systems-of-Systems increasingly combine open systems with closed and semi-closed ecosystems.

***Internet of Events*:** Although it is less popular than IoT, it corresponds to a perspective of the IoT that puts the emphasis on time dependency and discrete events handling [41]. As such, events modeling and management, time critical reactivity, and process modeling and supervision are the relevant issues here.

***Sensor Networks*:** Being implicit in all the above areas, sensor networks are a fundamental component of any smart environment which relies first and foremost on sensory data acquired from multiple sensors in distributed locations of physical environments. One of the most relevant topics in this area is the **wireless sensor networks** which typically comprise large numbers of spatially distributed autonomous sensors that have limited computing, communication, and energy autonomy capabilities. In this context, collaboration appears as a way to cope with those limitations, leading to the emergence of the notion of **collaborative sensor networks**. Examples of collaboration in such networks include [23]: collaboration in localization, energy awareness and collaboration to reduce energy consumption and extend system's lifetime, collaborative sensing and perception, collaboration in sending messages through different paths in response to security threats, self-adapting routing, covering "sensing holes" resulting from inactive nodes, etc.

Closely related to the increase in the sensing capabilities, the term ***big data*** has become popular. It refers to massive data sets and stream computing that due to their large size and complexity are beyond the capabilities of traditional databases and software techniques. The expansion of sensing capabilities, sensor networks, smart devices, and other sources, generating huge amounts of data, motivates the importance of this topic. Interest in big data has emerged in science, business, security, and many other areas [17]. Context awareness or collective awareness, supporting intelligent services for smart environments, may require the adoption of techniques being developed for big data.

2.3 Advanced Application Areas

Smart Home: Sometimes also known as home automation, are smart environments at home that rely on networked technologies to provide inhabitants with better comfort and security [24], [25]. Typical functions include monitoring and control of lighting, temperature and ventilation, home access security, entertainment, control of home appliances, etc.

Although home automation technologies have been around for the last thirty years, for a while, their developments evolved in isolated niches. Recent efforts are focusing on integrated solutions and the possibility of integrating different artefacts in a technology-agnostic manner, as aimed by initiatives such as openHAB [26], FHEM [27], or openRemote [28]. In recent years there has been a growing attention devoted to energy awareness systems and energy efficiency, an opportunity to integrate smart home and smart grid technologies [29]. Developments in Internet of Things, natural user interfaces, wireless sensor networks, and service robotics are also adding new dimensions to this area [30], [31].

Smart Cities**:** The concept of smart city has been gaining increasing importance in the research and policy making agendas, with many initiatives being promoted worldwide. And yet, the concept is not precisely defined, corresponding to different visions for different communities and stakeholders, also with variants according to geographical origin. A high level notion is that a smart city must be "*able to optimise the use and exploitation of both tangible (e.g. transport infrastructures, energy distribution networks, natural resources) and intangible assets (e.g. human capital, intellectual capital of companies, and organisational capital in public administration bodies)*" [32]. The results of an operational definition in this direction is presented in [33] that was applied to evaluate the degree of smartness of 70 medium-sized European cities, includes six dimensions of analysis: (i) "smart mobility", (ii) "smart environment", (iii) "smart governance" (iv) "smart economy", (v) "smart people", (vi) "smart living".

From an ICT focus, smart cities are characterized by pervasive computing and extensive sensing and information integration capabilities, in the various urban sectors, to help cities make better use of their resources. Implicit in all pilot initiatives towards building smart cities, is the need to engage and promote collaboration among multiple stakeholders, both public institutions and private organizations, as well as citizens. As such, collaborative networks can bring a fundamental contribution to this domain. As many projects are still at the level of building the base infrastructures, collaborative networks are not yet explicitly visible but undoubtedly they are a must when progressing towards providing integrated services.

Intelligent Infrastructures**:** are infrastructures that use computing and communication technologies, sensors, and other networked devices, to deliver relevant real-time data to their operators in order to optimize their use, minimize costs and prevent failures [34], as well as proving higher-level services to their users.

One example is given by the **Intelligent Transport Systems**, which are leading to the progressive introduction of new technologies based on electronics, sensorial systems, and communication and information technologies. For instance, road management policies, based on user-paying models, and the increasing concerns about traffic safety, establish requirements for a new family of emergent business services. A promising direction aims at offering new comprehensive service contracts integrating multiple possibilities of access to public transport systems, parking areas, subscription to innovative insurance policies, etc. [35], [36]. Another challenge is the development of collaborative eco-driving environments, focused on effective support of integrated services targeting transportation energy efficiency, costs saving, and improvement of safety in mobility.

Another example is the **Smart Grid**, or smart energy grid, which represents a move from a centralized, energy producer-controlled network to one less centralized and more consumer-interactive. Initially, it corresponds to an overlay of the energy distribution grid with an information and (smart) metering system [37], [38]. In the current stage, most efforts are very focused on infrastructure aspects. However, establishing a truly smart grid requires the participation of a large number of stakeholders, including producers, transmission and distribution operators, regulators, policymakers, and consumers. Thus, a next challenge is to adopt proper organizational models, governance structures, and to develop advanced tools to support collaboration among these players [39].

3 Some Technical Challenges

Earlier developments of smart environments, often led by specific application needs, contributed to the identification of key technical challenges and preliminary evaluation of promising solutions, some of which were briefly mentioned above. The urge to develop more advanced environments for diversified application domains raises various critical challenges, including:

3.1 Modeling Approaches and Collaboration Needs

Modeling is a fundamental part of the development of future smart environments. Although various modeling approaches have been used, a number of aspects need to be further addressed, including:

- How to represent objects / devices in the cyberspace. Two main approaches have been used: agents and service orientation. The first one is particularly appealing when modeling objects / subsystems with some level of autonomy and reasoning capabilities. In practical terms, this approach can be well supported by existing multi-agent platforms when focusing local, well-confined environments. When addressing larger physical environments, agent platforms have some limitations. Modeling devices through the services they provide is another common approach, which is not constrained by geographical limits, but does not properly encapsulate all relevant aspects of the object being modelled. Efforts to combine the two paradigms, as exemplified by the service entity notion [42], can be a good direction. Furthermore, when dealing with physical systems, it is also relevant to model events and pro-activity of devices / sub-systems [43].
- How to discover the objects / devices and their functionalities. Independently of the modeling approach, it is necessary to provide registry and discovery

mechanisms that also cope with the nomadic and volatile nature of some devices. For instance, devices / entities can "appear and disappear" from the cyber-space, or evolve over time. Associated to this aspect, it is necessary to also model access rights, which are closely related to the ownership of devices / subsystems and the business models available within the smart environment.

- Organizational structures. Besides the individual components, it is also necessary to model the organizational structures present in the environment. Particularly, it is necessary to model the various categories of networked entities and their organizational structures, e.g. devices, sensors, machines, enterprises/organizations, and human actors, covering both their functional and behavioral characteristics, as well as their specificities, e.g. mobility and evolution perspectives in this environment.
- Business services modeling. In a complex smart environment, some of the services offered to its inhabitants are likely to be jointly provided by various stakeholders.

Dealing with the complexity arising from the large and increasing number of artefacts and subsystems constituting smart environments, and the inherent dynamism involved in such environments, suggest organizing them around different “spaces”, constituting certain “communities” or “**ecosystems**” and **“societies” of artefacts**. Within such organizational structures collaboration among artefacts and subsystems is a requirement for the creation and provision of composed value-added services for the benefit of the environment inhabitants. To support value-added service creation, mechanisms are required for registering and sharing service components within service-developers communities, as well as supporting these developers with discovery and integration of such component services.

As such, collaborative networks concepts need to be applied to various levels, including: (i) giving an organizational scope to the structure of the smart environment and supporting collaboration among artefacts and subsystems, (ii) supporting the multiple stakeholders that participate in the building and operation of the smart environment, (iii) providing a framework for interaction between users and environment services, and (iv) coping with the communities of users and their organizational structures.

3.2 Other Technical Aspects

Human-systems interaction. In order to effectively improve life/comfort of inhabitants of the smart environments, new and advanced forms of interaction with users need to be considered. For instance, **natural user interfaces** and **augmented reality,** benefiting from well-proven techniques (e.g. from the gaming industry) are likely to play a relevant role here. In this area, it is also necessary to further handle a number of other aspects, such as: dealing with the “excess of information” that comes from large variety of sources, reducing the effort of users having to deal with many different interfaces, capturing user experience to adjust the systems to the user’s life style and preferences, etc.

Technological artefacts in smart environments are gradually changing people's habitat, while extending people's sensorial and acting capabilities in these environments. Therefore, the challenge is not only to consider the human in the loop when designing systems, rather the fact that the systems shall be human-centric. On the other hand, users can have a growing influence on the smart environments innovation process, namely through social networks, forums, blogs, rating systems, and similar mechanisms, which raises the importance of the concept of **co-innovation** in this area.

Risks and security. As the environments become increasingly permeated by technology and networked infrastructures, and their inhabitants become more dependent on such technology, the issue of **trustworthiness** of the components and systems, which is associated to the notions of reliability, risk, privacy, and security, assumes critical relevance. Therefore, the definition of environment-level trustworthiness indicators and their monitoring mechanisms, combined with recovery procedures contributing to system's resilience, need to be developed.

Furthermore, when smart environments are addressed as societies of artefacts and sub-systems, it is important to study and manage their **emergent behaviors**. Some behavioral patterns are "healthy" in the sense that they are aligned with the environment's purpose, generating value to the human inhabitants, while others are "faulty", due to either malfunctioning or cyber-attacks. **Systems resilience** is then a desired property, calling for new indicators of "system's health" and associated monitoring and diagnosis functionalities.

Technological basis. Smart environments involve a large diversity and increasing quantity of devices and infrastructures with different life cycles. In this context, **interoperability** and **scalability** are rather critical issues. The nomadic nature of many devices / gadgets that may enter / leave the environment also poses strong interoperability requirements. Therefore, the ability to easily integrate different artefacts in a technology agnostic manner remains a fundamental goal [26], [27], [28].

Technological developments need to also deal with the peculiarities of devices regarding their **constraints** on energy, communication range, computational power, memory capacity, etc., for which collaborative approaches can also provide ways to overcome individual limitations. Early examples in this direction can be found in the approaches to implement energy aware collaborative sensor networks [23].

Bridges to other fields. The growing availability of **cloud computing** resources can provide a solution to the constraints of some devices in widely distributed smart environments and thus a close link between the two areas needs to be explored.

Being smart environments potential sources of large volumes of data, a close link with the developments in **big data / data science** may open opportunities for the creation of new advanced business services.

3.3 Engineering Methods

While current engineering techniques have been good enough to deliver small-scale smart environments, they appear rather limited when addressing complex systems requiring a convergence of different technologies and knowledge areas [40]. As smart-environments constitute cyber-physical systems, traditional approaches used in a single discipline, e.g. software engineering, or product engineering, are not sufficient.

Furthermore, effective smart environments need to be considered as **socio-technical systems**. As such, besides technological developments, the design of these systems needs to also consider other elements, e.g. people, processes, organizational structures, culture, and surrounding environment.

In terms of system operation, besides the typical maintenance activities involved in traditional product engineering and software engineering, new dimensions have to be considered due to the heterogeneity, diversity, and possible autonomy of components, and interaction between different "communities / ecosystems" (e.g. home environment and external environments). Moreover, smart environments are not designed and built at once rather they gradually grow and/or evolve. For instance, in a smart home environment, new artefacts are *incrementally added* and/or existing artefacts are from time to time *replaced* by new ones.

Engineering methods need to be **user-centric** and also take into account the requirements of scalability and dynamism, multi-stakeholder collaboration and trustworthiness certification, maintenance and evolution, and support for user involvement in co-innovation processes.

4 Concluding Remarks

The convergence of developments in several basic technologies – e.g. sensors, devices, networking / pervasive computing – enabled good progress on the materialization of the smart environments paradigm, as already illustrated by several application cases.

As new cases emerge and new applications are devised, complexity increases and thus new conceptual, technological, and methodological approaches are needed. In this context, collaborative networks can bring an important contribution to the next generation of smart environments.

Particularly when moving from smart to intelligent environments, increasingly involving components / sub-systems with higher levels of autonomy and decision-making capability, looking at these systems from a collaborative networks lens facilitates architectural design and planning governance principles.

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Collaborative Systems of Systems Need Collaborative Design

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Abstract. Advances in smart devices and networks are enabling convergence between systems of systems and cyber-physical systems in which computing elements interact closely with the physical environment. The development and maintenance of such systems should be inherently collaborative, crossing boundaries of constituent system ownership as well as semantic differences between engineering notations and disciplines. We present instances of model-based methods and tools that aim to bridge these gaps. Using a case study from smart grid control, we discuss the challenges in realising collaborative systems of systems that merit the reliance placed on them.

Keywords: Collaborative Systems of Systems, Cyber-Physical Systems, Formal Methods, Model-based Systems Engineering.

1 Introduction

In areas as diverse as intelligent manufacturing or traffic control, advances in devices and networks are providing the basis of Cyber-Physical Systems (CPSs) that have potential to improve the quality of life of individuals and civic society. Such systems are assemblies of smart objects and pre-existing systems, many of them influenced by, and capable of influencing their physical environment. CPSs have potential to make spaces such as homes, factories and offices, smarter, more energy-efficient and comfortable because of the capacity to control their environment by making interventions in response to real-time data from internal and external sources.

In CPSs, the tight coupling of computing with the physical world found in embedded systems meets the independence, autonomy, heterogeneity and scale of Systems of Systems (SoSs). Although CPS technology is making significant progress, barriers to innovation remain, particularly the lack of modelling languages, tools, and associated foundations that support engineering of CPSs that are open and dynamic and yet dependable [1,2].

In this paper, we focus on the need to support the collaboration that is inherent in the engineering of SoSs and CPSs. This includes collaboration between the owners

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and operators of otherwise independent constituent systems, and between the engineering disciplines involved in the design of a system in which computing elements interact with the physical world. We reflect on our experience in developing modelling frameworks for both SoSs and embedded systems, and consider whether together they hold out promise for supporting the design of trustworthy CPSs. In Section 2, we review the characteristics of SoSs that make their model-based design and maintenance a challenge, and discuss the realisation of a formal contract-based approach to model-based design of SoSs in the COMPASS project. In Section 3, we look to CPSs, discussing the implementation of cross-disciplinary co-modelling in Crescendo[1]. In Section 4, we present an illustrative example of co-modelling of a smart grid CPS. This leads to a brief discussion in Section 5 of the potential for bringing the technologies for SoS and co-modelling together.

2 Collaborative Modelling for SoSs

SoSs are composed of independent Constituent Systems (CSs) that are brought together in order to deliver a new service that the individual constituents could not offer separately. Classical examples include accident response as a result of collaboration between emergency services, or the delivery of an urban transport system composed of multiple providers.

Collaborative systems bring geographically dispersed teams together, supporting communication, coordination and cooperation [3], and are a significant enabling technology in both the creation and the operation of SoSs. In fact, a growing match between SoS and the discipline of collaborative networks has been noted [4]. The characteristics of SoSs induce requirements on the collaborative engineering processes and systems used in their design. We briefly consider some of the more important characteristics below.

2.1 Challenges of Model-Based SoS Engineering

A SoS provides new *emergent behaviour* resulting from collaboration between constituent systems. However, unexpected emergence frequently has negative consequences [5], and a comprehensive approach to engineering SoSs must include provision to verify both the existence of positive emergent behaviour and the limits of unexpected and undesirable emergence.

Constituent systems are frequently *autonomous* in the sense that their behaviour is governed by their own goals rather than those imposed by the environment. Nevertheless, the reliance placed on the SoS's emergent behaviour necessitates an approach allowing constituents to offer behavioural guarantees to one another, sufficient to guarantee global SoS-level properties.

Constituent systems are *independently operated*, and would continue to function successfully if detached from the SoS. They are therefore likely to have much information about their day-to-day operation that is commercially sensitive. A

[1] `http://cresendotool.org`

collaborative engineering process should not require the exposure of this information. The guarantees required of a constituent system should not overly constrain its behaviour, but allow it freedom in deciding how to meet those guarantees. The ability to handle abstraction is therefore an important part of collaborative design.

In summary, model-based SoS engineering must support collaboration while allowing for constituent system autonomy and independence, and yet supplying sufficient information to permit verification of emergence [6].

2.2 Collaborative SoS Engineering: The COMPASS Approach

In previous work, we proposed formal model-based methods for describing SoSs in terms of the interfaces offered by the constituent systems, with each interface defined contractually in terms of the assumptions it makes and the guarantees that it offers when those assumptions are satisfied [7]. In the COMPASS project[2], this approach has been realised in a modelling language (the COMPASS Modelling Language, CML [8]) that allows description of data, functionality and communication over an architectural model of the SoS given in SysML[3]. CML's semantic basis is extensible [9], making it possible to verify emergence by a range of techniques including simulation, model checking and proof, while the contractual approach permits the description of constituents without over-constraining each system's internals [10].

While a model-based approach based on contractual specification can be realised and supported by tools, the practical challenges of SoS engineering necessitate a further strengthening of tool support. To a large degree, SoS engineering depends on collaboration between integrators and owners of constituent systems. How can collaborators exchange information, agree on interfaces, prevent misunderstandings and ensure consensus, particularly when confidentiality may limit the extent to which collaborators permit access to interface specifications of their respective systems?

The need to support collaboration while respecting confidentiality is inherent in SoS engineering. Supporting it requires a step beyond beyond the kinds of Integrated Development Environment (IDE) developed for formal modelling and programming languages towards *Collaborative* Development Environments (CDEs) enabling negotiation and information hiding [11].

In COMPASS, tool support for model-based SoS engineering is based on the *Symphony* platform which integrates architectural and systems modelling tools based on SysML with CML (Fig. 1). In order to support collaborative development and (re-) negotiation of constituent system contractual interfaces, the framework has been extended with the concept of a *collaboration group*. Such a group is a collection of stakeholders (typically constituent system owners and integrators) who agree protocols for the development and evolution of interfaces developed for the SoS in question (Fig. 2), [12]. Within the collaboration group, rules govern the exposure of model data and the iterative convergence on a mutually satisfactory set of reliances and guarantees. The analytic tools available in the COMPASS tool set are thus able to allow exploration and verification of alternative shared strategies, SoS architectures and allocations of responsibility to constituents.

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[2] `http://www.compass-research.eu`

[3] `http://www.omgsysml.org`

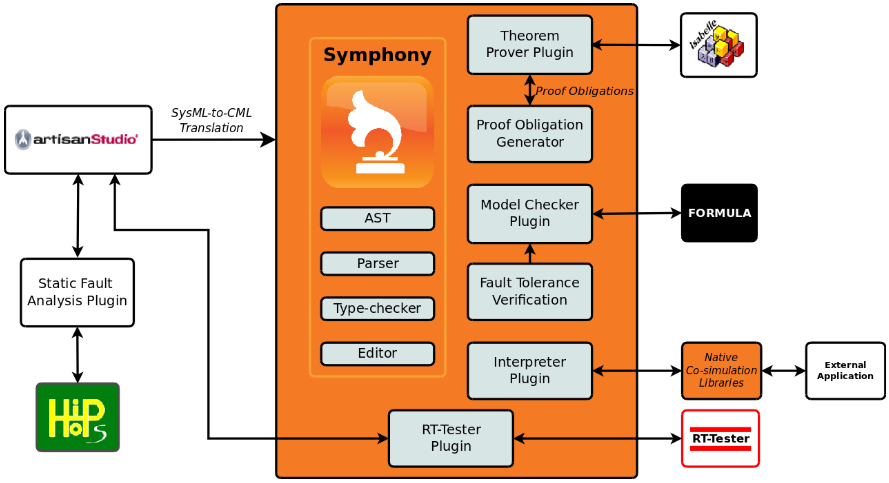

Fig. 1. COMPASS tool support for formal contract-based SoS modelling

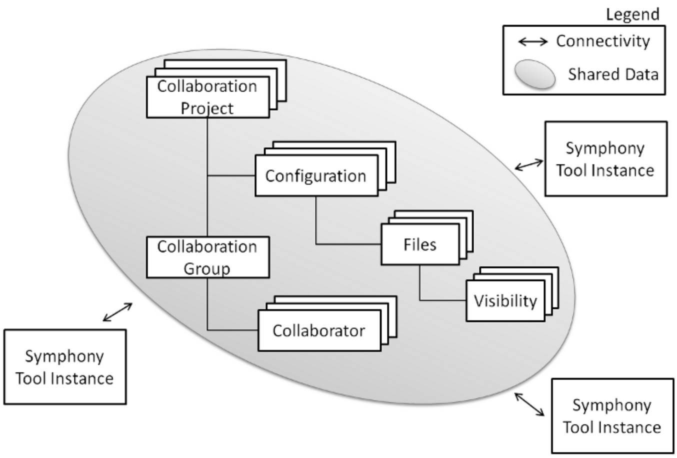

Fig. 2. Enabling collaboration in Symphony

This contract-based approach has enabled the development of architectural models and modelling profiles for SoSs, and enabled the analysis of emergent behaviour in applications such as content-streaming networks [6].

3 Co-Modelling of Cyber-Physical Systems

Our work on collaborative development of SoS models has focussed on the computing systems. However, CPSs demand semantically heterogeneous models. For example, there is a need to be able to allow developers to work together onelectro-mechanical and control elements most conveniently described in terms of Continuous Time (CT), as well as Discrete Event (DE) models of computing phenomena.

In our recent work, rather than developing a common hybrid modelling notation, we have sought to develop a common semantic basis allowing DE and CT models to be presented in established notations that would be familiar to engineers from different disciplines, but interfacing these (and their simulation environments), so that models can be developed and evaluated together in a common harness, rather than entirely separately (in a concurrent development process) or sequentially [13]. The resulting collaborative modelling (co-modelling) approach allows for DE and CT models in different notations (in our case VDM and 20-sim respectively) to be subjected to simulation in their own well-established simulation environments, but coordinated by a co-simulation engine (Fig. 3). The data and design parameters exchanged between the harnessed simulations are defined as a *contract* and the sequence of events and external inputs that are to take place during a co-simulation are termed a *scenario*.

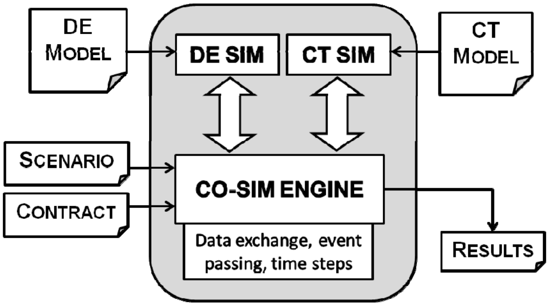

Fig. 3. Collaborative simulation across disciplinary boundaries

The co-modelling approach allows the systematic exploration of both cyber and physical aspects of a system's design space. An example of this is considered below.

4 Example: Co-Modelling of a Smart Grid

A *smart grid* uses digital technology to enable responsive and adaptive management of electricity generation, storage and consumption [14]. Data gathered from sensors on the grid enables forecasting, monitoring and response, including autonomous compensation for sensed failures. A smart grid is a CPS because of its computational integration with physical processes and has SoS characteristics through the integration of multiple constituent systems such as power generation and distribution facilities that may be independently owned and managed. A fault in such a system can have a marked impact. For example, a software defect was identified as a significant factor in the US Northeast Blackout of 2003 [15].

To illustrate the co-modelling approach, consider a simple network containing two generators servicing domestic, industrial and hospital customers via a transmission system. Fig. 4 shows a CT model of the network developed in the 20-sim tool using notations and methods familiar to electrical and control engineers. The physical system is represented by multiple elements represented by icons, connected with lines that indicate power flow. Each icon stands for a system of differential equations describing the CT behaviour of the corresponding element. Generators are modelled as modulated voltage sources producing output that is stepped up by transformers for transmission, before being stepped down for consumers (represented by resistors). The "S" units are current sensors and switches. Under normal circumstances, Houses 1-6 are powered from Generator 2, and the other consumers from Generator 1. The Control Center (CC) represents the link, via the co-modelling contract, to the DE model of the control logic that reads the sensors and operates the switches. Space does not permit the description of the DE controller model, but this is represented in terms of data and functionality at an abstract level using VDM – a notation that has markedly greater abstraction than conventional programming languages, but the elements of which are familiar to software engineers.

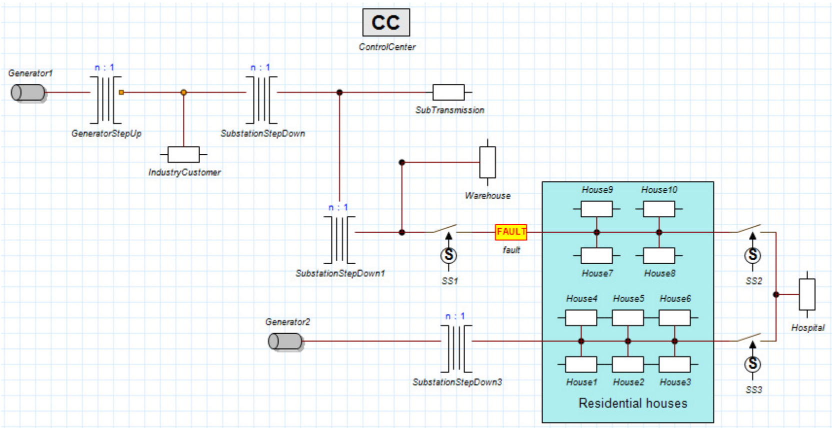

Fig. 4. Smart grid CT model

We model a fault by defining a resistance unit that can be set to a low or high value under control from the DE side via its scenario (patterns for modelling CT and DE-side faults have been presented in [13]). Error detection and recovery is largely enabled by the sensed on current resulting from the sensors deployed along the smart grid. Careful design is required in the cyber-side part of the system, which must store and analyse collected sensor data.

In order to model and analyse the effects on the system as a whole of faults and attacks, it is important to be able to model defective or malicious behavior in both DE and CT formalisms. For example, a physical sensor defect naturally modelled in a CT formalism can result in corrupt data analysis that is best described in the DE formalism. Going in the opposite direction, cyber faults and attacks, such as defective data transmission or SQL injection, are naturally modelled using a DE formalism, but their physical CT-side consequences are of real concern.

Co-modelling allows the specification of cyber-side faults and attacks in a notation suited for the purpose. For example, we can model a cyber-side fault in which sensor data is not read for a fixed period by a conditional in the DE controller model:

```
if time < 5E9 or time > 22E9 then updateSensordata();
```

In fact, when we combine this with the model of a physical fault introduced above, we observe the loss of the capacity to recover from the physical fault modelled CT-side. Since the database is not updated with the real-time sensor reading, the control centre (DE algorithm) uses the last data entry, and believes that things are running normally. Thus we are able to model the combination of DE-side and CT-side behaviours that might individually be tolerable but lead to emergent system-level failure. For example, in other studies, we have demonstrated power spikes resulting from a cyber-side attack that changes sensor values.

This ability to model and co-simulate collaboratively across discipline boundaries allows diverse teams of engineers to explore models rapidly in the early phases of their construction, in order to select optimal fault-tolerant designs.

5 Conclusions

We have examined the modelling of SoSs and simple CPSs. In the former, it is apparent that support for collaboration entails support for abstraction at constituent system interfaces, and a contractual approach has potential here. In the latter case, we have demonstrated the value of modelling techniques that allow the collaborative exploration of cyber-side and physical-side faults and attacks, and the consequences that they have *in combination* on the delivery of the overall system's emergent behaviour.

We would argue that the combination of co-modelling and a contractual approach to the modelling of interfaces of constituent systems has the potential for significant impact in engineering collaborative CPSs, although many challenges to fully realising this vision remain. A successful approach that permits the verification of emergent behaviour requires semantic support for multiple modelling paradigms. Our experience suggests that this should not supplant established formalisms, but should allow tool-level integration. Extensibility of semantic frameworks is important here, and COMPASS' UTP-based semantic framework is a first step.

We have examined only DE and CT formalisms, but one can imagine needing to integrate formalisms that support the description of features that are important to many CPSs, including the description of human behaviour, stochastic behaviour, and abstractions such as mobility and spatial characteristics. The integration of such modelling frameworks and appropriate tool support form a significant challenge.

Finally, our work has been motivated by dependability in the technical sense, but designing systems that command the less tangible property of trust from citizens demands more radical approaches, and the possibility of human-centred design of SoSs and CPSs remains an open and intriguing area for potential research.

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Adding Value to Manufacturing: Thirty Years of European Framework Program Activity

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Abstract. In the last thirty years, Europe's research community has grown to be more networked and collaboration-minded. Businesses have started to see European supported research as an opportunity to engage in open innovation. Research, development and innovation in manufacturing have been a key activity area throughout this entire period. Dedicated collaborative research and innovation partnerships emerged as new paradigms to leverage business investment and increase researchers' orientation towards entrepreneurship and new collaborative business ventures. The paper provides a brief overview of European funded research in manufacturing in the past thirty years and highlights key developments and successes.

Keywords: Manufacturing, R&D, innovation, public-private partnerships, EU framework program, European projects, public funding, collaborative research.

1 Introduction

Manufacturing is key to Europe's welfare, its social and cultural development [1]. With its approximately 20 industrial sectors it is the backbone of the economy. More than 30 million people work in it and an additional 70 million are engaged in peripheral related sectors. Manufacturing, the activity to make goods on a large scale through processes involving raw materials, components, assembly and operations involving different workers and extensive engineering activity, is increasingly seen as a priority area in economies hit by the recent financial and economic crisis.

Manufacturing has a huge potential to generate wealth and high-quality, value-adding jobs. In 2006, the total number of manufacturing enterprises in the non-financial business economy was estimated to be 2.3 million, representing a little over one in every ten (11.5%) enterprises in the then 27 EU Member States (EU-27). Manufacturing enterprises provided employment to 34.4 million persons. This was equivalent to 27 per cent of all EU-27 employment. In 2006, the sector generated EUR 6,816 billion in turnover of which EUR 1,712 billion was value added. This was equivalent to 30 per cent of the value added in the EU-27 non-financial business economy. Each employed person in manufacturing generated on average EUR 49,700 of value added. Total investment by the EU-27 manufacturing sector was valued at EUR 238 billion in 2006, equivalent to almost 14 per cent of the manufacturing sector's value added [2].

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In the last 20 years, Europe's economy has lost approximately one third of its value adding capacity. If this de-industrialization trend continues, Europe might lose half of its employment in manufacturing in the next 30 years. Europe therefore needs to develop new ways in re-industrializing and reactivating its capabilities to add value.

2 The Network Effect of Collaborative R&D

The Framework Program has played a catalytic role in strengthening and integrating the European research infrastructure, impacting industry and the research community. Structural effects promoted by the Framework Program include the creation or the strengthening of knowledge networks often evolving into long-term strategic alliances; the integration of research and industry communities – cross-sectorial, interdisciplinary or transnational - and collaboration networks between and among European and national R&D policy makers, in a growing number of cases resulting in a joint-programming of research.

At the base of the knowledge networking impact is the collaborative R&D model [3] that was adopted by the Framework Programs since their very outset. Throughout the history of the Framework Programs, the collaborative research model evolved into a veritable European open research and innovation model and many consider this to be its major long-term effect.

2.1 Adding Value through Research Collaboration

In many cases it may be advantageous to collaborate than to "go it alone". Some research activities are of such a scale that no single country can provide the necessary resources and expertise. European projects are set-up to typically pool resources and expertise from actors across many countries. Thus, collaborative R&D under European framework programs allows research efforts to obtain the required “critical mass” and produce a leverage effect on private investment whilst lowering the risk for participants. European-scale actions play an important role in the transfer of skills and knowledge across the EU as well as in expanding existing networks of knowledge by enabling participants to be exposed to diverse research methodologies and new or improved research tools. Being part of a European consortium of highly qualified researchers provides "spill-over" effects that may be more important than the monetary investment involved. The experience of European framework programs shows that while all participating countries enjoy knowledge multiplier effects, their size is roughly inversely related to each country’s total number of participations.

Another feature of this type of research is that public R&D funding carried out by enterprises leads to what is called a "crowding-in" effect on investment. In other words, it stimulates firms to invest more of their own money in R&D than they would otherwise have done. A study [4] has estimated that an increase of EUR 1 in public R&D investment induces EUR 0.93 of additional private sector investment. In the case of the framework programs, there is even evidence that many projects would not have been carried out at all without EU funding. Large-scale European projects enable participants to access a much wider pool of firms in a certain industry domain than would be possible at purely national level. This offers internationalization advantages to enterprises, in particular to SMEs, and broadens the scope of research by allowing a division of work according to participants' fields of specialization.

In many projects work ultimately leads to patents. This can be seen as indicator for partners' intentions to exploit research results commercially. Framework program participants are more likely to apply for patents than non-participants and tend to be more innovative, irrespective of size. In Germany, for example, firms funded under the framework program make three times as many patent applications as non-participating firms [5]. Participating enterprises are also more likely to engage in cooperation with other partners of the innovation system, as well as universities. Although no causal links can be proven by such findings, they provide a strong indication that public funding for research strengthens innovation performance [6]. A wide range of ex-post evaluation studies [7] show that as a result of framework program participation firms are able to realize increased turnover and profitability, enhanced productivity, improved market shares, access to new markets, reorientation of companies' commercial strategies, enhanced competitiveness, enhanced reputation and image, and reduced commercial risks. Results of econometric modelling indicate that the framework program generates strong benefits for private industry in the EU. A 2004 study [8], commissioned by the UK Office for Science and Technology, used an econometric model developed by the OECD to predict framework program effects on total factor productivity. It was found that the framework program "generates an estimated annual contribution to UK industrial output of over GBP 3 billion, a manifold return on UK framework (program) activity in economic terms".

2.2 Thirty Years of Support to Manufacturing R&D

The European Commission has been supporting manufacturing since the first framework program. Table 1 shows the key programs involved. Research was first placed on a broader footing in the mid-1980s, when the then European Community launched its first framework program for research and technological development. The programs subsequently became a central part of the European Project, a key approach to addressing Europe's economic and societal challenges through pan-European, multidisciplinary, multi-sectorial projects that engaged the entire technology supply chain - universities, research institutes, test labs, large and small companies, user groups, and society at large.

Asked about the impact of the first research programs, Esprit and BRITE, the Vice-President of the European Commission from 1977 to 1985, Etienne Davignon [9] commented as follows: "There is no doubt that these programs had a positive impact. However, there is no point in trying to quantify this in a measurable way. Attempts to compare what would have happened had they not existed with what actually happened because of their existence are somewhat artificial. … European research policy has helped to create a genuinely transnational relationship between companies, universities and government bodies, which was never the case before. If

Table 1. EU R&D programs supporting manufacturing related topics

Period	Framework Program	Programs relevant to Manufacturing
1984-1988	FP 1	Esprit I (CIM), BRITE
1988-1991	FP 2	BRITE-EURAM I, Esprit II (CIME)
1991-1994	FP 3	BRITE-EURAM II, Esprit III (IiM)
1995-1998	FP 4	BRITE-EURAM III, Esprit IV (IiM)
1999-2002	FP 5	GROWTH, IST
2003-2006	FP 6	NMP, IST
2007-2013	FP 7	NMP (FoF), ICT (FoF)
2014-2020	Horizon 2020	NMP-B (FoF, SPIRE), ICT (FoF)

we wish to learn from the first 15 years of European research policy, basically we must admit that it needs to be adapted. … In other words, if we wish European research policy to meet vital strategic objectives and if we wish to prevent its added value from becoming bogged down in bureaucracy, technocracy or disputes over sharing out the benefits, it must have built-in flexibility. ..."

The European Strategic Program on Research in Information Technology (Esprit) was a series of integrated programs of information technology research and development projects and industrial technology transfer measures. Already the first Esprit program, part of Framework Program I, focused on R&D relevant to manufacturing [10]. Under "Computer integrated manufacture (CIM)" the program aimed to "establish the technology base for progressive introduction of IT to all phases of the manufacturing cycle leading ultimately to fully integrated production systems. The main emphasis is placed on manufacturing elements as they are needed for discrete batch manufacturing". In the next programming phase the area was widened to encompass the whole range of computer-integrated manufacturing activities including architectures and communications, management and design of enterprises, and mechatronics, robotics and sensing technologies. The main objective of the CIME sub-program of Esprit was to expand the Community's share of the market for CIM to a dominant level in the European market and to achieve a significant penetration of non-EC markets. In addition, it was expected that it would help accelerate the modernisation process in a wide range of industries, ranging from discrete parts production to continuous processes, and so to improve the competitiveness of European manufacturing industry as a whole. 40 per cent of organizations participating in Esprit projects were user industry enterprises. In total 65 per cent of participants were industrial companies. User-supplier collaborations, often with large companies as users and SMEs as suppliers, were growing.

The CIME strategy was based on four concurrent and interrelated lines: (a) To promote the use of open systems and develop the associated methods and tools, including those needed for migration from existing proprietary systems, (b) to develop modular and compatible system components capable of exploitation within this framework and which SMEs can afford, (c) to develop new generations of handling systems and (d) to demonstrate the success of this approach and its benefits by early implementation in a wide range of production environments. The joint involvement of vendors and leading-edge users was fundamental to the success of this approach.

BRITE-EURAM was the other important channel for much of the Commission's support for R&D and innovation in manufacturing. The main aims of this program were to stimulate technological innovation, encourage traditional industry sectors to use new technologies and processes and to promote a multi-sectorial approach and multidisciplinary scientific and technological collaboration. The program covered two totally different worlds: the internal world of the laboratory involving R&D staff, scientists and academics and the external world of the market place. What was created in the laboratory had to be produced on an industrial scale in a fast-changing technological and economic environment. And this means over-optimistic expectations were confronted with a reality that was beyond the control of those running the project. A set of studies therefore aimed to evaluate its impact [11] and led to interesting conclusions showing the value of Commission-funded research and development as a catalyst for innovation and growth:

Firstly, potential economic gain (from benefits such as improved productivity or quality) for the companies involved amounted on average to 6.5 euros for each euro invested by the European Commission and the industrial project partners. Secondly, the number of jobs created or maintained in the five years following the end of the 291 projects assessed, amounted to 1600 jobs created and 1000 jobs safeguarded. This translates into one job created or safeguarded by EUR 80,000 invested in R&D. Thirdly, about thirty per cent of the companies involved in the study flagged an increase in skills levels and qualifications of employees as a result of the introduction of new technologies and methodologies. Ten per cent also reported workplace health and safety improvements. Fourthly, more than a third of the industrial participants reported at least one environmental impact within their organisation, the vast majority of which (97%) were positive: 39 per cent cited savings in materials, 32 per cent energy savings and 32 per cent cuts in the release of dangerous materials.

Furthermore, some 50 per cent of the large companies and nearly 60 per cent of the SMEs participating in the program fully achieved their science and technology objectives. Even more important is that the majority of large companies and SMEs were still making industrial use of the project results three years later. In the projects of the study SMEs registered 27 new patents, against 12 by large companies and 30 by industrial and commercial research organisations partnerships. 90 per cent of the universities and research institutions reported a rise in publications, with the sample of projects generating 426 publications, and 109 new PhDs across 75 per cent of these types of participants. 71 per cent of the universities and research institutes reported that, as a result of their project, they had won other contracts leading to more funding.

2.3 Structuring the Manufacturing Landscape in Europe

A first attempt to structure the manufacturing/engineering landscape was through the Advanced Information Technology (AIT) initiative [12], launched in 1993 by the major European effort shared by both programs, BRITE-EURAM and Esprit. The initiative was run in two phases. The 24 month pilot phase consisted of identification of end user needs, consensus building and requirements specification. The main phase focused on performing the necessary R&D work intended to provide enabling IT tools and engineering techniques for the requirements of Europe's automotive and aerospace industries, as specified in the pilot phase. Almost 100 organizations participated in the initiative with a total budget in the range of EUR 130 million. The main objectives of AIT were (a) to provide industrial leadership and facilitate a co-operation between IT users, IT vendors, research organizations, academia and standardization bodies, (b) to identify and define technical domains and user requirements for innovative products, (c) to propose appropriate R&D projects relevant to the needs of the industries involved, (d) to promote international standards and contribute to their development and (e) to jointly develop and utilize effective organizational, technical and operational guidelines for co-operation.

The Manufuture Technology Platform, ten years later, is a further example of incremental structuring [13] of the research and industry community: the platform itself as well as its strategic input in the form of a strategic research agenda are deeply rooted in activities promoted by the European Commission. It responded to the need for a horizontal technology platform related to the manufacturing industry, with particularly high expectations related to future economic impacts.

Manufuture was launched in 2004 as the result of a set of activities aiming at creating a platform for a more coherent definition of a European manufacturing strategy. At the beginning of the 2000s, the European Commission had started its activities to develop a Manufacturing Technology Action Plan. Among them was a range of foresight and road mapping exercises [14], such as FUTMAN and MANVIS. In the summer of 2003, DG Research established an Expert Group to discuss the future of manufacturing in Europe in a series of workshops. Its recommendations constituted a working document for the conference "European Manufacturing of the Future: role of Research and Education for European World Leadership" (Manufuture), held in Milan in December 2003. The conference led to the establishment of a High-Level Group with a balanced representation covering industry, research and education, trade associations and other stakeholders. Workshops were held around Europe culminating in "Manufuture, A vision for 2020 – Assuring the Future of Manufacturing in Europe", in December 2004. At the end of this exercise, representatives of four major stakeholders confirmed their support for a European Technology Platform on manufacturing and in 2005 work began on a Strategic Research Agenda [15]. In this agenda the priorities for maximizing added value were distilled into a strategic perspective linking the principal drivers of change with a series of activity pillars. The drivers identified were: (a) competition, especially from emerging economies, (b) the shortening life cycle of enabling technologies, (c) environmental and sustainability issues, (d) the socio-economic environment, (e) regulations and (f) societal values and public acceptance. To address these challenges of competitiveness and sustainability, five pillars of activity were considered necessary: new, added-value products and services; new business models; new advanced industrial engineering; new emerging manufacturing science and technology and the transformation of existing R&D and education infrastructures to support world-class manufacturing.

In November 2008 and as part of the European Economic Recovery Plan, the European Commission proposed the Factories of the Future (FoF) initiative with an estimated envelope of EUR 1.2 billion up to 2013. It was set up as a public private partnership (PPP) under the 7th Framework Program (FP7), shared between two R&D programs, NMP and ICT. Its aim was to improve manufacturing enterprises' technological capability of adapting to environmental pressures and of adequately responding to increasing global consumer demand for greener, more customized and higher quality products. It was expected that accelerated research and innovation efforts would lead to a paradigm shift towards a demand-driven industry with lower waste generation and less energy consumption. Four annual calls for proposals resulted in the launching of 151 projects, most of them running. At the end of FP7 participation of industry had increased to an unprecedented level of more than 50 per cent (30 per cent SMEs).

The Recovery Plan PPPs have significantly contributed to structuring the academic and industrial research communities Europe-wide by encouraging strategic thinking (in terms of road mapping, investment, generation of impact). Also the formation of industrial research associations, such as EFFRA [16], alongside the four calls in the PPP areas, in synergy with contributions of the European Technology Platforms - which in the case of Manufuture have also led to the creation of national technology platforms in almost every EU Member State and beyond.

2.4 Factories of the Future Project Examples

The Factory-in-a-Day [17] develops a robotic system which is inexpensive, leasable, and can be set up within 24 hours. The goal is to make advanced robotic systems, which currently take weeks or months to deploy, more attainable for small and medium sized enterprises. SMEs have not tended to invest much in robotics technology because human workers are more efficient at adapting to the small production batches typical of most SMEs, and state-of-the-art systems are not flexible enough to adapt to changing processes, making large financial investments in these systems infeasible even when the processes are easily automated. Factory-in-a-Day is such a system that can be easily re-purposed for new product lines. By reducing the system integration time to a single day, the project hopes to minimize investment risk for SMEs.

PlantCockpit [18] has developed research prototypes and demonstrators for software architectures envisioning a fully integrated, highly accurate and timely production cockpit. In order to achieve this goal, modern developments from all disciplines of computer science were considered. A description of various uses of how such a system can work in factories is offered in a dedicated brochure [19].

To manufacture microsystems and devices expensive large-scale infrastructures may not always be required. Project FEMTOPRINT [20] successfully developed and demonstrated a table-top printer that is capable of producing microsystems with nano-scale features. The development is likely to see further applications such as the production of optical and opto-mechanical devices, lab-on-chip devices used in opto-fluidics and optical memory marking. The printer has a strong potential to boost a series of further innovations in microsystems manufacturing and in particular to provide affordable rapid prototyping capability to SMEs. In addition to developing a prototype table-top printer, the project partners have filed applications for two patents and have set-up of a spin-off company to further develop and to market their innovative printing device.

A major challenge facing European factories is how to adapt existing machinery and tools to meet increasing demands for more precision in production. Project HARCO [21] has provided a solution by showing how “plug-and-produce” modules can reduce vibrations and shaking, helping to make production line machines more precise. Plug-and-produce technology borrows from the popular “plug-and-play” computing concept, where a user literally only needs to ‘plug’ in an additional device, such as a USB stick, to a PC and it will start working or ‘play’. Being able to ‘add on’ software or hardware as needed to improve manufacturing quality or output is a major step in industrial production. Smart actuators and sensors perform a range of actions, including regulating damping and stiffness, conducting measurements, and controlling temperature and motion. The smart – hardware and software – components are then fitted together to create adaptable modules that can be plugged into machines as versatile and dynamic add-ons.

3 Outlook: Manufacturing in Horizon 2020

The new EU Framework Program for research and innovation, Horizon 2020 [22], has started in January 2014 and is due to run over seven years with a total budget of around EUR 80 billion. Its structure consists of basic priorities (see fig. 1).

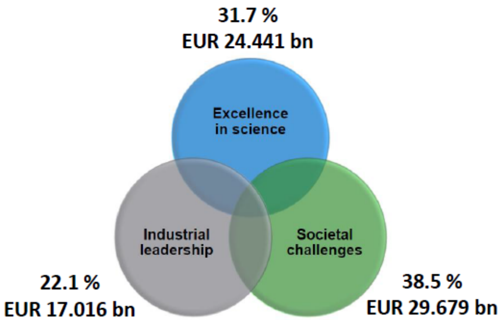

Fig. 1. The Horizon 2020 Framework Program (major elements)

Compared to previous EU Framework Programs Horizon 2020 brings together research and innovation in a single program, it focuses on multidisciplinary societal challenges European citizens face and it aims to simplify the participation of companies, universities, and other institutes in all EU countries and beyond.

The program's activities related to manufacturing are mostly concentrated in the area called "Leadership in enabling and industrial technologies". Key activities here focus on roadmap-based research and innovation involving relevant industry and academic research stakeholders.

Following a positive assessment of FP7 PPPs [23], the Commission decided to continue and even increase its stake in manufacturing R&D&I in the new Horizon 2020 program by launching the FoF PPP with a funding envelope of EUR 1.15 billion and a new PPP, addressing continuous process manufacturing (SPIRE), with funding envelope of EUR 900 million over the next 7 years [24].

The FoF PPP and other, similar PPPs operate based on industry-defined multi-annual roadmaps [25] which identify priority areas for R&D and innovation calls issued and administered by the Commission, thus ensuring that whilst there is an ongoing dialogue with industry and the research community regarding the scope and the content of the calls, fairness and transparency is maintained by the use of standard EU rules and mechanisms provided by the Framework Program.

4 Conclusions

In its evolution throughout human history, manufacturing has proven to be an important value creation activity. Its impact on the economy, society and the environment started to be felt on a massive scale through the industrial revolution's introduction of the steam engine. Machine intelligence began raising manufacturing productivity even further through automation and networking.

After a period of decline in developed economies, and following the detrimental effects of the banking crisis on the rest of the economy, manufacturing as a key value adding business activity appears to be firmly back on the political agenda. Recent econometric research points to the fact that a country's or a region's capacity to export products only few others can make is based on an accumulation of manufacturing knowledge and capability leading to its competitive advantage over others [26].

The question to research is: How can manufacturing continue to be a value adding activity in modern, Internet-driven economies?

4.1 Manufacturing Intelligence: from New Products to New Business

Today's products and processes are characterized by the growing level of intelligence [27] embedded in them. Smart products, such as the ones developed in the PROMISE project [28], enable the feeding back of up-to-date lifecycle information into design and production (adaptive production). Some examples:

(1) Product dematerialization: Mechanical parts are replaced by electronic parts and functions realized through software components making products lighter, smaller, cheaper and smarter.

(2) Product complexity: The ever growing product complexity is addressed through data and configuration management and radical modularization strategies.

(3) Customization: Software-enabled adaptation to customer requests facilitating personalization of product functions along a product’s entire lifecycle.

(4) Internet-of-Things capability: The integration of microsystems integrating sensing, actuating and information processing facilitating product interactivity, networking and M2M capability for on-board maintenance and other add-on services.

Intelligence not only affects the products but also the processes, in particular those related to material flows, distribution, delivery and operation. It improves activities related to the product's lifecycle. Real-time simulation and visualization increase process transparency and drive down costs. Virtual manufacturing thus drastically increases planning accuracy, ramp-up speed and shop floor productivity in discrete and continuous manufacturing. Embedded intelligence in manufacturing equipment allows for higher levels of accuracy while minimizing machine downtime and waste of energy and resource use. It further enables items tracking along transport and logistic chains and thus contributes to better process transparency [29].

Manufacturing innovation is about the creation of value. The production of high-tech products requires joint and multi-disciplinary efforts. As many products are becoming highly complex, the amount of multiply engineered components, their complex interoperation, the degree of sophistication and the number of possible variants have to be managed in a consistent way.

4.2 From Products to Value Propositions

The current focus of industrial companies is on the profitable development, manufacturing and selling of innovative high-tech products. Increasing global competition, decreasing differentiation of product features and shrinking project margins drive companies to rethink their actual business models. On the other hand, customers increasingly ask for a function to solve a problem, rather than a product. Furthermore, with increasing trends like "the sharing economy", traditional product ownership models are being substituted by models that focus on the provision of a function. As products increasingly have to comply with regulations that mandate end-of-life take-back, recycling or disposal, they are increasingly required to ensure value maximization, optimal energy and material consumption over their entire lifecycle.

In this global context, the manufacturing industry is undergoing a transition towards providing customer value via product-related services or solutions for individual customers including integrated product/service schemes. These schemes may offer opportunities and benefits to both, providers and customers. Providers generate additional profit from offering value-adding services across the product lifecycle and by engaging into a longer-term relationship with customers. By using product/service systems, customers reduce their initial investment, limit their risks and may thus achieve more individual value. Increased intelligence of products facilitates this integration. Thus the transition of enterprises from mere product suppliers to value providers generates a new kind of business and new dynamic cooperation models.

To exploit the potential of these new opportunities, novel methodologies, tools and platforms are needed. Understanding the impact of such business models and the degree of complexity of relevant methodologies and tools requires research and innovation efforts to be across multiple stakeholders and involving a multitude of scientific disciplines.

4.3 A Holistic View of the Lifecycle

The traditional ways of developing and producing goods are driven by market needs and by profitability considerations in highly competitive environments. The growing global industrialization, an increasing world population and standards of living are the cause of an ever-growing consumption of resources and energy as well as higher CO_2 emissions. These developments create an enormous sustainability pressure both on governments and the industry. Industrial enterprises have a key role to play in increasing the environmental compatibility of new products and processes. One of the major challenges for industry today is to be competitive on the market, whilst achieving sustainability objectives.

Today's product development, however, is mainly driven by functionality and cost, while considering constraints such as compliance with safety, reliability or regulatory requirements. In addition to these aspects, product development has to consider the whole product lifecycle and its costs but also the environmental "footprint", e.g. resource use efficiency and impact on CO_2 emissions. Companies are increasingly held responsible also for the social impact of their economic activities. These have to be analyzed and taken into account via holistic LCA approaches [30].

The industrial transition from "products selling" towards "solutions provisioning" contributes to raising responsibility for products across the whole lifecycle and will ultimately stimulate demand for lifecycle analysis and synthesis. The development of powerful tools for integrated lifecycle analysis and synthesis is a very complex task. Hence the need for joint R&D efforts.

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Behaviour and Coordination

Methodological and Technological Support for the Coordination of Smart Networks of SMEs

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Abstract. To develop and to manufacture highly innovative, knowledge-intensive products, processes and services, small and medium-sized enterprises (SMEs) often rely on the help of partners to be able to apply new technologies, to open up market opportunities or to extend production capabilities. Therefore, collaboration in dynamic networks has become a major success factor for SMEs. However, in many cases, companies are lacking the appropriate resources and capabilities to effectively and efficiently coordinate such collaborative activities. This paper presents a set of adaptable and easy-to-use methods and tools that support SMEs in building up, operating and terminating knowledge-driven, ICT-enabled and organizationally embedded collaboration in Smart Networks. The effectiveness will be illustrated with examples from three SME networks in different industry sectors that have applied these methods and tools in their industrial practice.

Keywords: Smart networks, network coordination, knowledge orientation, method support, tools.

1 Collaboration Need and Collaboration Support

Shortening product life-cycles, growing complexity and increasing market dynamics have become major challenges for companies, in particular for enterprises dealing with knowledge-intensive products and services. In order to anticipate trends and changes in the market, and in order to benefit from these rather than to lag behind requires extensive knowledge and competences in a large variety of fields. Small and medium-sized enterprises are rarely in the position to hold available such a huge knowledge base given their limited resources. They rather have to focus on core competences to stay competitive in their respective fields.

For that reason, since many years, SMEs have engaged in collaborations with other organizations to combine competences and resources and to share financial load and risks. Within the conceptual framework of collaborative networks [1], SMEs can collaborate with partners by setting up dynamic networks based on given requirements or identified opportunities.

However, industrial practice shows that operating such networks is done more on impulse than systematically. A shortage of SME-suitable methods and tools also leads

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 39–47, 2014.

to a strong impact of recognized weaknesses of dynamic networks: the lack of appropriate information, authority and control structures [2].

To improve the effectiveness and efficiency of such collaboration, and to at least partly overcome the above-mentioned deficits, this paper presents a set of adaptable and easy-to-use methods and tools that support SMEs in building up, operating and terminating dynamic networks. Particular attention will be given to an evenly distributed consideration of organizational, ICT and knowledge aspects of the collaboration, as promoted by the paradigm of the Smart Organization [3]. That means that methods and tools supporting Smart Networks draw equally on virtual teaming and ICT-enabled information exchange to create a knowledge-aware and knowledge-promoting collaborative environment.

2 Industrial Model of Smart Networks

Within the European research project SmartNets[1], a holistic industrial model for cross-sectoral SME collaboration both in development and production of knowledge-intensive products and services has been developed and evaluated in practice.

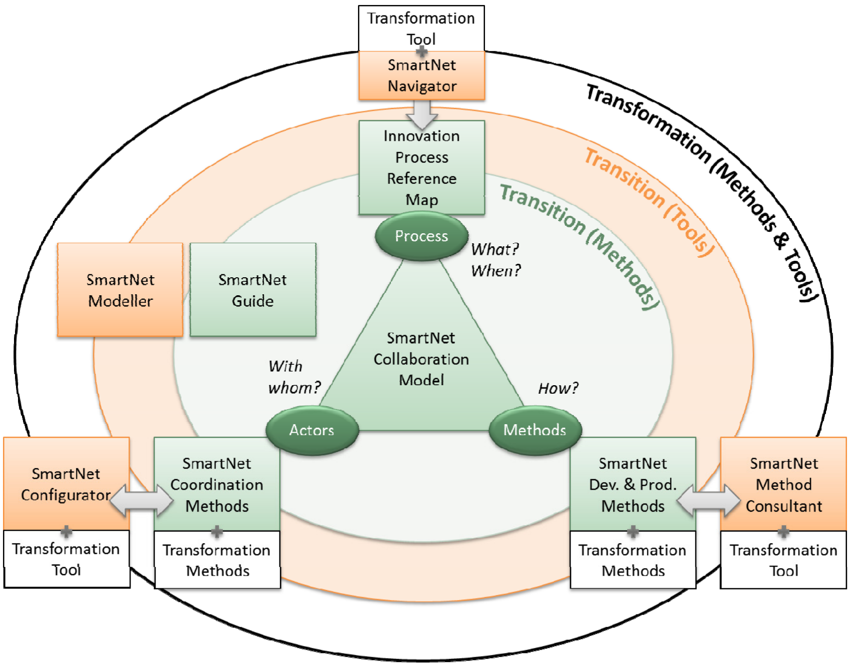

Fig. 1. Overview on SmartNets results [4]

[1] SmartNets, Project reference no. 262802, Website: www.smart-nets.eu

The industrial model is based on the *SmartNet Collaboration Model* which describes collaborative innovation using the elements process, methods, actors, and their respective interrelations [5]. Numerous methods and tools support the management of these elements (see Fig. 1).

As an example, the *Innovation Process Reference Map* provides in-depth methodological guidance on the *process* and how to implement it in practice. The *SmartNet Navigator* implements the methodological foundation on a collaboration platform and thus offers a directly executable tool for process monitoring and execution support. One particular focus of the project was on the efficient transformation from collaborative development to production networks, thus the respective transformation results affect all three elements.

The results of SmartNets can be applied both independent of each other and in combination to answer pressing key issues of collaborative development and production [6]. In the following, this paper is going to focus on results related in particular to the actors in such collaboration, the *SmartNet Modeller*, the *SmartNet Coordination Methodology,* and the *SmartNet Configurator*.

3 Method and Tool Support for Network Coordination

For the coordination of actors in the development and production process, easily applicable methods and tools are required to provide help in the day-to-day business of SMEs. They should offer support throughout the network life-cycle, from building up to termination, and should preferably also cover all functionalities attributed to network management, namely to tasks of selection, allocation, regulation, and evaluation [7].

All four tasks are covered by the three interrelated, dedicated methods and tools that will be introduced in the following chapter. The *SmartNet Modeller* supports the analysis of the network as a whole and promotes a common understanding of the partnership. Based on this knowledge, systematically analyzing the risks of collaboration with the *Networking Failure Mode and Effects Analysis* (NFMEA) becomes much more effective. Appropriate ICT support to counter some common risks and to improve the efficiency of collaboration has been implemented on a hybrid wiki system as *SmartNet Configurator*. Practical case studies on the application of these results in industrial networks will follow in chapter 4.

3.1 Modelling of Smart Networks

One key prerequisite for acting in collaborative networks is an in-depth understanding of the network and its ecosystem. Without basic knowledge about organizational structures and responsibilities, processes, resources, knowledge, and ICT systems, tasks like the selection of appropriate partners, allocation of resources, regulation of activities, and evaluation of network performance are nearly impossible to perform in an efficient manner. This concerns many SMEs which often engage in collaboration with only limited knowledge about the network itself.

Common approaches to business process modelling focus mainly on organizational aspects, like processes and resources. However, for knowledge-oriented networks, it is essential to understand how knowledge can be conjointly explored, retained and exploited [8]. Therefore, the approach of the Smart Network Modelling [9] focuses equally on organizational, ICT and knowledge aspects, by connecting five model types (see Fig. 2) which are recommended to be modelled top-down starting with the ecosystem. Using this modelling language enables SMEs to identify and to communicate within the network for example how conjoint knowledge creation relates to the described processes or how knowledge distribution can be supported by available IT systems.

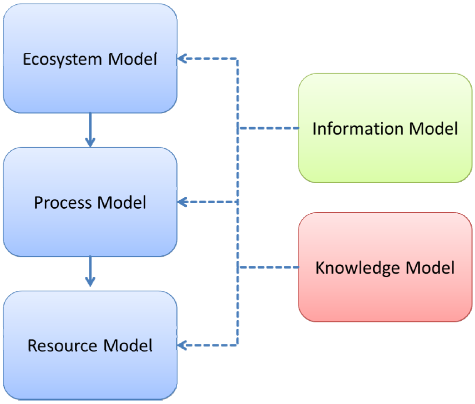

Fig. 2. Structure of Smart Network Modelling method [9]

3.2 Networking Failure Mode and Effects Analysis (NFMEA)

As mentioned above, sharing risks may be one motivation for a company to engage itself in collaborative innovation, but risks in collaborating are often pointed out as major reasons for companies not to collaborate with others as well. For a successful work in networks, it is the awareness of risks and a conscious, systematic handling that really can improve collaboration [10].

In terms of network management, systematically analyzing networking risks can be considered as part of the evaluation task. However, findings from this evaluation may significantly affect the other management tasks as well. For example, identifying a risk of knowledge drain will certainly affect the selection of partners, the allocation of (knowledge) resources and the contractual regulations.

One part of the *SmartNet Network Coordination Methodology* focuses on risks that are incurred by networking as such. For such considerations, a thorough modelling of the network, for example with the *SmartNet Modeller,* is a great starting point. To provide SMEs with an instrument to identify and analyze risks and to conjointly develop and implement countermeasures, a method has been developed that is based on the risk management method Failure Mode and Effects Analysis (FMEA).

The Networking Failure Mode and Effects Analysis (NFMEA) provides a framework in which first of all each network partner on its own carries out a thorough analysis of perceived networking risks [11]. A checklist with exemplary risks from six different categories can be consulted as basis for this step. Each risk will be evaluated regarding its likelihood and severity and most critical risks are passed on into a mediated discussion amongst all network partners. Within a workshop, the identified risks from all partners will be discussed from different perspectives and will then be re-assessed. All partners decide together which of the risks have to be mitigated, and how best effects can be achieved and by whom. From this point on, a process of periodical re-evaluation and contingency planning can be initiated [11].

3.3 Network Coordination Aspects on a Hybrid Wiki Collaboration Platform

Within SmartNets, the hybrid wiki collaboration platform Tricia has been used for the implementation of the methodology in directly executable, easy-to-use tools. Accordingly, also support for the network coordination is provided on this hybrid wiki platform by the *SmartNet Configurator*.

A hybrid wiki integrates social components and features for handling of unstructured information from common wiki systems with features of structured information handling like attribute definitions and advanced querying, as they are known from databases or business intelligence software [12]. It has been chosen for the project as appropriate tool to accompany the transformation from unstructured to structured knowledge which is characteristic for the transformation from development to production.

In terms of network coordination, these hybrid structures are used to automatically evaluate regular project documentation (meeting minutes, task descriptions, result reports) in order to semantically deduce the current project status and to make recommendations and suggestions based on that. Again, this plays a significant role in the management task of evaluation, but has further impact on selection, allocation and regulation as well. The status assessment is done by the *SmartNet Navigator* [13] which gathers structured components from the project documentation and reasons the status according to a pre-specified rule set. The status is visualized by highlighting open, running, concluded, and overdue activities and phases in the Innovation Reference Process Model (see Fig. 3). The major advantage of this approach is that there are no additional efforts in documentation required, but the evaluation is done on information that is already available.

As the status assessment is accessible for the whole network, it creates transparency on the overall status, thus also fostering trust within the network, and it serves as an instrument for a conjoint strategic alignment. Moreover, it can be used in decision support and, as the visualization not only points out current issues but also indicates lack of documentation, can also emphasize the importance of appropriate conjoint documentation for the project planning, execution and control. It helps to reduce some of the most common risks in dynamic networks and implements some information and control structures that facilitate the network coordination.

Based on the current status of the development, it is possible to give recommendations on which type of actors should be involved in the development. For example, when dealing with the IPR protection planning, patent consultants are crucial partners, but also R&D departments from customer or supplier might be worthwhile to involve (see Fig. 3). In conjunction with the Smart Network Modelling, it is even possible to identify real organizations that might fit this description.

The SmartNet Configurator comprises also a set of executable methods that can support network coordination. Templates and step-by-step instructions are provided to apply for example a partner profiling to identify the right partner at the right time or to perform the above-mentioned Networking Failure Mode and Effects Analysis.

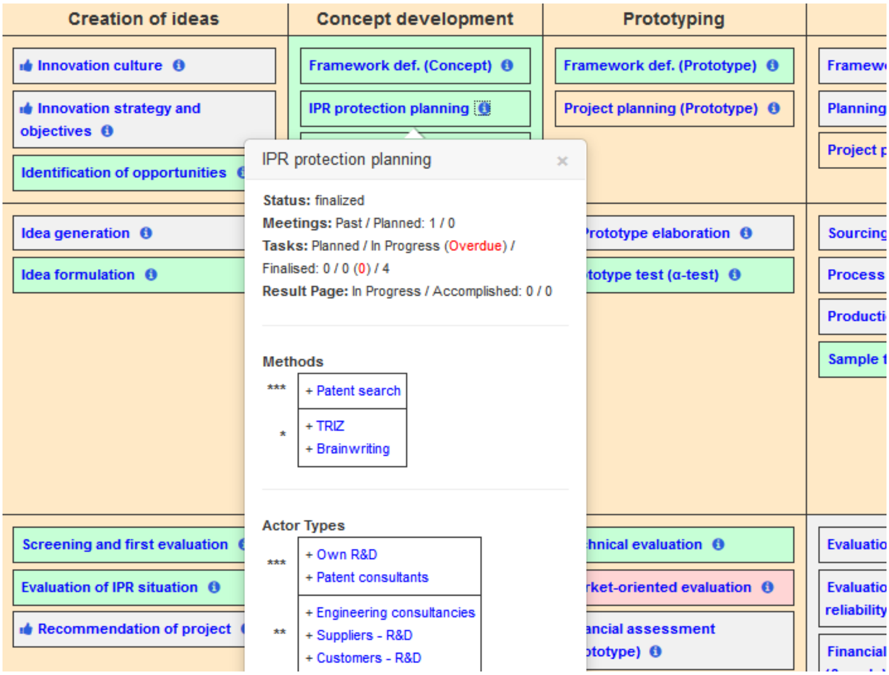

Fig. 3. Screenshot from the SmartNet Navigator, suggesting actor types for the crucial activity "IPR protection planning" [14]

4 Use Cases

Within SmartNets, the overall industrial model of Smart Networking and all related methods and tools have been applied in and thoroughly evaluated by three industrial SME networks. Feedback from the evaluation was directly considered in the further adaptation and refinement of the results. This also holds true for the application and assessment of the Smart Network Modeller, the Networking Failure Mode and Effects Analysis and the network coordination support on the hybrid wiki collaboration platform. All three networks have provided very positive feedback on all three elements.

The first network consists of three SMEs and is focusing on the development on an innovative motorcycle helmet by using a high-tech material for the inner shell the helmet. At the beginning of the project, the network and its surroundings has been extensively modelled with all related processes, resources and related knowledge. While at first, the partners considered this mainly as a time consuming exercise, the resulting models proved to be very helpful in the further development. Not only were the models used to structure the conjoint documentation on the collaboration platform, they were also helping the communication between the three partners. In particular after one partner changed the responsible employee, the new co-worker could be very quickly and efficiently introduced to the project. Last but not least, after realizing the potential of the raw material, the network models were used as basis for the extension of the network into various other industry sectors [15].

In the network focusing on the development of new interior textiles, the two involved SMEs and one research organization conducted the NFMEA to assess the risks connected to networking. Even though the partners know each other for a long time, several issues were brought up during the analysis. In particular, the diverging objectives of researcher and industry partner became visible through the analysis. This led to a conjoint understanding, convincing the industry partners of the helpfulness of the method, even recommending it themselves as important for the initiation of any kind of collaboration.

Last but not least, within a network consisting of six partners who focused on the development of a medical device, the use of the hybrid wiki to support network coordination was strongly facilitating the network coordination. In this constellation with extremely long-running, interconnected development projects the tools could provide the required overview and transparency to efficiently manage contributions of all involved partners at the right time. In the final assessment, all partners agreed on the benefits provided by the tool, in particular as it strongly supported a conjoint understanding of the project and the relevance of each partner’s contribution.

5 Conclusions

Even though the presented methods and tools are only an excerpt of the network coordination support offered by SmartNets, the practical experience from the application of these elements indicates that by offering SMEs easy-to-use, modular methods and tools for the systematic build-up, operation and termination of their networks, their effectiveness and efficiency in collaborative development will significantly improve and in the long run will also enhance their networking capabilities. An important factor is however that these methods and tools systematically promote knowledge orientation as key driver of the development.

Within SmartNets, a generalization of the overall approach has been carried out which indicates that the application of the methods and tools is not limited by industry sector or network constellation and thus can have significant impact on any manufacturing SME acting in collaborative networks. The broad applicability and the long-term effect have to be continuously evaluated in the future.

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Behavioral Norms in Virtual Organizations

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Abstract. Virtual Organizations (VOs) consist of groups of agents that collaborate towards achieving their specified goals. VO Partners are independent, autonomous, and heterogeneous, thus often exhibiting complex behaviors in co-working. Frictional behavior demonstrated by even a few partners, may cause drastic results and total failure of the VO. Therefore, it is necessary to model and analyze VO partners' behavior. This paper introduces the VO Supervision Assistance Tool (VOSAT), developed based on leveraging partners' commitments/promises, to monitor partners' behavior against the synergetic norms in the VO. For this purpose, three kinds of behavioral norms are defined, including: socio-legal norms, functional norms, and activity-related norms. Additionally, a fuzzy norm is introduced to indicate agents' trustworthy behavior. The functionalities supported in VOSAT enable the VO coordinator with identifying the high risk tasks and the weak or weakest points in the flow of VO planned operations. It further assists the coordinator with finding suitable candidate partners for handling the exceptions that arise during the VO operation phase. These in turn improve the success rate of the VOs.

Keywords: Virtual Organizations, Behavioral Norms, Promise Formalization, Trust modeling, Behavior Monitoring.

1 Introduction

An agile Virtual Organization (VO) can be effectively launched within a Virtual organizations Breeding Environment (VBE), to respond to the emerging opportunities, either for innovation or to reflect on market changes [1]. Typically VOs consist of autonomous, heterogeneous, and geographically distributed organizations, which collaborate to achieve the specified set of VO goals. As reported in [2], the study of Laciyt on the construction, benefits and risks of Virtual Enterprises indicates that less than 50% of these established VOs were successful, while more than 30% of these VOs ended up either in total failure or having high risk to fail. Primarily, two categories of risks - exogenous and endogenous - are highlighted in the literature [3] in relation to the success rate of virtual organizations. The former refers to the risks caused by external factors such as the external political risks, technical risks, financial risks, etc. The latter refers to the risks that caused by factors internal to the VO, which rise through its business activities. Furthermore, the behavior of involved

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organizations is identified as a main element of the endogenous risks. In the approach, which is proposed in this paper, the behavior of organizations can be monitored through the time, such that weak points can be identified and brought to the attention of the VO coordinators, to take appropriate strategic actions.

For this purpose, a framework is introduced for monitoring partners' behavior in the VO. Within this framework, we introduce three kinds of behavioral norms, including socio-legal norms, functional norms, and activity-related norms for the VOs [4], which constrain the partners' behavior and that can be monitored for predication of potential related risks in the VO. Although these three kinds of norms are briefly described below, please note that the main focus of the paper and the remaining sections is on the activity-related norms.

The main norms that rule over the socio-legal aspects applied to VO partners are either those that are known and generally observed in the society, or those that are formalized as clauses within the consortium agreement prepared for the VO, and which are agreed and signed by all partners. We have adopted the approach proposed in [5] to categorize the socio-legal norms as *obligations*, *prohibitions*, and *permissions,* although formalization of these norms is not the main focus of the paper. For example, leadership rights are considered as socio-legal norms from the permission category.

The general terms of operational collaboration among agents involved in a VO are officially negotiated among them via the contracts signed during the VO formation stage, indicating that the partners together fulfill the VO's objectives. In our framework, based on the specifications provided in the VO contracts, a *responsibility template* is first assumed to be extracted and formalized partially as a time chart, and partially as textual terms specified in the contract, indicating the main roles and general responsibilities of the VO partners. However considering the dynamic and adaptive nature of the VO, these contract terms do not and/or cannot specify the details of day-to-day activities of the VO partners.

Functional norms in the VO correspond to and reflect on the assignment of coarse-grained tasks, but with partial responsibility for each partner, according to what is expressed and represented within the VO responsibility template. Furthermore, the functional norms together with the responsibility template provide the base for definition and assigning of day-to-day activities to each partner, throughout the VO operation phase. However, before such activity assignment is made, it needs to be planned and agreed among the VO partners. In fact such agreement must be reached between two parties, e.g. the task leader who suggests the sub-task, and the partner who commits to the sub-task. In our proposed approach, after reaching each agreement, a *promise* is made by the partner to the task leader, to perform the needed activity. Fulfillment of a promise made as the result of the agreement described above shall correspond to the *activity-related norms* in that VO. Therefore, the activity-related norms are also in conformance with the functional norms at the VO.

In this paper, the presented examples target the fine-grained behavior of VO partners. In other words, while contract-based obligations of partners are reflected within responsibility template and can be checked against the functional norms in the VO, the presented examples focus mainly on detailed promises given by partners, in relation to their daily activities. Through the proposed framework, activity-related behavior of partners can be monitored and their possible violations against activity-related norms are identified. The decision on how to deal with the violation of norms and which sanction to impose on violating partners is also usually specified in the consortium agreement document. But the decision on applying a sanction to a partner is typically made by the VO coordinator and the management team.

As a consequence of supporting the monitoring of activity-related behavior of VO partners, it is also possible to reason about partner's trustworthiness level, based on their past behavior. For the purpose of reasoning on trust level of partners, a fuzzy norm is defined in the framework. We can also monitor and check for the violation of this defined fuzzy norm representing the partner's trustworthiness level. Using the information about partners' trustworthiness, it is possible to reason about the risk factors in the VO. For instance, considering the complete set of current promises at the VO, the least trustworthy promisee(s) can be identified. Furthermore, establishing the trustworthiness of partners can also be used for making other decisions by the VO coordinator. For instance when and if an exception is raised for which VO partners need to volunteer to take over some tasks, the VO coordinator can select the most trustworthy among all volunteers.

The remaining structure of this paper is as follows: Section 2 addresses a high level formalization of behavior in Virtual Organization. Section 3 discusses monitoring the activity-related norms. Section 4 specifies how our tool enables the VO coordinators to monitor the trustworthiness of agents. Section 5 addresses some related research, and how our proposed framework compares against them, and Section 6 concludes the paper.

2 High Level Formalization of Behavior in Virtual Organizations

Virtual Organization is a temporary goal-oriented collaborative network, which is formed in response to the emergence of a business opportunity, e.g. a manufacturing project, and will be dissolved when its goals are achieved. To fulfill the VO's objectives, typically at its creation stage, a number of contracts and a VO Consortium agreement are prepared and signed. A Consortium agreement represents the base for socio-legal norms in the VO, consisting of authorizations, permissions, prohibitions, and obligations. Although socio-legal norms are very important to be defined, they do not directly relate to the operational goals of the VO, rather they support the collaboration atmosphere/infrastructure, which is required for fulfilling its operational goals. These norms include both the generic norms common to all VOs, as well as certain specific norms relevant only to each VO as a single virtual entity. The co-working norms, the norms for sharing data / knowledge / resource, and the prohibitive norms are some examples of these generic norms. The inheritance of the VO assets and responsibilities at the VO dissolution phase, among others are examples of domain specific norms. Socio-legal norms can be categorized using the approach proposed in [5], and are not the main focus of this paper.

As mentioned in the Introduction section, the general responsibilities of VO partners can be extracted from their contracts, which are established during the VO creation stage, and presented in a responsibility template. For example, Fig. 1 shows the responsibility template in the VO established for an R&D project.

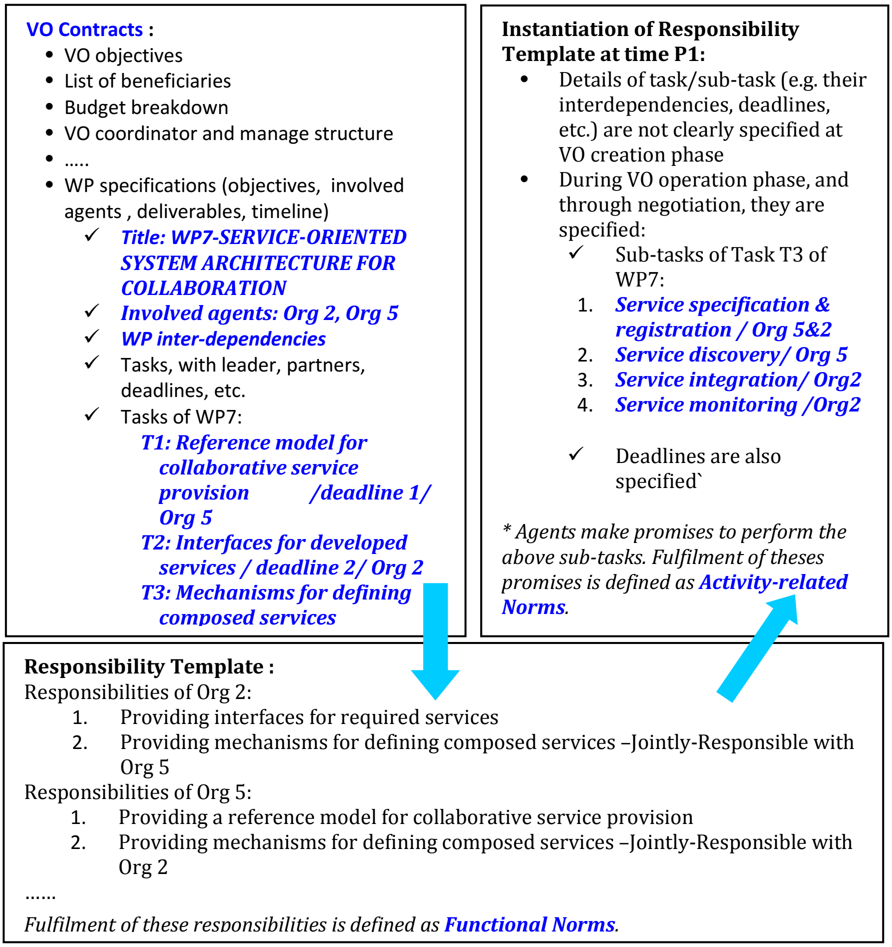

Fig. 1. Example of responsibility template for R&D projects

However, usually a task involves several partners, and pre-defining all details of the sub-tasks cannot be effectively done during the VO creation stage. It is rather during the VO operation stage when the responsibility template constituting the functional norms is further instantiated with the definition of more detailed activities for each sub-task, with their interdependencies and specific partner assignments.

We consider that all agreements made among agents for performing their day-to-day activities (sub-tasks) are specified as promises. As such, the promises made in a VO provide the definition of activity-related norms. One important and challenging issue in Virtual Organizations is how to deal with joint-responsibilities. Usually, there are activities that should be performed by a group of agents, for which all agents are jointly responsible. In VOSAT framework, these kinds of day-to-day activities are referred to as joint-promises [4]. Making a joint-promise by several agents leads to each of them obliging itself to performing its own responsibilities as well as contributing to the fulfillment of parts for which other partners are responsible. This is due to the fact that with joint responsibilities, the reputation and financial interests of all involved partners are at risk. To support fairness in keeping joint-promises, the framework requires that agents involved in a joint-promise also rank their collaborators on the level of cooperativeness and performance toward the joint-responsibility.

The supervisory function of VOSAT provides an enforcement mechanism to detect when a norm is active as well as when and if it gets violated. In other words, to support the VO supervision, it is needed to monitor agents' behavior. This is done partially through checking the compliance of agents' behavior with the norms of the VO, and imposing corresponding sanctions on agents that violate norms. Additionally, since functional norms are in conformance with the activity-related norms, it is sufficient to monitor only the activity-related norms. Besides the activity-related norms, as a part of functionality for monitoring partners' behavior, the level of partners' trustworthiness is also monitored and analyzed against a fuzzy norm defined in the VO.

In a normative environment like a VO, norms can have different levels, norms at level zero are triggered by the external events, whereas a level k + 1 norm, with k > 0, is triggered in case of a violation of some norm(s) defined at level k [5]. In VOSAT framework, trust level is defined as a fuzzy norm for each agent. Activity-related norms are at level 0, because these norms are triggered by environment-related facts. However, the trust(worthiness) level, which is typically triggered by the violation of activity-related norms, is at level 1.

Imposing related sanctions against the norms' violations is very important in Virtual Organizations. For instance, if a promisor notifies the VO coordinator before reaching the deadline that it cannot fulfill its promise on time, it should then be punished less than if it were in the situation in which the deadline is passed and the promise if not fulfilled. But clearly, the sanction policies are not the same in different VOs. Usually, there are two kinds of sanctions that can be applied in order to incentivize the norm compliance and to discourage deviation from norms, one affects agent's resources (e.g. financial punishment), and the other one affects agent's reputation (e.g. black listing), and both leading to the need of re-assignment of the agent's tasks to others. Sanction rules are either mentioned in the consortium agreement or specified by the VO coordinator, and can be defined as response to the violation of norms at each of the mentioned levels.

3 Monitoring Activity-Related Norms

In VOSAT framework, as originally introduced in [4] and further extended in this paper, a promise is defined as a tuple <x, y, p, d, q, d′> where x is the *promisor agent*, y is the *promisee agent*, p is *the proposition* which a promisor should bring about before *deadline* d, q is a *pre-condition* for realizing p by x, and d′, is the *deadline* before which q should hold.

Please note that the VOSAT system considers the notion of time, and can decide when and if a deadline is reached. In this framework, as shown in Fig. 2, different states are considered for a promise. If the pre-condition of a promise is fulfilled on time, the promise's state is Conditional, but if it is not fulfilled before reaching its deadline, the promise's state is Unconditional. However, if the deadline of pre-condition is passed and its pre-condition is not fulfilled then the promise is Dissolved. If the deadline of a promise is passed and the promised proposition is fulfilled then the state of the promise is Kept, but if it is not fulfilled by the deadline, the promise's state is Not Kept. The Invalidated promise is the one that has not been fulfilled due to some reasons beyond the promisor's control. If the promisee cancels its promise its state is Withdrawn, while if the promisor cancels it, its state is Released. For example Pr^{C}, as it appears in Fig. 3, represents a conditional promise.

Promise States	**Description**
Conditional (C)	There are some conditions that need to be fulfilled first.
Unconditional (UC)	All conditions are fulfilled before their deadlines
Kept (K)	The promise is assessed to have been kept.
Withdrawn (W)	The promise is withdrawn by the promisor.
Invalidated (In)	The promise has not been fulfilled due to some reasons beyond the promisor's control.
Released (R)	The promise is not needed any more, so it is cancelled by the promisee.
Not Kept (NK)	The promise is assessed to have not been kept.
Dissolved (Dis)	When conditions are not fulfilled before their specified deadlines.

Fig. 2. Different states of a promise

Furthermore, in VOSAT, the state of promises made by each partner is monitored. For this purpose, a set of rules are defined that apply to promises during their life cycle, and represent how the facts from the environment, and actions taken by the promisor potentially cause the state transition in given promises. Fig. 3 represents a set of rules, which are further explained below.

- $T, T, Agree(x,y,p,d,q,d') \Rightarrow \quad Pr^{C}(x,y,p,d,q,d')$
- $Pr^{C}(x,y,p,d,q,d')\,,\ \neg d'\,, Fulfill\,(z,q) \Rightarrow\ Pr^{UC}(x,y,p,d,q,d')$ *where z is an arbitrary agent*
- $Pr^{UC}(x,y,p,d,q,d')\,, \neg d\,, Fulfill\,(x,p) \Rightarrow \quad Pr^{K}(x,y,p,d,q,d')$
- $Pr^{UC}(x,y,p,d,q,d'), \neg d, Withdraw(x,y,p) \Rightarrow \quad Pr^{W}(x,y,p,d,q,d')$
- $Pr^{UC}(x,y,p,d,q,d'), d \wedge \neg p\,, nop \Rightarrow \quad Pr^{NK}(x,y,p,d,q,d')$
- $Pr^{C}(x,y,p,d,q,d'), d' \wedge \neg q\,, nop \Rightarrow \quad Pr^{Dis}(x,y,p,d,q,d')$
- $Pr^{UC}(x,y,p,d,q,d'), T, Fail(p) \Rightarrow \quad Pr^{In}(x,y,p,d,q,d')$
- $Pr^{UC}(x,y,p,d,q,d')\,, T\,, Release\,(y,x,p) \ \Rightarrow \quad Pr^{R}(x,y,p,d,q,d')$

Fig. 3. Rules for state transition of a promise during its life cycle [4]

The rules primarily express how agents' interactions influence the state of promises. In these definitions, we use "T" for *true* and "nop" for *no-action operation*. A rule is represented as $\rho, \varphi, \alpha \Rightarrow \psi$ where ρ , φ, α respectively represent a *promise-related fact*, an *environment-related fact* and *an action*, and ψ represents a *promise-related fact*. Promise-related facts describe the state of a promise as addressed above, e.g., $\mathrm{Pr}^C(\mathrm{x, y, p, d, q, d'})$ denotes the fact that this promise is in conditional state.

Environment-related facts describe the state of the environment e.g. if φ *is d*, then it represents that a deadline is reached, and if φ *is T*, it represents that the environment facts are irrelevant to this rule.

We further define a specific set of actions that influence the state the promise as shown below. For instance, the creation of a new promise is achieved through an "Agree" action.

- $\mathrm{Agree(x, y, p, d, q, d')}$: x agrees with y to make the proposition p true, before the deadline d, if the proposition q is true before deadline $\mathrm{d'}$.
- $\mathrm{Withdraw(x, y, p)}$: x informs y that he withdraws his promise to make the proposition p true in the environment.
- $\mathrm{Release\ (y, x, p)}$: y tells x that it is no longer needed to keep his promise to make the proposition p true in the environment.
- $\mathrm{Fulfill\ (x, p)}$: x fulfills its promise and thus the proposition p is now true in the environment.
- $\mathrm{Fail(p)}$: proposition p can no longer become true in the environment, due to an external failure. This is considered as an environmental action rather than an agent's action.

The state of our proposed behavior supervisory system makes a transition either when an agent performs an action, as mentioned above, or when a deadline is reached. Agents' actions may also cause some environment-related facts to become true, which in turn may trigger some rules applied to the life cycle of a promise. Consequently, in time both the sets of promise-related facts and the environment-related facts will be changed, and new facts are derived.

It should be noticed that for each promise, at most one of the mentioned states is true at any point in time and that some states including kept, not kept, withdrawn, invalidated and dissolved will in principle remain true in the VOSAT framework, once they are true. Not kept and withdrawn states are considered as violation states, and may be decided in a VO to remove them once the sanctions (e.g. charging some damage costs to an agent or adding the agent to some blacklists) are applied. Other states except for conditional and unconditional will remain in the promise-related facts forever.

The derived promise-related facts, such as the withdrawn and not kept states of promises, may in turn also trigger some *sanction rules*, and result in some new facts, which should then be transmitted to the VO coordinator. For instance $Pr^{NK}(x, y, p, d_1, q, d_2) \Rightarrow Add\ balcklist\ (x)$ is a kind of sanction rule, relating promise-related facts to environment-related facts. This sanction rule adds the promisor of a not kept promise to a specific black list, for example to be used later for making decisions by the VO coordinator, such as in the case of selecting suitable VO partners for creation of a new VO.

We have used Organization Oriented Programming Language (2OPL) [6] as the organizational setting to implement our supervisory assistance tool. Some details about our implemented tool are addressed in [4].

4 Agents Trustworthiness Level as a Fuzzy Norm

The violation of activity-related norms may only trigger sanction rules but also trigger some new norms, such as the trust(worthiness) level norm related to involved agents. In other words, the trustworthiness level of an agent may increase/decrease depending respectively on its fulfillment or violation of its activity-related norms. Therefore, as explained earlier, the activity-related norms are norms of level 0, while the trustworthiness level norms are norms of level 1.

4.1 Trust Modeling

There are a large number of approaches introduced in the literature for an agent to build a model of trustworthiness for other agents in an environment. In [7], a survey of trust models and approaches is presented and two categories of techniques, i.e. objective external evaluation agencies [8] and subjective external evaluation agencies are introduced. Our approach applies a combination of these two general approaches, i.e. a VOSAT's normative artifact collects on one hand the information related directly to an agent's behavior norm abidance containing certain pre-defined criteria, and on the other hand collects the ranking by others about each agent's collaboration, as provided by other agents when together performing joint-responsibilities. These two factors are then combined for calculating an overall trust value of each agent, applying a fuzzy comprehensive evaluation method. Our approach is flexible and different factors can also be added to it if needed for evaluating agents' trustworthiness. The fuzzy comprehensive evaluation method [9], which we introduce for trust evaluation in VOs, considers various factors $(\text{each indicated as } f_i)$ that influence a certain element, and it applies fuzzy mathematical methods to evaluate the merits and demerits of that element [9]. At the first stage, the fuzzy factor set $F = \{f_1, f_2, \dots, f_n\}$ and the evaluation set $E = \{e_1, e_2, \dots, e_m\}$ are established. In VOSAT approach, we have considered two fuzzy factors of individual norm abidance - evaluated in the interval of [0,2], and collective norm abidance - evaluated in the interval of [0,2]; thus f_1 denotes individual norm abidance and f_2 denotes collective norm abidance. To evaluate the individual norm abidance for an agent A, the interaction/collaboration experiences of agent A with all other agents are considered, namely the number of all kept promises made by A to other agents, and the number of all violated promises. To evaluate the collective norm abidance for an agent A, all received ranking recommendations from other agents about A are aggregated.

Our proposed evaluation set for trustworthiness, i.e. $\{e_1 = \text{high distrust},\ e_2 = \text{medium distrust},\ e_3 = \text{low distrust},\ e_4 = \text{low trust},\ e_5 = \text{medium trust},\ e_6 = \text{high trust}\}$ is defined in the interval of [0,2].

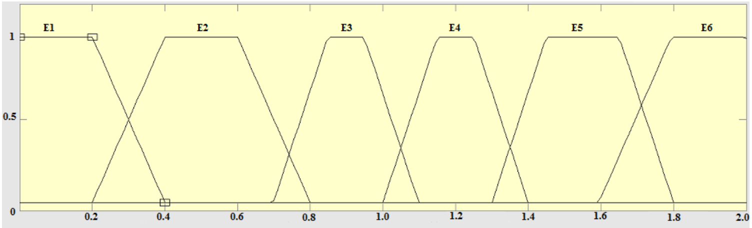

Fig. 4. The proposed trust evaluation set

As Fig. 4 shows, membership functions from left to right correspond to $\{e_1, e_2, \dots, e_6\}$. At the second stage, we establish the fuzzy evaluation matrix R. So far, we have defined how to collect/calculate the value for each factor. Then according to the value of factor f_i, we can determine its grade of membership in each e_j, which is expressed as r_{ij}. For example, if for agent A we have $\{f_1 = 1.6, f_2 = 1.2\}$ then the fuzzy evaluation matrix R to calculate its trust level is $R = \begin{bmatrix} 000010 \\ 000100 \end{bmatrix}$.

At the third stage, we introduce different weights for each introduced factor, i.e. $W = \{w_1, w_2, \dots, w_n\}$, where $\sum_{i=1}^{n} w_i = 1$. Depending on the type of VO the importance of one factor may be more than another factor. Assuming the $W = \{0.7, 0.3\}$ relating to the factor set of $\{f_1 = 1.6, f_2 = 1.2\}$, the result of the comprehensive fuzzy evaluation is calculated as $B = W \cdot R = [0.7{,}0.3] \cdot \begin{bmatrix} 000010 \\ 000100 \end{bmatrix} = [0\ 0\ 0\ 0.3\ 0.7\ 0]$.

For the defuzzification process, we directly apply the center of gravity method, as introduced in [10]. As a result of defuzzification, the result of B will transfer to a single value, denoting the overall trustworthiness of each agent. For the mentioned example, the $[0\ 0\ 0\ 0.3\ 0.7\ 0]$ is then defuzzified to 1.49, showing the overall trust value of agent A. If in a specific VO, the minimum accepted level of trustworthiness is "*medium trust*" then the violation of this agent (with the overall trust value 1.49) is zero.

In our approach we also emphasize the importance of having sufficient information about an agent for evaluating its trustworthiness level. Therefore, for fairness purposes, a confidence level should also be considered for each factor related to the agents in the VO. In other words, if the confidence level for a factor is above a predefined threshold, then it has a direct effect on the trust evaluation results. For example, if an agent's involvement in the VO is either for longer than T period of time or in more than C number of activities, his trustworthiness level norm is active and it will be monitored if any activity-related norm of his is violated. Trustworthiness level norm can also be treated differently based on the type of the VO. For example in one VO it may be sufficient to have a medium trust level for agents, while in another one it may be necessary to fulfill the high trust level for all agents.

One advantage of monitoring this fuzzy norm for trustworthiness of agents is to enable the VO coordinator with finding the best potential candidate for handling the exceptions that require re-assignment of tasks. Another advantage is to assist the coordinator with identifying which one of the running tasks (current promises) might involve risks, through identifying which agents' trustworthiness level norm are violated.

5 Related Works

In relation to agents formal commitments, a number of research in the multi-agents community address the area of agents' formal contracting, the concept of leveled commitment contract [11], and reasoning about commitments and penalties [12]. The authors in [13] propose a contract fulfillment protocol based on the normative statements' lifecycle. Our approach however differs from the above approaches due to targeting the specificities of the VO environments, e.g. the aspects of continuous evolution, joint responsibilities, etc., for which we introduce and apply the concept of promises that are not necessarily bilateral.

Related to categorization of norms in agent communities, in [14] a two-level normative agent interactions is proposed for a society of agents including an institutional level, and an operational level. The institutional, constitutional, and operational levels are also addressed as a hierarchical organization of norms in [15]. Although our proposed approach has some aspects in common with these approaches, it addresses the VO dynamism as activity-related norms, defined as promises, which do not directly represent contractual obligations. Furthermore in our approach, such dynamic aspects are specified gradually during the VO operation phase.

In relation to research on the formalization of promises and norms, in [16] and [17] some definition of promises are represented by Modal logic. However this logic does not allow for reasoning about the complex life cycle of promises, which is needed in our proposed operational framework for VOs. In [18] norm conflicts and inconsistencies in Virtual Organizations of software agents are addressed. Dynamic nature of a VO results in changing the agents' normative position, and consequently conflicts may occur in an agent's norms. In their model of norm-governed agency inspired by the BDI model, agents can independently decide either to obey their norms or to violate them. However, in VOSAT framework, the internal states and operations of individual agents are not considered and only the external actions of agents are monitored against the given set of norms. Moreover, agents' actions are not limited to the two types of actions - obedience and violation- rather a number of different states are considered for promises.

According to the theorem of "duality of structure" [19], in a VO where agents repeatedly refer to the social structures (norms) to do their actions, trust is a medium of structuration. In relation to computational reputation and trust models, in [8] four different categories are classified, which are explained below. In the so called category of Agent-Oriented Solitary Approaches [20], the evaluations are calculated by the agent itself according to its own previous experiences without any exchange of information. In the category of Agent-Oriented Social Approaches [21], agents calculate the evaluations considering both their own experiences as well as the third-party information. Trust modeling in social networks is usually categorized in agent-oriented approaches [22]. In the categories of Objective External Evaluation Agencies [8] and Subjective External Evaluation Agencies [23] instead of agents, external agencies collect the information. The former computes evaluations according to certain objective criteria, while the latter aggregates the subjective agents' evaluations that are collected by the system. In proposed approach, we combine elements from the last two approaches above, to make the trust model for VO partners.

6 Conclusions

This paper addresses a framework and tool called VOSAT for virtual organizations to assist with controlling the behaviors of agents involved in VOs, through monitoring their activity-related norms and imposing appropriate sanctions when agents fail and norms are violated. To perform day-to-day activities a number of individual and joint promises are made by the involved agents, which in turn define the activity-related norms in the VOs. The main focus of the paper is on the definition of the needed framework as well as the extension of the tool to define and monitor trustworthiness level of agents as a fuzzy norm. Consequently, the VOSAT enables the VO coordinator with both finding suitable candidate partners to replace a failing partners and handle such exceptions during the VO operation phase, as well as identifying the weakest points or the high risk tasks in the VO's planned operations. These in turn assist with improving the success rate of VOs. The proposed tool is prototypically implemented using the Organization Oriented Programming Language (2OPL) [6], and more details about the tool implementation are addressed in [4].

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A Governance Reference Model for Virtual Enterprises

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Abstract. During its entire lifecycle the Virtual Enterprise (VE) partners should share a sort of assets and sensible information as well as execute intra- and inter- organizational business processes in a coordinated and secure way, mostly supported via computer networks. VE partners are however independent enterprises and have their own business strategies. Therefore, it is relevant to properly govern a VE in way to minimize conflicts among its partners and hence the risks for achieving the VE goals. This paper presents a VE governance reference model allowing the instantiation of more concrete governance models for given VEs. An important contribution of this research is the consideration of the economic dimension of governance, not covered in related works.

Keywords: Collaborative Networked Organizations, Virtual Enterprises, Governance, Reference Model, Instantiation Approach.

1 Introduction

With the increase competition in the global market, enterprises have been open to participate much more actively in strategic alliances. In this context, *Collaborative Networked Organizations (CNOs)* have arisen as a paradigm to support a number of competitive advantages for all involved organizations, including the exploitation of new market segments and opportunities, costs reduction and risks mitigation [1].

There are many types of CNOs manifestations. This work focuses on the *Virtual Enterprise (VE)* type. Generally, a VE can be defined as a temporary alliance formed by autonomous, heterogeneous and geographically dispersed enterprises that join their complementary core competences and resources to better attend to a given demand, dismantling itself after finishing all its legal obligations [1]. VEs are mostly originated from long-term strategic alliances, namely *Virtual organization Breeding Environments (VBEs).* A VBE formally groups organizations in order to provide enough pre-conditions and basic operating rules for collaboration among its members aiming at creating VEs with the most adequate partners in a more agile and trustful way [1].

During its entire lifecycle VE partners should share a sort of assets and sensible information as well as execute intra- and inter- organizational business processes. VE partners are however independent enterprises and have their own business strategies, which creates a complex and intrinsic conflicting VE operation scenario. Therefore, it is of extreme relevance to properly govern a VE in way to minimize conflicts among its members and involved external and hence the risks for achieving VE goals.

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Some related works on VBE and VE governances (e.g. [2], [3] and [4]) assume that a given VE should generally inherit (partially) the governance model from the VBE whose partners belong to. This seems correct as a VBE somehow imposes to its members a set of common principles and operating rules. In spite of that, this paper goes one step forward. It facilitates the instantiation and definition of *particular VE governance models*, but keeping them aligned to the *VBE governance model* [2] [3] in order to preserve the VBE values and bylaws [4].

This assumption is grounded both in empirical observations from some real VBEs implementations (e.g. as described in [5]) as well as in literature review (e.g. [6]). Basically, it has been realized that a VE is mostly unique. Even though the good to be produced is similar to someone previously manufactured, VE partners' composition can be totally different. This may happen due to many reasons, such as the eventual unavailability, non-interest or low historical performance of some previous partners in the related past VEs. Besides that, collaborative business opportunity's requirements, customer requests and commercial rules deeply affect many aspects in the way a VE should behave and hence be managed, like as the required legal framework, logistics itineraries and type of logistics partners, the setting-up of the decision model (between partners) and its structure, and the influence of the customer along the general production process. Therefore, an *additional* and *complementary* coordination instrument should be created, which is represented by the *VE governance model.*

Very few works in the literature have tackled the VE governance from that more comprehensive view. It was also observed that the works on networked governance are very abstract (e.g. [2] [7]), creating difficulties for SMEs to deploy them.

As a contribution in this direction and from a more business processes-oriented perspective, this paper presents a proposal of a *VE governance reference model.* It allows the derivation of concrete governance models for given VEs, defining the actors, relations among them and with the *VBE governance model,* rules and mechanisms to be used along each phase of the VE lifecycle (creation, operation/ evolution, dissolution) regarding VE partners' rights and duties, and taking the given business demand's characteristics into account.

This paper is organized in five sections. The first one has introduced the problem and the context of the research work. Second section describes the basic concepts of governance in networked enterprises. The third section presents the proposed VE governance reference model. Section fourth illustrates an instantiation of the governance reference model. Section five summarizes some conclusions of the work.

2 Governance in Networked Enterprises

Governance in networked enterprises can be defined as "the specification of rules, criteria for decision-making, responsibilities, and boundaries of actions and autonomy for the involved actors. It is created by the own set of organizations to regulate itself. The fundamental role of governance is not managing; but to delimitate/guide the management instead. Actors can use their knowledge within the defined governance framework in way to help organizations to best reaching their common goals [8]".

Networked enterprises governance have to consider two *complementary* dimensions: one related to the coordination of the economic activities, and another one to the network structure and coordination of its activities [8]. The essential rationale is that the market and power influence directly the way a network should execute and manage its processes and all related information, and hence on how it should be internally organized to correctly and efficiently respond to that.

There are a number of approaches about networked enterprises governance in the literature regarding the economic dimension, providing different perspectives and classifications in terms of governance strategies. However, almost all of them are in practice devoted to “classical” networks, as VBE-like or more static ones.

Under this dimension and in the context of this research, five works were taken as the theoretical foundation basis to identify the required elements for VE governance and to propose a reference model. They are basically explained below, in a sequence, which corresponds to how they have also evolved along the time.

Williamson [9], for instance, was one of the first ones who identified the relevance of networks, pointing out that the power could no longer be governed by a single enterprise. Storper et al. [10] depicted the power itself among enterprises using two concepts: *core* (main enterprise) and *ring* (suppliers). By means of the combination of these concepts they identified four types of governance in terms of power concentration or distribution: *all-ring, no-core; core-ring with coordination firm; core-ring with lead firm;* and *all-core, no-ring*. Gereffi [11] has seen the network from the value chain point of view, identifying when the network was fundamentally *producer-driven*, *buyer-driven* or *information-driven* (e-commerce related). In another work, Gereffi [12] complemented this work seeing the network also from the point of view of power relation among buyers and producers as a consequence of the required network’s production structure for a given demand. For that, they proposed five other categories of governance types: *market, modular value chain, relational value chain, captive value chain* and *hierarchical*. In all these approaches authors assumed a tight connection and *a-priori* knowledge between the involved enterprises. Provan et al. [13] was one of the first ones who addressed the problem considering the enterprises as a set of totally autonomous and decoupled organizations but that should also work for a common goal. They have identified three basic governance types: *shared governance* (when the power is more or less equivalent among the members), *leader organization governance* (when the power is clearly more concentrated on a given single organization), and *network management organization governance* (when the network delegates the power to an external organization).

Very few works were found out in the literature proposing more concrete means for a VE governance model from the network structure and coordination dimension point of view. Albers [14] has identified two sub-dimensions for that, called *structural* dimension and *instrumental* dimension. Structural dimension basically copes with the network structure and which tasks partners should do. Instrumental dimension basically refers to the networked coordination and incentive mechanisms to sustain the collaboration. Albers [14] model is however too abstract, it does not consider anyhow the ‘economic dimension’, and does not provide any concrete guidelines on how those dimensions should be instantiated to support the network operation. In spite of the importance of this contribution, the author considered a classical network, with fixed partners. Dekkers et al. [15] recognizes the influence of the market and external contexts in the way a network is organized, coordinated and managed. However, they do not propose a model for that.

In terms of governance *models*, Romero et al. [3] tackled governance explicitly from the CNOs point of view, but with a focus on VBE-like networks. This first work has generally identified the *structural* governance elements that a VBE should have: *principles, bylaws* and *rules*. Rules in turn can be of *functional* (e.g. operational procedures to manage the VBE) and *behavioral* (e.g. ethical code) natures. In another work, Romero et al. [2] have extended this general model to VEs. Actually, it corresponds to an instantiation from the VBE model and with a focus only in the VE creation phase. That model is however a bit abstract, does not consider the economic dimension, and processes are described at a general level, which creates some difficulties for SMEs to understand how to use and deploy it.

A substantial part consumed in the VE creation process refers to the governance model setting-up [4]. Within this context, the underlying value proposition of this work is to provide more systemized, concrete and transparent means to govern VEs considering those two main dimensions simultaneously. This gives better conditions for faster VE creations as well as for more confidence and trust among partners along the VE lifecycle as long as all roles and rules are clearly defined and agreed.

3 A Virtual Enterprise Governance Reference Model

3.1 VE Governance Model Elements

Four key aspects are behind the rationale of the proposed *VE governance reference model.* The first one refers to the consideration of the two fundamental dimensions of governance: economic and structural. The second one refers to considering governance at its essential, i.e. that it does not manage itself, but rather restrains the limits of management. The third one refers to see that the VE governance is influenced by the VBE governance model. The fourth one refers to considering the requirements of VEs, which are different than the other not dynamic networks.

Camarinha et al. [16] points out the following VE main characteristics that then should be supported (requirements) by any VE-related model: *i)* VE partners come from another network: a VBE; *ii)* VE partners are autonomous; *iii)* VE partners are heterogeneous at several levels; *iv)* VE members do not know to each other *a priori* when they become VE partners; *v)* Due to the fact VE partners come from a VBE, a sort of common principles are agreed and hence the trust building problem is mitigated; *vi)* a VE (and the way partners should behave) can be totally different from another one created in the past to respond to the equivalent business; *vii)* VE partners have different roles and hence different rights and duties along the VE lifecycle; *viii)* a VE should be kept alive until all of its legal obligations are ceased.

This last requirement demands for an extension in the classical VE lifecycle [16], with the addition of the "*after sale*" phase (e.g. maintenance, warranty, devolution and new extra services). This means that a governance model should also embrace a set of concrete actions that VE partners should carry out after the "product" (in a broad sense) has been delivered (dissolution phase), assuming that the VE has accomplished the business requirements successfully [17].

Considering those four key aspects above mentioned; Figure 1 shows the proposed VE governance reference model, highlighting the wider framework it is inserted in: as a model that is influenced by the VBE governance model and that behaves according to external business conditions. These conditions are actually affected by the nature of the given collaboration business opportunity, customers, regulations and all external issues that can influence the network from the economic and power perspectives.

Inspired in the work of Romero et al. [2] and Albers [14], the proposed VE governance reference model is composed of four fundamental constructs: *Actors, Rules, Mechanisms* and *Principles*.

The basic logic of the proposed model can be understood as: *actors* will be organized and act along different phases of the *VE lifecycle* making use of *rules* and *mechanisms*, and all such actions should respect the VE and VBE *principles*. The different actors have *roles, rights* and *duties* respected to each VE phase in way to guarantee its correct and good functioning, concerning the *business requirements* and the *economic* and *power constraints*.

Actors represent the involved participants in a VE. Considering the different level of responsibilities actors can have, they can be inter-organizational [15] (e.g. *VE manager, VE broker*, and *VE coordinator*) and intra-organizational (e.g. *the company manager, an engineer*, and *a technician*).

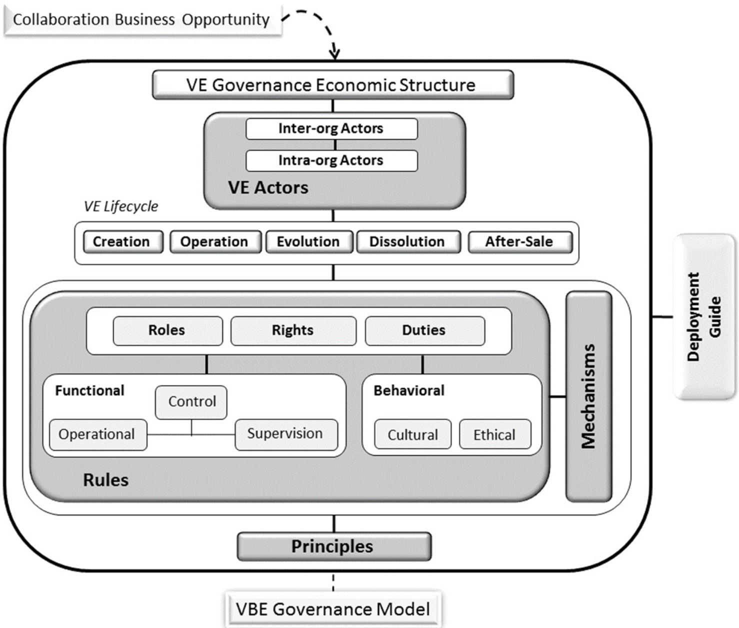

Fig. 1. VE Governance Framework and Reference Model

Principles represent the underlying values (e.g. *honesty*, *commitment* and *mutual respect*) that companies and people must follow. They usually come from the VBE and can also be complemented with other principles at VE level, depending on the given collaboration business opportunity's requirements. These principles should be somehow reflected in the governance rules. For example, *commitment* can be "deployed" as *rules* related to certain type of actor(s) to "send up-to-date information about tasks to the other actors for follow-up purposes" at the VE *operation* phase.

Rules represent concrete actions that given *actors* should execute at given VE phase(s) by means of *mechanisms* respecting predefined *principles*. Rules are associated to the *roles* and hence to the *rights* and *duties* that VE partners have at the different phases of the VE lifecycle. This means that a given actor may have more than one single role in a given VE. A role is represented by "unitary" actions that given actors can perform (e.g. *inform clients about production execution*). Depending on how the other governance elements have been decomposed, this exemplified role can be of responsibility of actors *VE coordinator* and *VE manager*.

Rules can be of two main categories: *functional* and *behavioral*, which in turn are subdivided into *operational*, *control* and *supervision*; and *cultural* and *ethical*, respectively. In essence, while functional rules are devoted to help framing the daily operational routine along the VE life (and where control rules are hierarchically above the other two ones), behavioral rules are devoted to people. For example, "*supervising the product delivery*" is seen as a functional-supervision rule; "*sending the information about any delay and the responsible sector as soon as the problem is detected*" is seen as a behavioral-cultural rule.

In resume, rules should be handled at a given VE phase by a given actor who has a given role that is settled as his duty, and this only exists because there is another actor(s) who has some rights related to that.

Mechanisms are basically the available or necessary means required to help actors in the rules execution. They can be formed by techniques (e.g. project management methods), software (e.g. groupware systems), devices (e.g. data collectors) and infrastructures (e.g. larger broad-band Internet for some specific situations).

In those hypothetical examples, this would be only possible and correct because (from the economic dimension perspective point of view) the business would have required (regarding the current VBE's members profile) a production structure and governance mode of type *relational value chain* (when there is a tight connection between the client and producers along the entire production). It would be *buyer-driven* as the client would have a strong influence all over the process. As the company which got the business (assuming the 'VE coordinator' *role*, for example) would be clearly the main producer (i.e. *core-ring with lead firm*), it would be allowed to have the power to ask for qualified information from any VE partner (this would come from a VBE governance model's rule) and then the whole network has to run under the *leader organization governance* mode.

3.2 VE Governance Rules Formalization

An instance of a given VE governance model can have plenty of rules. Having in mind that the most important goal of a governance model is to be indeed followed by the involved actors, it is of extreme importance that its rules should be documented. In fact, rules are the element to which all the economic and structural elements converge to and are reflected in.

There are different ways to express and to formalize such kind of *rules* (which is not the same than modeling *business processes*). Regarding the reality of SMEs, the formalism should be simple even though less rich. Writing rules textually is difficult but as some rules' details can be easily forgotten. Rules should be easy to understand by typical SME people, to document, to maintain, and to be quickly consulted and checked. In this sense, this work has opted to model rules using the very known and simple *5W2H* technique. By means of a set of "questions", rules can be comprehensively and formally expressed, as showed in Figure 2.

Question	Description	Element
What?	It defines the concrete action that has to be done.	Functional or Behavioral rule
Who?	It defines the actor who has the role to do the "what".	Actors and roles
When?	It defines when (the VE lifecycle phase) that the "what" has to be done by the "who".	VE lifecycle phase
Where?	It defines where (general or specific place) the "who" has to perform the "what" at the phase "when".	Physical place
Why?	It explains in details the purpose of the action "what".	Aim
How?	It indicates the way (methods, procedures, protocols, etc.) that the "what" has to be done by the "who" as well as eventual related performance metrics.	Mechanisms
How much?	It gives an indication of the costs (or notes about it) to do the "what" (if applicable and if values are relevant).	Costs

Fig. 2. 5W2H technique adapted for the VE governance reference model

4 Instantiation of the VE Governance Model

This section presents examples of the instantiation of the proposed VE reference governance model. Actually, this corresponds to a real scenario, based on a case of a Brazilian network of mould-makers called *NuFerJ*, to which the governance model was applied, tested, and validated. NuFerJ has been found 19 years ago and its members are SMEs, completely independent to each other, although some of its members used to always work with some members in some cases. Since 2010 NuFerJ has started an initiative to (also) work under the VE strategy aiming at enlarging business possibilities (via larger production capacity) and maximizing resources utilization. NuFerJ uses to receive a "package" of moulds. VE partners can then be responsible for an entire mould, part of it, or for some specific operations of it. This VE notion is also communicated to the customers before contracting, i.e. they know the companies that will participate in a given VE.

NuFerJ customers are mainly automotive, electro-electronics and home appliances sectors, from a number of different countries, although Brazilian (large) companies are the ones which mostly generate demands. Therefore, NuFerJ - and so VEs that are generated to attend such demands - has to deal with a variable economic environment.

Taking into consideration the governance approaches described in the section 2, NuFerJ "fits" some of them, depending on the collaboration business opportunity, customer, and other general requirements. In order to illustrate a given instance of a derived governance model for a given VE and due to size restrictions of the paper, the example below will take only one "business scenario" and only two rules will be showed. Actually, the current version of NuFerJ VE governance "reference" model is composed of 54 rules that cover important situations over the whole VE lifecycle.

From the governance structural dimension perspective point of view, besides the bylaw, etc., principles of NuFerJ network (so at the VBE level) include *honesty* (in the sense of always sending trustful information and do not lie during conversations), *commitment* (partners will indeed put all efforts to keep the business requirements), and *collaboration* (willingness to help members in the case of problems).

In this example, the general governance "framework" would be classified as *buyer-driven*, *relational value chain* and *core-ring with coordinating firm*.

The two rules below show the VE governance model instantiated in two situations. Figure 3 shows a rule to be used in the VE creation phase when a given partner decides (meaning that it has this degree of autonomy in accordance to the governance 'framework' and expressed in the contract) to subcontract another company to make a specific operation which any of the other members are capable to.

What	Hire an outside company. Rule: *Right – Functional – Operational.*
Who	Inter-organizational Actor: VE manager, VE broker, VE customer.
	Intra-organizational Actor: Member manager.
Why	In order to cope with very specific product's technical requirements.
When	VE creation phase / partners' search and selection sub-phase: In the case of any VE partner is no longer capable to fulfill the needed requirements.
Where	Not applicable.
How	Following the specific contract clauses. Mechanisms: *Partners' Search and Selection* software system
How much	Costs cannot be added to the whole contract and are of responsibility of the VE partner contractor to handle this.

Fig. 3. Example 1 of Governance model's rule

Figure 4 shows another situation, of a rule to be used in the VE evolution phase, when the VE manager observes that, after some attempts to solve the problem close to a problematic company that is not working as expected, he is allowed to withdraw the assigned given mould (entirely or part of it) from it.

What	Withdraw a task, part or entire mould from a given partner. Rule: *Right – Functional – Operational.*
Who	Inter-organizational Actor: VE manager.
	Intra- organizational Actor: Member manager.
Why	In order to keep product delivery date.
When	Evolution phase. When it is realized that a given VE partner is no longer able to keep producing what it was contracted considering the contract specifications.
Where	NuFerJ office
How	Following the specific contract clauses. Mechanisms: groupware and PMBOK project management
How much	Costs and penalties expressed in the contract clauses.

Fig. 4. Example 2 of Governance model's rule

The process of defining the rules is however "manual" and has some degree of subjectivity (although all rules must be agreed among partners before the VE start).

This rational process is reasonably complex to make and involved managers (and even the VBE staff in some cases) are the ones who should analyze the given business scenario and its requirements (from the economic perspective) as well as configure a proper and feasible structure for the VE governance model regarding the VBE governance model (principles, bylaws, etc.) and members' profile. In other words, such manager(s) should know the VBE governance model to "guarantee" that the VE governance model inherits the essentials of that one, and hence that it is aligned with it. The VE governance reference model should then be derived for the given VE and its constructs be instantiated accordingly. Some basic governance model's constructs should be prepared, configured and set up "some time" in advance (depending on the existing conditions) of the VE creation or when it is going to be created.

The 54 used rules can be taken as templates for other derivations as they follow the reference processes and activities typically executed in a VE along its lifecycle [18].

Actually, deploying a VE governance model is far from being trivial. This is even more critical regarding that a typical VBE is mostly composed of SMEs. In order to mitigate the deployment work, the proposed governance framework also provides a *deployment guide* (not presented here due to paper length restrictions). Roughly, along five macro steps, it leads the person(s) in charge of that to go through the model and create an instance of the VE governance reference model for given VEs. To be noted that such person(s) is actually an actor, who is linked to a given role, and that is linked to the VBE and/or VE governance model.

5 Conclusions

This paper has presented a proposal for a VE governance reference model, integrating two referential perspectives: structural and economic. Dealing with VE governance from those two main dimensions simultaneously and providing concrete means to deploy a model in real cases is, however, complex and challenging. The proposed model represents a contribution towards filling up an existing gap in the literature.

The developed reference model is generic and can be instantiated for different VEs for different business scenarios. The value proposition of this model is concentrated in some perspectives, like faster VE deployment and confidence among VE partners and customers about more formal procedures to minimize VE risks in the accomplishment of its goals.

From the scientific perspective, its main contribution refers to the integration of the economics governance dimension and that the model is very concrete, more formally expressed, and indicates how the model's elements can be instantiated.

Deploying a governance model for given VEs is however not trivial. The analysis of every economic and structural detail of the collaboration business opportunity and deployed VBE demands much experience from the managers. Yet, the agreement about some rules is far from being easy and quick to reach a consensus among the involved actors, requiring many discussions. On the other hand, once reached, the governance model trends to achieve its essential goal: to be followed by all actors, with a more robust commitment, and more customer confidence.

Both VE governance reference model and instances-of it are not completely static once set up. As in any organization, several factors can contribute to change the rules as long as VBE governance model and businesses environments evolve.

The main limitation of the identified rules and view upon the economic dimension is that all information is handled fundamentally from the engineering point of view. Legal, social, management and accounting supporting foundations are not ready "transformed" into rules and will require additional guidelines in the model. Besides that, the model was only evaluated in one network. Therefore, larger evaluations are necessary towards a still more comprehensive reference model. These two issues are the main ones planned to be tackled in the short-term of this research. Another research action refers to evaluate richer modeling formalisms to better capture and express the network dynamics and the governance rules as 5W2H is relatively poor. Finally, a deeper research is needed to better identify the conceptual borders between governance and VE coordination tasks in a more global VE management framework.

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Virtual Enterprise Process Management: An Application to Industrial Maintenance

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Abstract. The paper firstly reviews the relevant concepts on virtual enterprise operations as well as industrial maintenance processes. Then a virtual enterprise enabling platform is presented. The architecture of the platform and its main modules are briefly introduced. Within this platform, a smart object extension is highlighted. This smart object is used to collect data from remote equipment and pass it to the Virtual Enterprise Management Platform (VEMP) through a gateway. The data collected by the smart object will be aggregated and monitored, using the business intelligence tools of the platform, enabling the implementation of maintenance strategies, rising fault conditions that will trigger a repair business process. In the final part of the paper, it is discussed a business case for a SME with worldwide operations.

Keywords: Virtual Enterprise, Business Process Monitoring, Industrial Maintenance, Virtual Enterprise Management Platform.

1 Introduction

The literature and technical references on virtual enterprises often focus on the supply chain processes. This paper presents a different view once it discusses the use of virtual enterprise enabling technologies in the context of industrial maintenance processes. Due to the nature of their key business activities, maintenance processes require local operations that are performed close to the technical apparatus. As SME’s often lack the resources needed to offer a suitable quality of service level to remote clients, they need to find partners all over the world that will be engaged in business processes accordingly to their specific needs. When a robust worldwide operation network need to be set-up, the use of virtual enterprise platforms can be a rather valuable enabling technology for formation, management, adaptation and monitoring of the dynamic collaborative processes [13]. There are various forms of business collaboration such as business community, industrial cluster, collaborative network organization (CNO) [1], virtual organization (VO), [3] and virtual enterprise (VE)

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 71–79, 2014.

[4].In such business environment, there is always the need to continuously monitor and manage the underlying business processes, as discussed in this paper.

This paper is organized in 5 sections and presents the results of a research that was carried out in four main steps. First of all, we reviewed the existing literature in areas such as Industrial Maintenance and virtual enterprise for collaborative business. Secondly, we specified a hardware integration tool to apply to the field equipment, which is then integrated with a Virtual Enterprise Management Platform (VEMP). Thirdly, a requirement elicitation process is carried out, which includes semi-structured interviews to two different business enterprises, namely; a machinery manufacturing SME located in the north of Portugal (Engineer-to-Order business model) and an electronic and automation SME located in the United Kingdom (Engineer-to-Order business model). The results of these three steps conclude the requirements elicitation process through collecting the expected requirements list. Fourthly, a set of discussions were carried out with the platform development team to understand the hardware integration and technical requirements.

Section 2 of the paper reviews the literature about predictive maintenance, virtual enterprises, and business activity monitoring and process analytics concepts in order to build a theoretical background and to support the business process monitoring. Section 3 contains the main contribution presenting the results of this research with the requirements, functionalities and design of a VEMP applied to the maintenance processes management. Section 4 presents a case study where the concepts presented were tested and validated. Finally, section 5 presents some concluding remarks and perspectives for further work.

2 Literature Review

2.1 Business Collaboration through Virtual Enterprise

The uniqueness of virtual cooperation between companies in the form of VO or VE is that this type of collaboration is orchestrated through the direct use of Internet or Web-based technologies and tools. Such technologies and tools ensure real-time communication between the partner companies, while they are physically located in different regions or countries.

The beauty of business collaboration through VE is that it represented a temporary alliance of organizations that come together to share skills or core competencies and resources, in order to answer to a specific business opportunity" [1]. The formation of such business collaboration begins after selecting potential partners based on predefined criterions and invites them to join the virtual enterprise. Before joining the network partners also need to agree and sign the contractual terms and conditions to execute the VE effectively and efficiently [4], [13]. After formation of the VE, next available steps are to execute (monitoring, simulation, optimizing, forecasting) and dissolute (share out, liabilities assignment, partners evaluation) the VE.

In the VE business environment, all the required business processes are designed after consultation with the participating partners. Usually, the broker company who initiates the collaboration invites partners to design the processes needed to execute the VE operational activities. The VE process can be defined as the group of activities carried out by individual partner or group of two or more partners with the objective to fulfil certain requirement(s) that successively creates value to the end customer[7][2]. The creation and operation of manufacturing processes within the VE are done in a modular way.

The aim of VE is to provide tools and processes that will help to facilitate information exchange between partner enterprises and move beyond the boundaries of the individual enterprises involved. Within the VE collaborative manufacturing processes are optimized by enabling the integration of partner selection, forecasting, monitoring, and collaboration during runtime. The essential monitoring and governance of the collaborative processes are supported by smart technologies such as Internet of Things, smart objects, wireless sensors, etc.,[6]. Existing tools and services of the VE partners also can be integrated during the development of the VE platform [5].

2.2 Industrial Maintenance Management

Today's complex and sophisticated equipment needs to enhance up-to-date maintenance management systems. These maintenance systems are recognized as the high costs including inspection, repair, and equipment downtime with advanced manufacturing organizations [9]. High maintenance cost highlights the expectation to clearly define the maintenance objectives and to enhance modern maintenance management methods and to implement intelligent computer-based maintenance systems. In industrial domain two major maintenance management approaches are available namely; failure-driven and time-based maintenance [10]. There are also other maintenance systems such as conditioned-based maintenance (CBM), statistical-based maintenance (SBM), etc., are used to reduce the uncertainty of maintenance according to the needs indicated by any industrial equipment condition [11]

Predictive Maintenance (PM) is used as a maintenance methodology to monitor and detect incipient problems and to prevent catastrophic failure. The PM can be defined as comprehensive maintenance management program that optimizes the availability of process machinery and greatly reduces the cost of maintenance. It is a philosophy or attitude to regular monitoring of the actual mechanical condition, operating efficiency, other indicators of the operating condition of equipment and manufacturing processes and to improve productivity, product quality, and overall effectiveness of manufacturing and production plants [12]. PM is basically a condition-driven maintenance program, where instead of relying on industrial or in-plant average life statistics the maintenance activities are planned on schedule. It utilizes non-destructive testing technologies such as infrared, sensors (like smart objects), acoustic, sound level measurements, vibration analysis and other specific online tests.

PM solution opens up innovative new possibilities for companies. It does not depend on industry statistics but relies on real signals demonstrated by a single and specific piece of equipment. Any data or signal from specific sensors monitoring machine condition is automatically reviewed to pick up any patterns that indicate a possible fault. It offers the onset of stoppage to be recognized early and corrective measures to be planned. In addition to early fault detection PM also can be used to avoid unplanned downtimes and both staff and resources can be employed more effectively [8].

One area that many times is overlooked is how to, in an efficient way, transfer the predictive maintenance data to a computerized maintenance management system (CMMS) system so that the equipment condition data is sent to the right equipment object in the CMMS system in order to trigger maintenance planning, execution and reporting. Unless this is achieved, the predictive maintenance solution is of limited value, at least if the predictive maintenance solution is implemented on a medium to large size plant with tens of thousands pieces of equipment.

3 Virtual Enterprise Management Platform

The goal of a Virtual Enterprise Management Platform (VEMP) is to simplify the establishment, management, adaptation and monitoring of dynamic manufacturing processes in Virtual Factories. This includes the finding of partners, the design, forecasting and simulation of Smart Processes, and their execution and real-time monitoring.

To establish processes between different companies, data about the partners wishing to collaborate in a virtual factory is needed. Therefore, each Virtual Factory member needs to be able to add data about his company, products, services and processes. To achieve this in a user-friendly way, VEMP has to provide an editor in the scope a Data Provisioning and Discovery component to enter, view, update or delete this data. For reasons of availability, accessibility, access-control and the possibility to have redundant backups if needed, this data should be stored in the cloud. The Cloud Storage component should support several types of data storage, including NoSQL semi-structured data storage, used internally by the VEMP, as well as semantic data necessary for semantic company descriptions and also data storage for binary files. Binary files may be used for storing documents such as specifications or even multimedia files.

To design the VEMP, the platform has to provide a Process Designer. To improve and facilitate the usability of all user interfaces should accessible via a single application interface with a single look and feel and a quick learning curve. All the user interfaces should therefore be embedded in the Dashboard, including the process designer.

The Process Workflow Execution component, executes process models and the Real-time Process Monitoring shows the actual status of the process execution and can additionally query machines interfaces for their current state, collecting information for preventive and predictive analysis.

The Machine sensor interfaces as displayed in Figure 1 will be integrated via the Gateway, with acts as a Client for the Smart object services, the gateway will then communicate with the platform via the Message Routing. External systems like legacy systems etc. should also be able to communicate with the VEMP's Message Routing component making use of the Gateway component, which effectively fulfils the role of a bridge, connecting the external system with the platform. The Gateway as well as the Message Routing may invoke Transformation Services that can be used to translate between external (legacy) technology which will use different messaging protocols, interfaces and message formats. The Gateways therefore will be the only components that might need to be expanded or recreated when a new member wants to connect uncovered legacy systems to the message routing. The message transformation may be used as a base by the gateways to transform a variety of data formats, hence allowing a wide support of systems.

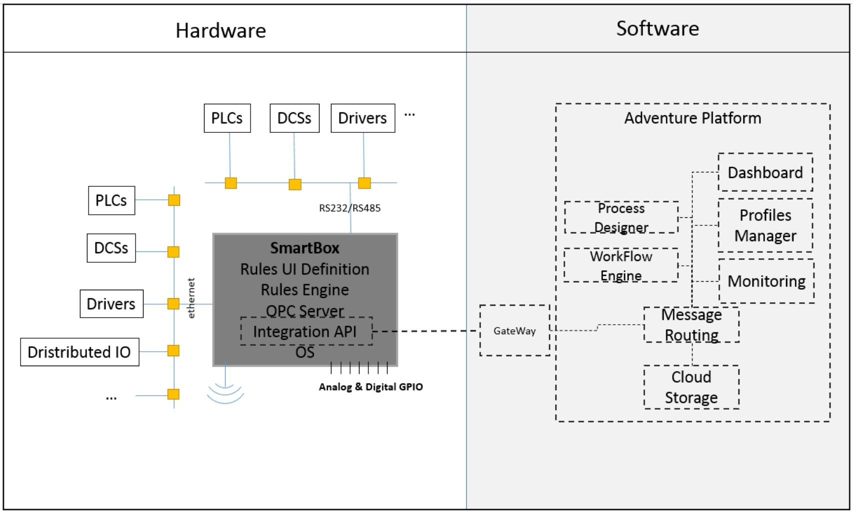

Fig. 1. Smart object integration with the VE Management Platform

A new process model is created in the process designer either as an empty model or based on a ready-to-use template from templates repository. As the broker starts to design (edit) the process, the model enters its 'in design' phase. This is the core phase for the process designer and the designer can perform several types of tasks in it: manage process metadata with the goal to enable automation and make the process discoverable; design process models, e.g. add/configure/remove process activities or other process model elements, using the notation and semantics supported by the process model design tool; use the simulation module to trigger simulation of the process and verify its qualities before executing it and potentially return to redesign for better results; use the optimization module to trigger optimization of the process for optimal business goal results and potentially return to redesign for better results; save for further work or share the designed process model; load, if the process model has been saved earlier or has been shared by another user.

The workflow process execution component will be at the heart of the platform, as it will orchestrate all interaction in a virtual factory. Its purpose is to execute processes, modelled in the process designer. This component will deal with processes, process instances and the communication with gateways and logging.

The monitoring component in the platform is the component that provides the real time monitoring of ongoing process, historical data relating to finished processes and instances and business analytics relating to process and activities types. The Process Monitoring component provides real time, log and performance data relating the virtual factory processes. The Monitoring Engine captures the events produced by the smart process engine and stores the relevant event data in the cloud. The real-time monitoring component provides a live view of the ongoing processes using the process editor interface, so that virtual factories brokers may decide to undertake flow adjustments and efficient decisions in order to improve the performance of the manufacturing processes.

An integration smart object was designed and developed to interface with the virtual enterprise's equipment to be monitored and managed. As displayed in Figure 1, the smart object enables the integration with the overall virtual enterprise platform via gateway implemented services. The black box itself works as a smart object with sensors, collecting raw data from programmable logic controllers, Industrial PCs, DCSs and spread sensors from different vendors using different communication protocols and physical layers.

A gateway will comprise of standard components and custom components with functionality developed or created for connecting to a specific external system type and/or instance. A gateways mission is to communicate with a specific system, meaning that a significant part of a gateway implementation is tailored for specific technology or communication/interface protocol.

4 Business Case

In this section, we explain the use of the VEMP and the smart objects integration for managing distributed maintenance processes. The request for service (call) could be done as follows: The customer (machine owner) opens a new call via the VEMP dashboard or mobile app. Moreover, with the inclusion of the smart object, it is possible to send maintenance alerts directly from the equipment to the manufacturer technical team as well as to the customer, helping those to shift from a corrective to a preventive maintenance and thus decreasing the risk of failure and downtime.

Using the VEMP dashboard, stakeholders have access to the list of machines installed, their status, location, manuals, technical assistance plans, procedures and drawings. Thus, it becomes simple to select equipment and ask for assistance, introducing the problem description. Manufacturer is then notified in real time and knows exactly which is the equipment that needs service, having access to all the machine data, history, manuals, drawings and service records instantaneously, even if the service manager is out of office. It's a huge advantage in terms of time to market.

Moreover, if the equipment is connected to the internet (wired or wireless) and the problem is about software, it is possible to solve it remotely and have real time feedback from the equipment. This is quite useful for costumers far from the manufacturer plant. For customers far from equipment supplier plant, it's common to subcontract 3rd party firms (partners) to assist their customers. One of the advantages of this new approach is that the manufacturer becomes able to remotely monitor the process by using equipment's control software integration and the mobile applications where the partner updates the service status and the details of the technical intervention. Customer will be able to: make a new service call, track their service calls, and access technical documentation. Service Manager will be able to see all customer calls, evaluate and control customer calls, create service orders, schedule service orders, assign technicians to service orders, access related documentation, manage human resources, and manage maintenance warehouse stock. The technician will be able to see service orders assigned to him, access equipment technical documentation, report the status of his work, and submit the order at the end of the intervention. Sales Manager is able to see the overall view of the calls and service orders performance indicators such as: mean repair time per equipment, customer or technician, uptime as well as mean time between repairs per equipment.

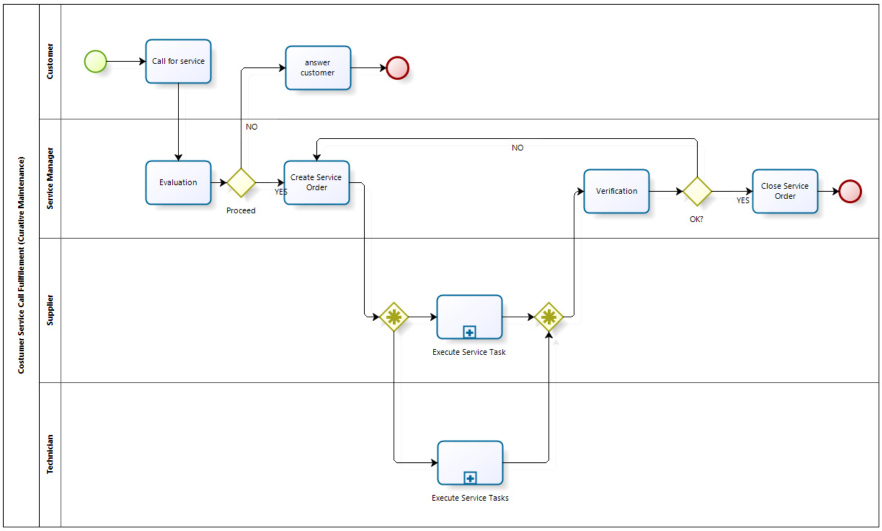

Fig. 2. Maintenance process BPMN Diagram

5 Conclusion

In the advancement of technological knowhow, companies are forming business collaboration or network between each other within shorter pace of time. The up-to-date and available technology such as Internet makes the collaboration easier with added mutual benefits between the partners. In such rapid business environment, collaborative partners need for real-time information update of their processes and resources. This information update ensures partner companies to take corrective actions against abnormal situations if there any. The real-time information update also contributes to predictive repair and maintenance of the equipment or resource's used in any business network. Business process monitoring in collaborative environment avoids potential risks and ensures sustainable growth.

The main focus of this research is to highlight a complete loosely coupled virtual enterprise management tool applied to the virtual enterprise maintenance processes. This tool is composed of with nine modules: (i) The integration Smart object, (ii) Gateway with OPC Client, (iii) Process Execution Engine, (iv) Message Routing, (v) Process Designer, (vi) Process Monitoring, (vii) Data Provisioning and Discovery, (viii) Cloud Storage and (ix) Dashboard. This study mainly highlights two components such as Process Monitoring and Smart Object Integration that are directly interfaced with VE business process monitoring and management. All other components are the supporting ones and are responsible to execute the virtual enterprise management platform successfully. The integration 'smart object' as highlighted in this research collects resources or equipment data and visualizes over the dashboard through gateway services. The collected data from an individual equipment or resource by the integration smart object acts as the source of predictive maintenance of the specific equipment. The overall real-time status information of the specific equipment can also be used as the condition-based maintenance program. This conditioned-based monitoring data can be used as the forecast information of the specific equipment and supports actively towards the scheduled maintenance. This approach consequently contributes to the cost cutting of the equipment in terms of getting well-ahead information before the equipment failure and ensures its uninterrupted operability.

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Product-Service Systems

A Coopetition Space for Complex Product Specification

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Abstract. Due to peculiarities and complexities embedded in complex service-enhanced products, e.g. automated buildings, these products are one-of-a-kind, largely customized, and may involve a large number of competitive / cooperative multi-stakeholders. Life cycle of complex products typically includes a substantially long creation phase, followed by its operation and evolution phases that last over decades. Although, the majority of complex product components (e.g. equipment and services) are specified gradually and by varied stakeholders during its creation stage, further specifications are also provided later on to support its evolution. This paper addresses challenges in both specification of varied and numerous components, and managing these specifications thought-out the complex product life cycle. We address reusability, modularity, and federated sharing requirements in the coopetition space of complex product specification, and within the context of Virtual organizations Breeding Environments (VBEs). Our developed product specification system, which is already alpha tested, addresses these identified requirements, and is described and exemplified.

Keywords: Complex Products, Product Specifications, Virtual organizations Breeding Environments (VBE), Service-enhanced Products, Coopetition.

1 Introduction

Complex products (e.g. solar power plant and intelligent buildings) are one of a kind in their design specification and massively customized in their production. Furthermore, the Product Life Cycle (PLC) of such complex products runs over several decades. The specification of complex products is therefore typically not performed in one session, rather iteratively during its life cycle, and potentially involving a number of different stakeholders, from equipment manufacturers and service providers, to experts at an EPC (Engineering, Procurement, and Construction) company. These stakeholders need to collaborate within a coopetitive environment, in order to gradually and incrementally specify different components and sub-components related to the complex product.

Additionally, based on our findings in the area of solar plants and intelligent buildings, which are relatively young industries, the design and engineering of these complex products cannot be resulted through the mere searching and identification of

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the needed components among the existing products in the market. In other words, although familiarity with the existing related product/service details, as provided by different manufacturers and suppliers in the market, are the necessary starting point for the complex product designer, the mere existence of these product details are not sufficient to fully specify the ***Project Design*** of the complex product. Rather, the nature of our targeted complex products mandates detailed and concise design and customization processes for its sub-products, including the equipment, devices, and enhancing services, as well as involving different stakeholders in these processes.

We propose an environment for complex product specification, to provide the coopetition space needed through different PLC phases. A number of earlier research works address collaborative environments for product specification and design, e.g. for collaborative CAD systems [1][2]. In this paper however, we investigate requirements for a product specification environment that can support collaboration among competing companies (the so called Coopetition), within the context of VBEs and goal oriented Virtual Organizations (VOs). Considering the coopetition environment that is supported in the complex product VBEs, a main aim in this environment is to support the *reusability, modularity,* and *sharing* of the generated assets. As mentioned above, the addressed complex products are young industries and therefore their stakeholders can very much benefit from sharing the specification of sub-products that are designed by others. Therefore, supporting both the reusability of sub-product specifications and the possibility of granting access privileges on them to other stakeholders are important requirements. Furthermore, considering that these complex products are one-of-a-kind, their designed sub-products can be reused only in the case where sub-product's specifications follow a modular design approach, so that the pieces of their specification can be accessed and copied for reuse.

Besides the specification of various equipment and devices needed for complex products, we also address the specification of variety of needed business services, that can range from software systems to human-provided (the so called manual) services, and which in one way or another enhance the complex product.

In the knowledge-based economy, services have an increasingly important role in manufacturing industries, which use functionality provided by services to differentiate their products [3]. In fact, by adding business services, while it also increases the value of the products, a higher level of differentiation can be realized [4]. Therefore, in our design of the specification framework for complex products, we consider that sub-products typically come with a set of business services that offer some beneficial enhancement to the customers of these products. Capturing different aspects of these business services as well as the inter-relationships and links between these services and other sub-products of the complex product (e.g. devices), are main requirements for our proposed complex product specification framework and system. Many approaches and standards have been developed by the research community in the area of Service Oriented Architecture (SOA) to specify and formalize business services [5]. There are however still challenging and open questions related to how make services interoperable, so that they can be shared and reused, as well as how to assist authorized service providers with composing other services, thus producing value-added service to support complex products. Furthermore, there are still gaps in correlation between services and products in the context of complex products.

Please note that this research on product specification framework is performed within the GloNet[1] [6] project, and constitutes one of its subsystems.

The remaining sections of this paper are structured as follows. In Section 2 we address the role of product specification in different phases of our target complex products' life cycle. In Sections 3 and 4 we will focus on how to realize the main requirements (non-functional and functional) for complex product specification framework and provide some details related to the implementation. Finally in Section 5, some concluding remarks are provided.

2 Product Specification in Different Phases of the PLC

The PLC of a complex product can be divided into the following three main phases [7], each having its own peculiar features:

(i) **design and engineering,**
(ii) **construction and commissioning,** and
(iii) long term **operation and maintenance**.

In this section we address these three phases, primarily in relation to the specific product specification needs of stakeholders that are involved in the phases. But before focusing on each phase, we should point out that the product specification is also needed before the PLC of the complex product starts. This is mainly due to the need for preparation of the bid for the targeted complex product, for instance in response to a call for tender. Figure 1 indicates the product specification process during different phases of the complex product's PLC, as well as during the pre-phase of bidding for the complex product, in order to preform cost estimation and initial partner selection.

Design and Engineering phase: Being the first phase in the PLC of the complex products, the design and engineering phase plays an important role in the success of the later phases. Activities during this phase are typically divided into the three steps of: project assessment, project design, and project implementation. *Project Assessment step* includes the complete analysis of the site and the technical assessment of the entire project, at this step a ***high-level specification of the complex product*** is made in order to assess the feasibility of the project. After the Project Assessment has been successfully preformed, during the *Project Design step* the early engineering and selection of technology takes place. These include the following activities, which are reflected in some ***detailed specification of complex product***:

(i) Pre-engineering - e.g. achieving initial specifications of the complex-product,

(ii) Evaluation/selection of technology or equipment - e.g. evaluating for selection or extension of existing devices and equipment suitable for complex product), and

(iii) Selection of sub-product specifications - e.g. adding sub-product specifications as components of complex- product specification.

[1] `http://www.glonet-fines.eu`

Finally after the Project design step has been successfully preformed, during the *Project Implementation step*, the ***planned specification of the complex product is finalized*** and the product specification is used for selecting the relevant organizations and for sub-product procurement.

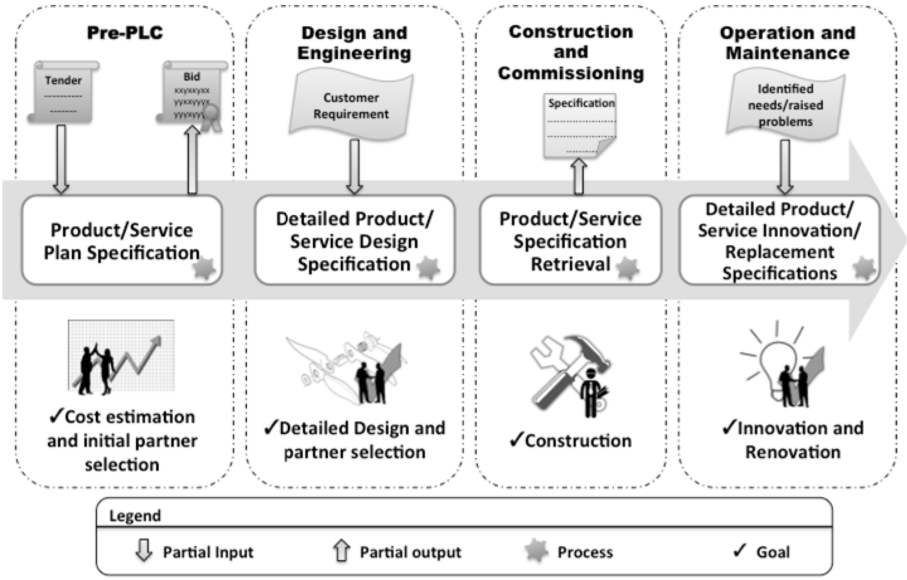

Fig. 1. Product specification in different phases of complex product's PLC

Construction and Commissioning phase: Typically during this phase, no new product specification is made; rather the existing ones might be accessed to retrieve some detailed design information.

Operation and Maintenance phase: Although as discussed above, the product specification is fundamentally required during the entire design and engineering phase of the product life cycle, it is also usually needed to be used later during the long-term operation and maintenance, but rather infrequently. This occurs mostly due to the continuous need for evolution of the complex product and/or to innovate and provide new products either in response to "newly identified" needs or some problems emerged during the operation phase. Example cases of such requirements vary from enhancement or upgrading a control box in a solar plant, to replacing the panels damaged in an earthquake.

3 Realization of Non-functional Requirements

At its base, system requirements address *why* a system is needed, *what* are the functions it must provide, *how* the system must be constructed and implemented, and *what* conditions must be satisfied by the system. The two main types of requirements are the *non-functional* and the *functional* requirements [8]. This section addresses the most important non-functional requirements for our product specification space, namely the: *security, integrity, scalability,* and *portability*.

3.1 Security

Security plays a very important role in systems. This is due to the fact that improper access to a system might bring loss and even bankruptcy to the organization using the system. Proper prevention of threats via competitors, both from the outside world (enforcing authentication) and from the inside of the system (enforcing authorization), is a must. The main steps in this process are addressed below.

3.1.1 Authentication

There are three different main techniques that can be used for authentication, including [9]: *what you are, what you have,* and *what you know.*

Among the above, and considering the usage/user of the product specification space, we have selected the *"what you know"* technique. In this approach the product specification sub-system (developed on top of the cloud-based GLONET platform) receives a *token* about each user's authenticity. This token is generated through the "Single Sign-On" mechanism implemented within in the GloNet platform [10].

3.1.2 Authorization

A very important requirement for any system that deals with multiple stakeholders (specifically within a coopetitive environment) is its secure and proper information sharing as well as mechanisms for granting access privileges to authorize users. This is due to the fact that although different stakeholders in VBEs may cooperate to achieve some specific common goals, they are potential competitors on many others.

To preserve users of the product specification space, against unwanted data access to their private information, we have designed and implemented three different data spaces (levels of access) for users of this system, that limit who can access what. As also illustrated in figure 2, these spaces include: Private – only for personal use of the user, Restricted – specified by the user to be shared only with the partners of certain VO or one specific project, and Public – to be shared with all in the VBE.

Please note that the user who defines a product specification within the system is the owner of that specification. Therefore, only that user can with some condition move such specification from one data space to another, e.g. from private either to restricted or public, in order to share it with others.

Private data space: The first step in the process of product specification is to specify sub-products of the complex product. To accomplish this task, designers should have a private space to do their specifications before making them available to other stakeholders involved in specification process of the complex product. This space is called *private space* and specifications in this space are only accessible by its owner.

Public data space: After one has specified a product he/she might wish to share the specification with the public, meaning within the VBE. This can be exemplified by a sub-product manufacturer or provider who wishes to promote the use of its already built product (e.g. an equipment), to be used as a sub-product for building other complex products. However, a number of users nowadays may be involved and interested to participate in open access movements. To enable this possibility, system provides a VBE public space for users, to provide access to owned specifications.

Restricted data spaces: Within the process of specifying one complex product, multiple stakeholders are typically involved. This usually happens within a VO, when users would be interested to share certain specifications only with the other VO partners. To enable this feature, one user can indicate the restricted space for its product specification. Consequently, every time a VO is created a restricted data space is created for it.

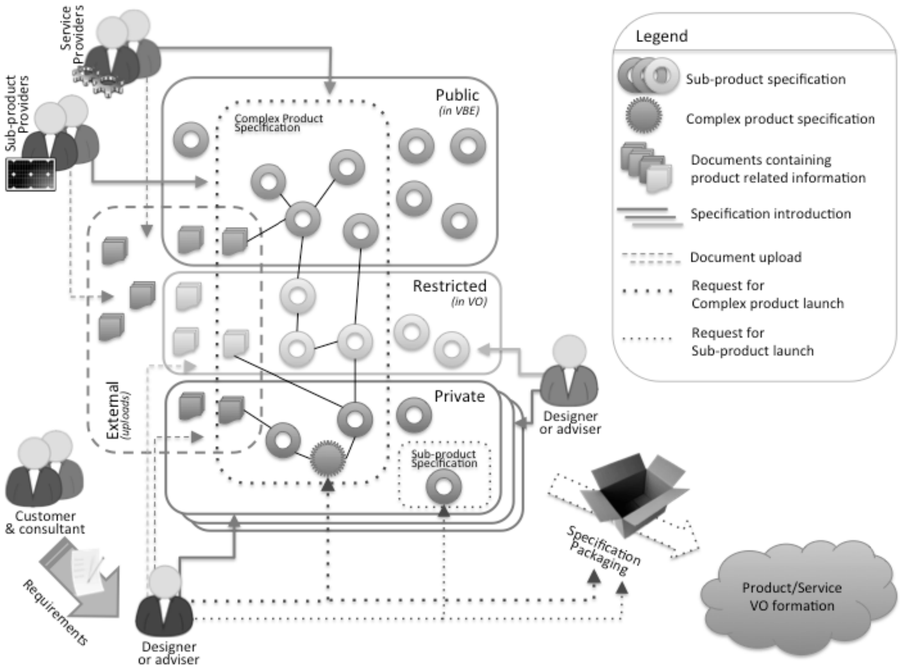

Fig. 2. Three Data spaces in relation to product specification framework

We shall now address how the users can view and/or move their owned specifications from one data space to other data spaces. Once a product is specified, it can be viewed by its owner. The screenshot in Figure 3 illustrates how product specifications can be viewed by a user. Depending on the selected *VO-name* or *project-name* (as indicated in the upper right corner of the screen), a list of associated specifications for which the user is authorized to view will appear, sorted by their product names. Please note the symbols that appear in front of the product names, where (-) represents private and (#) represents restricted. Also note that the semantics of *projects* and *VOs* are very different, and while the former indicates one optional user-defined folder, the latter is dedicated to all restricted specifications belonging to a specific VO. Please also note the following three cases:

- If neither a specific project nor a specific VO is identified by the user (on top right of the screen), then all ***public*** product specifications in the system, further to all ***private*** specifications of that user, will be illustrated.
- If no project is mentioned by the user, but a VO is specified for which the user is authorized, then only ***restricted*** specifications related to that VO will be illustrated.
- If the user specifies no VO, but a project-name, then all the ***private***, ***restricted***, and ***public*** product specifications that the user has associated to that folder will be shown.

In the example of Figure 3, the user Prolon has selected/indicated the VO's name "Electrical Design". Consequently, all restricted product specifications that belong to this VO, as well as the all those public sub-products associated to this VO are illustrated. Please note that while Prolon might itself own some of these restricted products, other users (who are also partners of this VO) own the others.

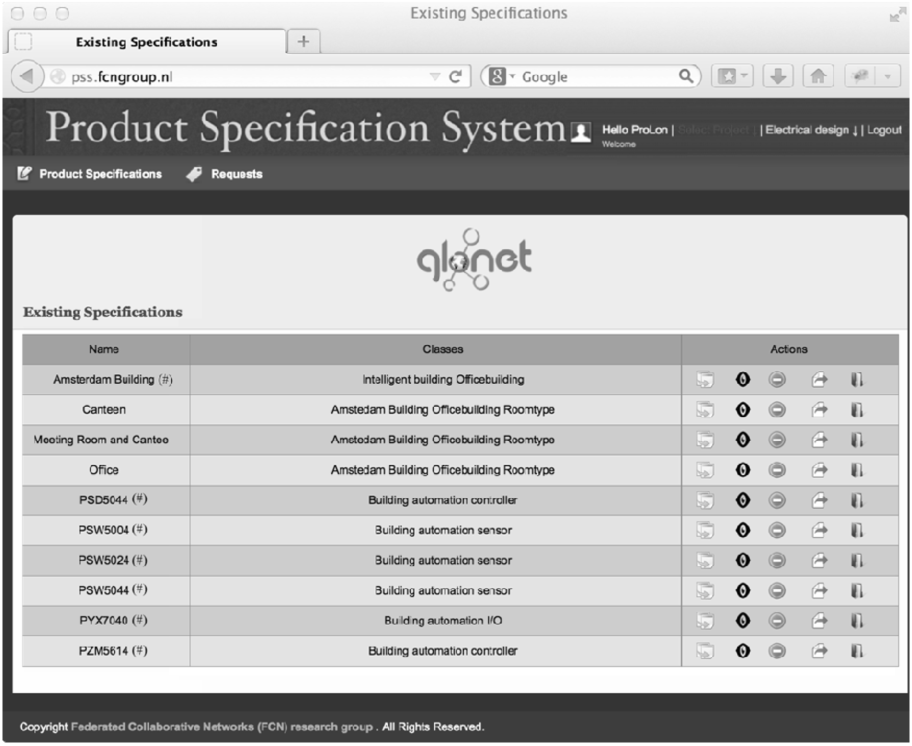

Fig. 3. Existing Specifications Window (restricted to one VO)

Other than viewing the product specifications, authorized users can also change the accessibility of these specifications by preforming the following set of actions:

- **Share** action (shown with icon), which provides the user with the option to change the access rights/sharing status of a certain product specification that he/she owns. The share options are available through existing products window, when the user clicks on its icon. Please note that when defining a new product specification, by default the access right to that specification is made private, that is if the user has not indicated a VO on the top right corner of the screen, in which case by default the specification becomes restricted to that VO. At any point in time, the owner of the product specification is allowed to only broaden the access to that specification. This means that if a specification is private, then the owner can change it either to restricted within a VO, or to public. In other words once the owner of a product specification grants certain access rights to others (e.g. to view the specification) he/she cannot withdraw that right later.
- **Assign to Project** action (shown with icon), which provides the possibility to provide access to an already defined specification, to which user has access and is already indicated as private, public, or restricted, to an existing project folder of that user. This is mainly to assist the user with organizing his/her product specifications in different folders. This means that by default if a project is indicated on top right corner while specifying a product, then that product will be allocated to that project folder. Nevertheless, through this action, as provided in the Existing Specification window, specifications may be assigned and reassigned to different project folders.
- **Delete** action (shown with icon), which allows hiding certain specification(s) from the users' screen, for instance if the user finds a sub-product useless for him/her to keep, its specification can be deleted from his/her view.

3.2 Scalability

During its PLC, a complex product might potentially deal with hundreds of users. To support such a user base, and to enable possible expansions to both the user base and the product specifications, we have leveraged the possibilities supported by the cloud environment that allows allocation of more resources on demand, when and if needed. This leveraging has been done through applying three different techniques. *First*, different components of the system (i.e. the executable building blocks of mainly the Controller layer and the DAO implementation layer) are decoupled from each other, which include decoupling: the web service controllers, web interface controllers, Hibernate DAO Implementations, GloNet DAO Implementations, etc. This means that none of these components depends on how another component is implemented or executed, which in turn enables the execution of different components on different physical and/or virtual machines. *Second*, the implemented product specification space is layer-based (e.g. having Application, Data, etc. layers), while existence of each layer is transparent to the other layers. Consequently, not only the components of our designed system are decoupled, but also the different layers are decoupled and can run on different physical/virtual machines. And *third*, the implemented system can take advantage of load balancing mechanisms for their data, supported through separation of data access to objects, and how it is implemented.

3.3 Portability

The product specification space has been developed as a web-based application, using Java programming language that enables the server side code to run independent of the platform. The server side program generates standard outputs (e.g. HTML 5 [11]) that could be consistently and easily rendered by different browsers. The client side (Browser side) of the program is based on JavaScript and is written using jQuery framework [12], to insure that JavaScript code is compatible with different browsers.

The combination of java as the programming language of the server side and the compatibilities of the client side, such as compatible JavaScript and standard HTML 5, makes both the client (browser) and the server side of the system highly portable.

4 Realization of Functional Requirements

The *complex product specification space*, addressed in this paper, needs to provide a set of functionalities to support: ***product and service specification and registration.***

Within the context of the *data level* of the PLM (Product Lifecycle Management) framework [13] for complex products, three main product models need to be captured throughout its lifecycle. These include: its Geometric-oriented product models (e.g. through CAD system), the Structure-oriented product models (e.g. through DMS – Digital Manufacturing System), and the Meta-data-oriented product models (e.g. through a database). The *product and service specification space* primarily captures, handles, and manages the detailed *meta-data* about the complex product and all its sub-products, and assists users with their specification. Furthermore, the product specification space captures and stores links to a set of files that represent the other two product models, which are mainly produced in certain industry specific systems, e.g. CAD, CAM, and DMS software.

The main requirements for the functionality provided by the product and service specification space are three-fold. The **first** requirement is to support ***gradual*** specification of the complex products. This is needed to reflect the reality of complex products that are neither defined in one session, nor by one stakeholder. Therefore, detailed specifications that capture and transform customer requirements for a complex product into discrete sub-product specifications, can be gradually defined by the involved multi-stakeholders, using the developed product specification space. The **second** requirement is to properly capture the classification of all relevant sub-products in a ***granular and modular*** manner in the complex product environment, e.g. distinguishing and capturing both the electrical and mechanical aspects of a sub-product, as well as their inter-relationships. This will in turn support effective multi-perspective retrieval/discovery of information related to sub-products, as well as creating their concise descriptions, as needed for common understanding among different related stakeholders. The **third** requirement is to capture all details related to sub-products in a ***reusable*** from. As such, the existing specifications of already introduced sub-products can be either fully or partially (e.g. at the level of certain detailed feature-kind) reused for the specification of other sub-products.

In the following subsections we address an approach and different steps involved in defining details of sub-products and services related to complex products, through the use of the *product and service specification and registration space*.

4.1 Supporting Granular and Customized Specification of Sub-Products

Supporting different levels of granularity and customizability is a necessity for complex products, due to their dynamic and complex nature. At the lowest level of granularity, the *features* of a specific sub-product can be defined. Every feature is an instance of a *feature-kind*. Through the granular definition of feature-kinds and instantiating the features, the system enables the user to specify any sub-product from scratch, and without being limited to only defining sub-products as instances of already existing type of products, with a pre-defined set of fields/attributes.

Here the required functionality for the product specification space includes enabling the user to define feature-kinds, as needed for definition of classes of sub-products, as well as to specify the sub-products based on providing their features. Furthermore, the specification of feature-kinds makes them reusable, so that once they are defined; all users can use them both for the specification of new class of sub-products, as well as for instantiating features related to specific sub-products. Example screen shots of the product specification space are presented in Figure 3 and Figure 4.

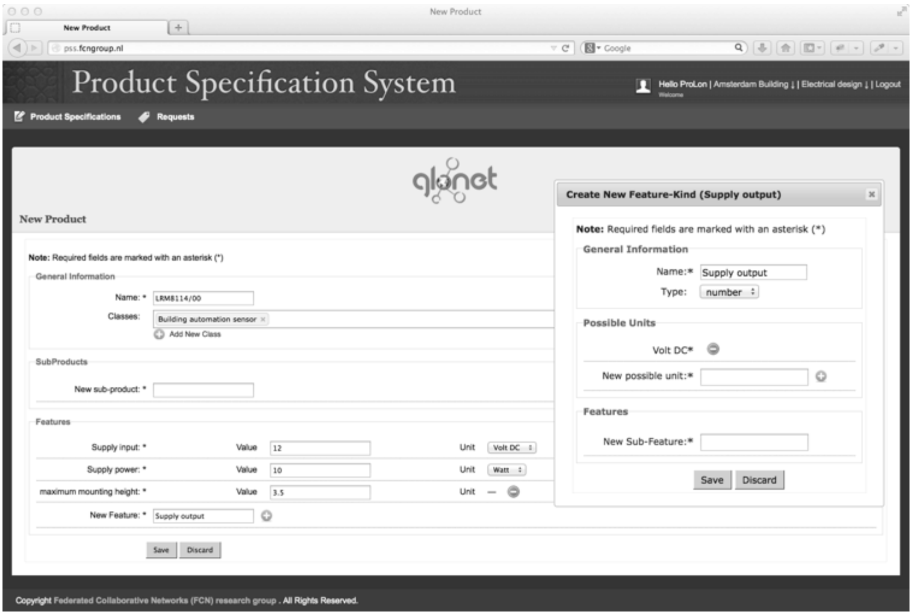

Fig. 4. Add New Specifications Window

4.2 Capturing Product Specification Perspectives Using Classification

When specifying a sub-product related to a complex product, due to the multi-disciplinary nature of complex-products, it is important to enable the user by providing different perspectives of that sub-product, based on their related features. This can be supported through definition of classes in product specification. Furthermore, classes guide the users to provide proper feature information related to sub-products. For example one can define feature-kinds to be obligatory for a given class, so that if a user identifies a product as belonging to a certain class of products, then the user is warned to also provide features for its obligatory feature-kinds.

4.3 Supporting Sub-Product Re-Specification

When dealing with complex products, the user may wish to slightly re-specify a sub-product for its own design, or customize an existing sub-product specification in order to enhance, extend, revise, and finally perhaps assign it for restricted sharing. Several of the above needed functionality from the product specification space area already addressed in the paper, and represented in Figure 3. Two more functionality are required, as indicated in Figure 3 and described below.

Duplication action (shown with icon ), which takes the user directly to a pre-filled "New Product" window. This simplifies the task of users, since in that window the specification information about the selected product is duplicated, which can be further modified/edited by the user to define a new but similar specification.
View action (shown with icon ), which takes the user to the view window of the product specification.

4.4 Complex Product/Sub-Product Launch Request

After the designer has specified a product, its specification should be used for planning a VO that can configure and establish its realization. Figure 2 illustrates this functionality as the request for sub-product/complex product launch. This request can be issued by a sub-product designer, and must result in packaging of the product specification, and sending it through the cloud to the system that supports the VO formation for the sub-product.
The product specification space needs to support this functionality to enable the user with requesting the initialization/launching of the process that can realize the targeted specification. Thus, this request triggers the process of planning a goal-oriented VO.

4.5 Service Specification and Registration

Each business service (BS) is materialized through some business sub-processes [14]. These sub-processes represent *how* the services would be performed. The actions involved in the business service delivery can either be materialized automatically through some software (e.g. web services), manually through several human tasks, or even through a combination of these two kinds of activities. The automatic solutions are usually called software services, and the manual solutions are referred to as manual tasks. In order to develop a unified ICT-based business service specification environment, also for representing manual tasks we consider a simple software service that only indicates the start and end points of the corresponding task.

We consider four characterizing aspects of business services as being required to be provided during the service specification stage. These four aspects are required to improve functionalities supporting service interoperability, namely to support service discovery and service composition. These four aspects of the proposed service specification are described below, while the formalisms and standards that can be applied for representation of each aspect are also introduced. We have also adopted one specific notation for representation of each aspect, as also addressed below.

- Syntax: Typically, syntactic properties of a service are represented by XML-based standards and languages, such as the web service description language (WSDL) and Simple Object Access Protocol (SOAP) [15]. Some examples of syntactic aspects of the BS specification include: service name, the name of operations contained in the service, as well as their needed arguments. WSDL is selected as the notation for syntax specification in our development.

- Semantics: Conceptual properties of services, here referred to as semantics, are typically defined with ontology, as an explicit specification of a conceptualization of the knowledge about the service. The service ontology definition encompasses a group of vocabularies that specify semantic attributes of services (e.g. goals and category) and their inter-relationships, which together present a meaningful concept about the service [16]. In fact, the semantics description of BSs would enrich the lack of information about the services, which cannot be specified by syntactical descriptions, including: goals, context, pre-conditions and post-conditions of the BS. Here, OWL-S [17] is used for capturing service semantics within the proposed service specification. OWL-S provides the rich description language needed for representing semantics related to services.

- Behavior: Besides semantics and syntactic description of the services, we also need to specify and formalize the externally observable behavior of each service, which shall represent the proper invocation order of its operations. These behavioral properties can be used later within the functions support service discovery and integration, for improving the accuracy of service matchmaking and facilitating the automation of integrated service execution [18], [19]. Furthermore, the behavioral aspects of the BS specification address its functionality, to the level that it can then be unambiguously implemented by software developers. We have proposed to formalize the behavior of the services in terms of Constraint Automata [20], within which every state of a Constraint Automaton (CA) represents an externally observable internal configuration of a service, and every transition represents the exchange of one or more messages by this service. In fact, a CA allows the user to capture the behavioral specification of a service by a finite number of states and some labelled transitions, as well as enabling software developers to follow the sequences of executed operations, in order to decide and implement the behaviors of the service. This behavioral specification comprises essential information for automated service invocation in case of stateful services [21]. Stateful services are defined where a client intends to keep either some data or some states during one invocation of the service, and then deploying those data and states during a subsequent invocation. In other words, the invocation of a stateful web service depends on its pervious invocations. To put it briefly, the formal specification of the stateful services' behavior provided by Constraint Automaton specifies the desired sequence for operations' invocation. The specification for stateless services consists of several single state CA, namely one Constraint Automaton for each operation in the service.

- Quality Criteria of Service (QCS): While the service discovery is usually done according to the functional properties of the BS specification (i.e. syntax, semantics and behavior of services), non-functional properties of services, i.e. Quality of Service (QoS) parameters also play an important role in customer's service selection. Therefore, we have also proposed to specify some QoS metrics as quality criteria of services to assist customers in service selection and to improve the accuracy and optimization in service matchmaking. The QoS values of services are usually claimed by service providers and ensured through a service level agreement (SLA) as a part of a contract between the service provider and the customers [22]. We have identified some quality criteria for assessment of offered services such as the execution duration, the maximum response time, and the service availability. The QCS agreements in SLAs are represented as promises among the involved partners in the VO. In [23] different states of such promises are introduced, including: conditional, unconditional, kept, not kept, withdrawn, released, and invalidated.

5 Concluding Remarks

This paper addresses the area of service enhanced complex product specification within the context of VBEs and goal-oriented VOs, which involve collaborations among competing companies, the so called coopetition. We presented a set of functional and non-functional requirements for product and service specification within this context and in different phases of the complex products life cycle. Furthermore we have introduced and provided some design and implementation details for developing a coopetition space to support complex product specifications, while realizing its identified non-functional and functional requirements. The implementation of this system has been developed in Java programming language, using the Spring [24] and Hibernate [25] frameworks. Its database is built using the GloNet platform [10] and the MySQL [26] database management system. The general framework applied for development of the complex product specification space follows the layer-based MVC (Model–View–Controller) software design pattern [27]. This system is already beta tested by industrial partners within the GloNet project. Some more details over its design and implementation are presented in [28].

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Negotiation Support for Co-design of Business Services

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Abstract. During the last years, manufacturing and service industries faced a global change in the production paradigm. Besides the manufactured products, companies also focus their attention on business services that can add value to their products, which often need to be provided by different entities, offering different competences/services that collaborate to achieve a service-enhanced product. In this context, the collaborative process of design and/or creation of new business services can also be improved if supported by a negotiation environment that facilitates the interaction among the various involved entities, and the process of modeling and reaching agreements. For that, this paper presents a support system for service co-design negotiation that facilitates the design of new business services under a collaborative perspective.

Keywords: Collaborative Networks, Negotiation Support Environment, Service-enhanced Products, Business Service, Co-design, Service Design.

1 Introduction

Due to unstable and highly competitive business environments, companies and organizations need to adapt themselves in order to keep their market competitiveness. They need to continuously adjust their operating principles to act in response to a new business or collaboration opportunities. One trend is to move from traditional models to a new business paradigm, where enterprises strategically join competences and share skills, costs and other assets, and can access each other's markets, leading to new collaboration structures of enterprises [1]. In this context, the collaborative networks concept provides support in this change of paradigm, giving companies and organizations an expression of agility and survival mechanisms in facing market turbulences because they can share an interoperable structure, operating principles, and some cooperation agreements that can serve as a base of trust among them [2, 3]. Also, collaboration of enterprises and organizations imply the sharing of risks and losses, which increases their survival capability [4].

Nowadays, there is an increasing demand from customers for highly customized products. Therefore, one tendency for manufacturers is to associate business services to the products they offer [1]. From a collaborative perspective, these services are designed and created by multiple stakeholders to meet the individual customer needs and/or requirements. One approach is to follow a service design which typically is a

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non-structured approach. Therefore, this paper presents a solution to improve the design of new business services that is being developed in the context of the European research project GloNet. This project aims to design, develop and deploy an agile virtual enterprise environment for networks of SMEs involved in highly customized and service-enhanced products through end-to-end collaboration with customers and local suppliers [5]. The major use case in the GloNet project are the solar parks, so the service enhanced-products are the physical solar plants (product) combined with the services that can enhance or improve the product. Here the interaction with the customer and local suppliers is fundamental and leads to the notion of co-creation and co-design of products and business services.

2 Negotiation Support in Collaborative Networks

To promptly respond to business or collaboration opportunities (BO/CO), the topic of collaborative networks (CNs) appears significantly promising because if the enterprises or the organizations share a common interoperable infrastructure, common operating principles, common cooperation agreements, and a base of trust among them, then their ability to rapidly form a virtual organization (VO) is increased [6]. If on one hand, the consortium formation process mainly consists on planning and scheduling the work order and selecting the appropriated partners to join the VO, on the other hand, the consortium associated risks, vulnerability, robustness and flexibility are also aspects that should be considered [4, 7]. In this respect, in the collaborative process of VO formation it is important to have a support environment to improve the entire negotiation process of establishing a VO agreement that can lead to the governing rules and principles of the consortium during the operation phase [8]. Moreover, a negotiation support environment should also improve the agility level of the VO formation, being agility an indicator of quality or state of the organization to have a quick resourceful and adaptable response [9]. To have an effective negotiation support environment for VO formation and to facilitate the decision making of human actors, some of the critical issues are [8, 9, 10]:

- Support for privacy of negotiations, where only the involved partners have access to the information being negotiated;
- Considering the potential risks in collaboration: reaching agreements concerning the sharing of risks among the involved partners;
- The agreement should follow a basic set of templates: It is important to depart from common templates, selected for each kind of BO/CO, and extend it to cope with the detailed agreement specifications using “add-on” clauses;
- Reaching agreements concerning coordination aspects, activities and scheduling;
- Reaching agreements about information exchange: i.e. how should information be exchanged among partners, and also which kind of information should be exchanged; and
- Provision of a mechanism for tracing the history of the negotiation.

3 GloNet Co-creation Networks

One of the relevant business scenarios identified in GloNet is aimed at providing an environment that supports and promotes the collaborative design of business services. This scenario pursues solutions to identified needs, in a co-creation network that is a particular case of a VO and represents the collaboration among manufacturers but also includes the customer so that his specific requirements can be properly met [1]. During the life-time of a certain product, several service co-creation networks might be created depending on the number of times new promising ideas come up for new business services [11] or when solutions must be achieved to solve problems. These networks shall be based on a collaboration environment that helps designing and providing business services based on innovation, knowledge and customer orientation, through collaboration between the different stakeholders. In this context, two main concepts are used: business services (BS) and service design.

Business Services and Composite Business Services. A business service refers to an organized set of added value activities from a business perspective [12], considering issues such as the delivery conditions, service level agreements, period, availability, etc. [1]. It corresponds either to the manual services, and/or software based services that are delivered to the customer, and can be modeled by different business processes. Also, the business services provided to the customer can be composed of several atomic business services. In this case, the service providers of such business services can together form a virtual organization to deliver the composite business service through a new entity that is the service integrator (that acts as the service provider of the composite business service) [13].

Service Design. Aims at designing user-oriented services making them useful, effective and different from existing ones. It is a methodological approach in the designing of services that connects relevant stakeholders from interdisciplinary areas. Therefore it potentiates co-design and co-creation among the different users of a service, and the providers [14]. Although numerous methods and tools have been emerging for service design [15], most of them are just manual methods to organize a collaborative process. Some methods are supported by software tools, but no integrated environment is available, neither any integration between service design and service delivery environments is available. Some of these tools can be found in http://www.servicedesigntools.org/.

4 Service Co-design Negotiation Support System

The proposed system intends to cope with one of the aims of GloNet that is to achieve an environment that supports and promotes the collaborative design of business services to enhance physical products.

To properly model the core processes involved in co-design, the main actors with the correspondent roles are identified in Table 1 and the dependencies between them related to goals and resources are illustrated in Fig. 1 using the i* modelling framework.

Table 1. Actors and roles in co-creation teams

Actor	*Role*
Co-creation Team	The Co-creation Team represents all the involved actors within the collaborative space aimed for co-design of services. These actors are essentially the VO Partners and the Customer.
VO Planner / Co-creation team mediator	The Co-creation team mediator is the VO partner responsible to conduct the entire co-design process. He acts similarly to the VO Planner in generic VOs.
VO Partners	The VO Partner gives support for the service co-design and co-innovation according to its knowledge and skills.
Customer	The Customer together with the VO Partners plays an important role in the service co-design once his satisfaction must be attained. He maybe also responsible for providing the services requirements and for giving feedback during the collaboration processes.

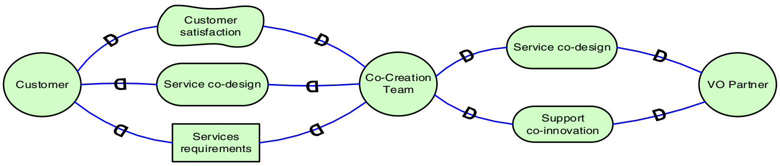

Fig. 1. Strategic dependency model for co-design

The co-design process is therefore conducted by a co-creation team mediator and can be initiated when a new innovation or requirement is identified either by the co-creation team or by the customer. Fig. 2 illustrates the co-design process being initiated by the co-creation team, where the strong interaction of the co-creation team (group of partners including the mediator) with the customer is illustrated.

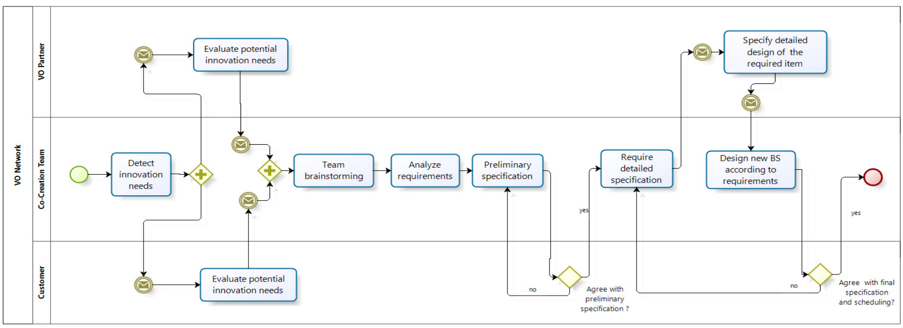

Fig. 2. Co-design process diagram

Considering the described process and that the GloNet project is not focused on designing specific business services but rather on creating a collaborative environment where new multi-stakeholder services can emerge and be provided, it is evident that this collaborative environment should contain functionalities that combine collaborative aspects with methodologies already used for designing business services that allow the co-creation team to reach agreements on the specification of requirements. Therefore, in this context, a negotiation support environment, which copes with the requirements mentioned in section 2, facilitates collaboration in co-design. To prevent some potential collaboration risks, this environment also permits an assessment of partners' expectations and value systems alignment to avoid potential conflicts [9]. Being the main aim of the negotiation support environment to reach agreements between VO partners, the same mechanisms involved in the classical negotiation for VO formation can as well be used for the negotiation of the co-design of a new business service. The system description, is later presented in this section. Nevertheless, this negotiation should follow an established methodology, so a service design methodology is used and adapted, being the main steps summarized in Table 2 [16].

Table 2. Service design methodology

Service Design steps		*Description*
1	Identify needed service	Brainstorming exercise involving an analysis of the needs and characteristics of the customer.
2	Design touchpoints diagram	To identify user interaction points with the service.
3	Design blueprint diagram	To describe the nature and the characteristics of the service interaction in enough detail to verify, implement and maintain it. It includes: temporal order, timings, and line of visibility (denoting what the customer sees and *back-office*).
4	Storyboard / storytelling	A tool derived from the cinematographic tradition; it is the representation of use cases through a series of drawings or textual description, put together in a narrative sequence that illustrates a sequence of events such as a customer journey.
5	Service prototyping	Involving the selection, assembly and integration of the various service components (atomic services).

Besides the service design steps, it is also important to identify: who are the participants; the touchpoints with the customer; and how the participants can share information and documentation. Table 3 summarizes the relevant characteristics from service design and their relevance for co-creation teams.

Service Co-Design Negotiation Support System. The *Services Co-Design Negotiation Support (CoDeN)* system is intended to provide a collaborative environment for the design of new business services where the various involved participants can reach agreements on what is decided. In this process, the involved participants (including the customer) are defined from the beginning. As mentioned, similar to a negotiation support system for VO creation [8, 10], this system is also intended to cope with the requirements mentioned in section 2 and generate an

Table 3. Service design methodology in co-creation teams

	Service Design characteristics	*Relevance for co-creation teams*
Participants	Service design assumes the involvement of various participants from different backgrounds and specially the interaction with the customer.	Co-creation of a new service is expected to involve a temporary collaborative network (VO), including different stakeholders, from geographically dispersed manufacturers, to the providers and supporting institutions close to the customer. The customer is also an active part.
TouchPoints	In service design it is particularly relevant to identify the customer journey in the process of receiving the service, and thus the points of interaction with the service provider.	Aiming user-centered services and being the customer an active part of co-design, it is very important to consider his interactions with the service, namely the moments and places that he gets into direct contact with the service.
Sharing	Service design methods, even if not supported by software tools, a shared space where all participants can visualize the progression of the design process is assumed.	Collaborative environment where the involved participants can interact in the design and creation processes and reach agreements.

agreement that represents the reached consensus. Nevertheless, in this case, the consensus is reached based on a service design methodology that serves as a guide for the negotiation. Fig. 3 illustrates the main flow and interactions of the system considering the detailed specification of Fig. 2, and the numbered steps of the approach summarized in Table 2. The darker rectangles represent the negotiation interactions that are required in the co-design process.

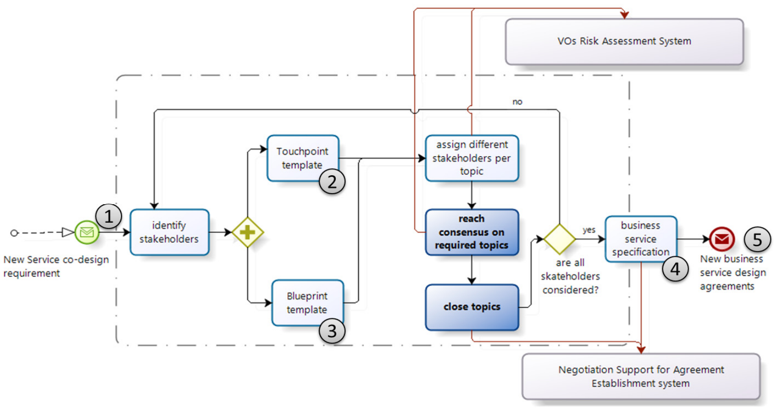

Fig. 3. Services co-design negotiation support system interactions

Also, this system interacts with two other systems so that it can on one hand assess the involved risks in the co-design process; and on the other hand provide reliable documentation. These systems are:

- *Negotiation Support for Agreement Establishment System* [8, 10] that allows clients to exchange information with warranty of authenticity and validity, digitally sign documentation, and providing a safe repository for saving and requesting documentation; and
- *VOs Risk Assessment System* [9] that allows the VO Planner or Co-creation team mediator to identify and assess the potential risks of a certain consortium concerning the value system alignment of the consortium members and their expectations towards collaboration, so that it can be possible to adjust the consortium according to the assessed indicators. Also, other potential conflicts or risk issues might be considered, such as economic or social.

Considering the above, Fig. 4 illustrates an adapted i* Rationale Strategic model where the involved actors as well as their dependency objectives with the system are illustrated. The functionalities that directly interact with the involved actors and other related systems are also depicted. The validation scenario for this system is planned and based on a real co-design case study. The case study is centered on the panel cleaning process of the solar plant of Charanka, in the north of India, which due to the geographical localization is of extreme importance in order to maintain or increase the performance ratio of the plant. The traditional process that this park follows is not supported by an ICT collaborative environment, thus most of the activities require a number of trips and face-to-face meetings with associated costs. Therefore, the usage of an ICT environment to support the process can be much more cost-effective either in economic terms or time spent.

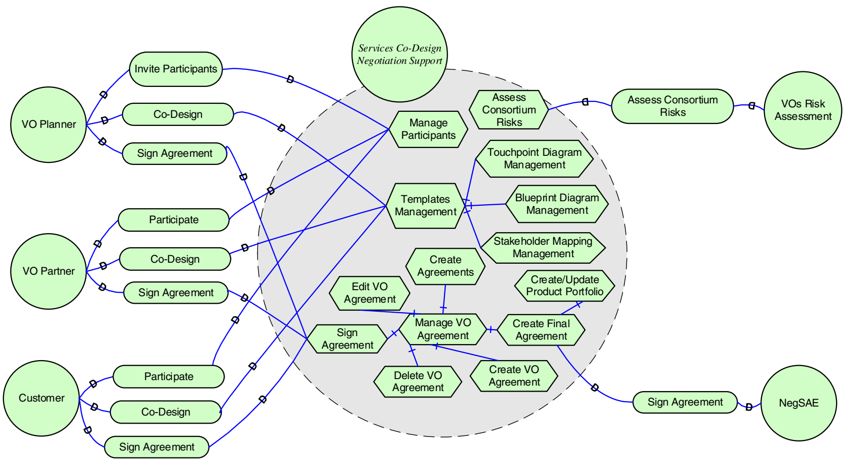

Fig. 4. Rationale strategic model for the services Co-design negotiation support system

In this scenario, after some brainstorming among the involved stakeholders, the idea of a new service for a soiling loss system came up. Fig. 5 illustrates the involved concepts for the scenario: the involved stakeholders, used templates, and ICT support system (CoDeN System). All the agreements on the design of the new business service are then reflected in cooperation agreements, which are digitally signed by all involved stakeholders. The final output of the system is a structured documentation set to support the development of the designed services.

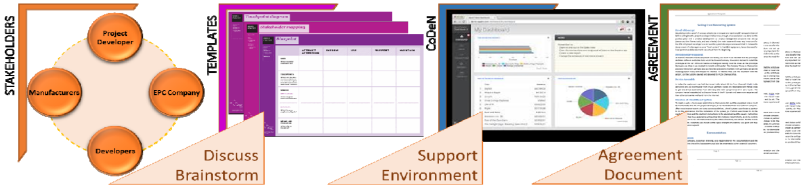

Fig. 5. Example of Soiling Loss Measuring System Co-Design

5 Conclusions

The work presented in this paper is the result of a service co-design negotiation support system specification aimed at supporting the co-creation team mediator in the negotiation process of a new business service design. The support environment to achieve agreements on the business service design is based on a software system that assists the human decision making and guides the generation of the final agreement based on service design methodology, making the process structured and traceable. Moreover, the intended environment is based on the same mechanism already specified in [8, 9, 10] for negotiation during a VO formation phase, meaning that it can be adaptable to different types of collaboration as is the case of classical VOs for business opportunities bidding and co-creation teams for the design of new business services. Also, and according to the planned validation scenario, the services co-design negotiation support system facilitates and makes the process of co-design of new business services more agile either in terms of time or adaptation.

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Applying Platform Design to Improve Product-Service Systems Collaborative Development

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Abstract. The promise of Product-Service Systems (PSS) is that it might revolutionize the consumer experience, increase the manufacture's profits and reduce environmental impacts by providing comprehensive solutions instead of pure physical products or services. However, most of the existing researches and applications on PSS are focus on the new PSS development (NPD) which could increase the customer satisfaction but could not enhance the profits of an enterprise effectively. Therefore, the platform design theory is adopted to support collaborative development of PSS. The customer requirements are forecasted by Kano model. Instead of completely innovation design, existing products and services are analyzed by function decomposition methods and the modular technology to support the PSS development. Finally, a case study of the crane machine PSS portfolios shows the effectiveness of the proposed approach.

Keywords: Product-Service Systems platform, platform design, collaborative development, modular technology.

1 Introduction

Product-Service System (PSS) is emerging as an important method for the manufactures to realize servitization. However, most manufacturing enterprises suffered drops in profits when increasing investment in services. One of the important reasons is that the manufacturing company's core competitiveness still stays on product design and manufacturing, and cannot expand its capabilities to all the services in the product life cycle to keep superior competitiveness. Cooperation with companies who have complementary core competitiveness has become mandatory for the PSS offers to obtain competitive advantage. For example in the communications industry, smartphone manufactures, operating-system developers, application developers and mobile operators often collaborate together to provide wireless service. Long-term collaborative relationships result in fast project development times, lower development and production costs, increased cooperators originated innovation and better product quality. At the same time, it also challenges the cooperators to rearrange their business models in terms of developments, manufacturing, sales, and so on to adapt to the collaborative environments.

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L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 107–116, 2014.

PSS conceptual design plays an important role in PSS development, because most life cycle cost and critical performance of a product or service is determined in this stage, and it is very difficult to correct the fundamental shortcomings in the later embodiment and detail design phases [1]. In spite of the pivotal role of conceptual design, companies find it difficult to design a PSS, especially in the collaborative environments where different organizations take charge different components of the PSS. Companies tend to design their components separately, and then an authoritative company or an third party takes on the role of system integrators and integrates the sub-systems into a whole PSS. When the sub-systems are not compatible, redesign is inevitable. Besides, many innovative parts exist in the new developed PSS and the customer requirement changes quickly. Thus, the design cycle of PSS is very long. Although there are some researches dealing with PSS conceptual design approaches [2,3,4], little considered this problem in the collaborative environments. This article adopts the platform design methods and the modular technology to solve the collaborative development of PSS.

In product design area, platform strategies provide sufficient derivative products for the market while maintaining economies of scale and scope within their manufacturing processes. Platform-based product development offers a multitude of benefits including reduced development time and system complexity, reduced development and production costs, and improved ability to upgrade products. Platforms also promote better learning across products and can reduce testing and certification of complex products [5]. Therefore, platform strategies are adopted to assist the system integrators with developing PSSs in the collaborative environments. Evans et al. [6] argues that platform strategies can also be a significant enabler to multi-actor PSS. By considering the product-service system as being made of multiple elements, potentially delivered by different actors and integrated through a platform architecture, it may be feasible to create high-performing PSSs. However, no studies have shown clearly how to develop a PSS platform. This paper is dedicated to answering these questions:

(1) What is a PSS platform? What constitutes a PSS platform?

(2) What is the different among the PSS platform, the product platform and the service platform?

(3) What are the procedures to develop a PSS platform? Are there any methods that can be used to support the development?

(4) How can the platform methods assist the collaborative development of PSS?

2 PSS Platform

2.1 Definition of PSS Platform

Synthesizing the definitions of product platform [7], service platform[8] and PSS[9], we define PSS platform as: A set of common assets such as components, modules, parts, processes, knowledge, people and relationships from which a stream of derivative product-service systems can be efficiently developed and launched.

The PSS platform is designed, manufactured and operated in a value created network involved many stakeholders. The PSS provider is the system integrator who develops platform plans, selects cooperative partners, integrates subsystems or modules and offers a whole solution to customers. The customers take a more important and active role in the PSS development. Elaborate requirements and timely feedback help the provider to adjust planning and other partners, ensure the quality of the final solution. Local providers adjust the service contents or frequency to customers' personalized needs. For example, rust-proof is more important in humid areas than arid areas. Local service providers, especially the maintenance centers, usually need components from component manufactures.

2.2 Comparison among PSS Platform, Product Platform and Service Platform

The main differences among PSS platform, product platform and service platform are the component and interface (see Table 1).

Table 1. Comparison among PSS platform, product platform and service platform

	Component	Interface
Product platform	Product module, interface	Industry standards determines the interfaces and technologies
Service platform	Service module, interface	Little influence form industry standards
PSS platform	Product module, service module, interface, support system	between the product platform and the service platform

3 The Process of PSS Platform Development

In order to assist PSS providers to develop a PSS platform in a collaborative environment, an integrated approach is proposed (Shown in Fig. 1).

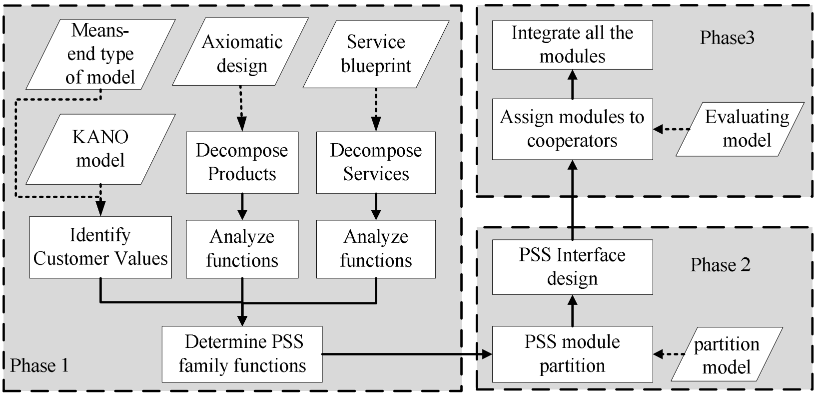

Fig. 1. The process of PSS platform development

3.1 Phase 1. Determine PSS Family Functions

A PSS family is a group of individual PSSs that share common subsystems and yet possess specific functional features to satisfy a variety of market niches. A platform may support one or more PSS families. In this paper, we constructed a PSS platform from one product family and relative services. One of the most important objectives of PSS is to maximize the customer value. The customer values must be analyzed before determining PSS family functions. Customer value is a customer's perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations.

Step 1. Define customer value elements
The means-end type of model is used to capture the customer value. Firstly, customers' goals and purposes are described. Then, considering use situations customers' desired consequences are analyzed. Finally, customer expected value elements are obtained.

Customer value often changes based on time, technology and market niches. These changes will influence the platform's component. Kano model is adopted to classify the customer value elements into basic value elements, expectable elements and adjunctive elements.

Step 2. Analyze the functions of existing products
Axiomatic design has been widely used in new product design, and it can also assist the product redesign[10]. The function decomposition process is a zig-zagging process. Functional requirements (FR) are mapped to design parameters (DP). A product's total FR is first specified, and then the corresponding DP satisfying this FR is found. This DP leads to the analysis of lower lever of FRs. Thus, the product's function is decomposed into a hierarchy structure.

Step 3. Analyze the functions of existing services
Existing services are analyzed by service blueprint. Service is in nature a process thus its function is constructed in the form of a process structure [11].Every action performed by the customers and activity performed by the staff are analyzed to obtain the function.

Step 4. Determine PSS family functions
(1). Construct the mapping matrix between PSS family required function and existing product and service's function (as shown in Fig. 2). The columns are PSS family required functions obtained in Section 3.1.1, and they are classified into basic functions, expectable functions and adjunctive functions. The rows are functions of existing products and services. If a FR can deliver a customer value element, the corresponding cell is filled with 1.

(2). Check the rows to find the replicated functions, which may be between two products, two services or a product and a service. The first two kinds of replication are caused by the lack of commonality between different products/services in the sense that different components/activities are used to deliver similar functions [12]. These replicated functions should be redesigned to be delivered by uniform

Replicated FRs between products

Replicated FRs between products and services

Replicated FRs between services

		Customer value											
		Basic value elements				Expectable value elements				Adjunctive value elements			
product/ service	Existing function	BV1	BV2	•••	BVn_b	EV1	EV2	•••	EVn_e	AV1	AV2	•••	AVn_a
Product 1	FR1	1							1				
	FR2				1								
Product 2	FR3	1									1		
	FR2				1								
	FR4		1										
⋮	⋮												
Service 1	FR3	1											
	FR5												
	FR6					1							
Service 2	FR7	1							1				
	FR8									1			
	FR6					1							
⋮	⋮												

Existing functions

Fig. 2. The mapping matrix between customer value and existing product and service's function (modified from [12])

components/activities. The replicated functions between products and services should be considered in a different way. In PSS, product and service may support or replace each other, in which situation there is no need to abandon one of them. For example, although both the automatic teller machine and the bank staff can provide accepting deposits service, a bank may retain both of them to serve the customer. Besides, some FRs may have no relation with any customer value elements (see FR5 in Fig. 2). These functions may no longer be needed by customers, and should be abandoned in the new developed PSS family.

(3). Check the columns to find the value elements which are delivered by no functions, such as EV2 and AVn_a. For basic value elements and expectable elements, new functions should be added to achieve these value elements for all customers, while for adjunctive elements, new functions could be added as optional functions for those customers who are willing to pay for that.

(4). Arrange the remaining functions in step2 and the new functions added in step 3. The functions of new developed PSS family are obtained. Classify the functions into basic functions, expectable functions and adjunctive functions based on their corresponding value elements.

3.2 Phase 2. Modularize PSS

Step 1. Partition PSS module

(1). Product module partition. There are many mature approaches for product partition, such as heuristic methods and clustering methods. This paper will not designate one approach, and the reader can choose any based on the concrete case.

(2). Service module partition. Analyze the correlation coefficient between the service activities from the viewpoint of function correlation, class correlation and process correlation [13]. The function correlation describes the closeness of two activities in achieving the same function. The correlation coefficient has five levels (1.0, 0.7, 0.5, 0.3, 0). The definition of class correlation is that some service activities have the same characteristics, and these activities can be put into the same service groups and form a module, which will facilitate the service management and provide more similar services [13]. The correlation coefficient has four levels (1.0, 0.8, 0.4, 0). The process correlation describe that whether the service activities are continuous or not.

Establish correlation integration analysis matrix, M [13].

$$\mathrm{M}=\{m_{ij}\} \tag{1}$$

$$m_{ij}=\sum r_{ij}\mathrm{F}_f+\sum r_{ij}\mathrm{F}_c+\sum r_{ij}\mathrm{F}_p \tag{2}$$

where r_{ij} is the correlation between the service activities respectively. According to the correlation integration analysis matrix, we can calculate the correlation between service activities and get the service module partition scheme at different levels [13].

(3). Determine the basic module, the indispensable modules and optional modules. The modules that deliver the basic functions are basic modules, the modules that deliver the expectable functions are indispensable modules, and the modules that deliver adjunctive functions are optional modules.

Step 2. Design PSS interface

Design the interface between different modules. In a PSS platform, there are three kinds of interface, the interface between product modules, the interface between service modules, and the interface between product and service modules. The interface between product modules has been fully discussed by many scholars [14,15]. This article concentrates on the interface between service modules and the interface between product and service modules. These interfaces are classified into two categories: one is the customer interface, which has direct interaction with customers, and the other is the module interface. Design the customer interface could be performed in the following dimensions: purpose, duration and time delay; breadth and depth of options, nature of contact and media employed [16]. The service blueprint is a good tool to find interactions. The module interface should be designed considering its purpose. For example, designing the interface between product modules and its corresponding maintenance service modules, equipment failure information is important.

3.3 Phase 3. Assign and Integrate Modules

After module partition and interface design, the modules detailed design tasks are assigned to cooperators. Lead times, prices, quality, credibility and other factors should be considered when selecting cooperators. The system integrators configure these modules according to customer's requirements.

4 Case Study

This case (crane machine PSS concept evaluation) comes from an engineering machine manufacturer (company H) in Shanghai, which provides overall solution (including product and service) for customers. Company H has five industrial parks in China and four R&D and manufacturing bases in America, Germany, India and Brazil. The main products consist of concrete machinery, excavator, crane machinery, pile driving machinery, road construction machinery, port machinery, and wind turbine. In order to respond rapidly to changing demands in today's competitive markets, company H launched PSS platform plan. The crane machinery PSS with well structured product modularization and extensive service experience is selected as a pilot project. Fig. 3 shows the hierarchical structure of a crane machine. Company H defines the crane machinery characteristics and select appropriate internal and external suppliers for corresponding product modules. The crane machine family has 6 kinds of lifting capacity, 450,500,600,650,900 and 1400 tons, and 28 types of crane machine.

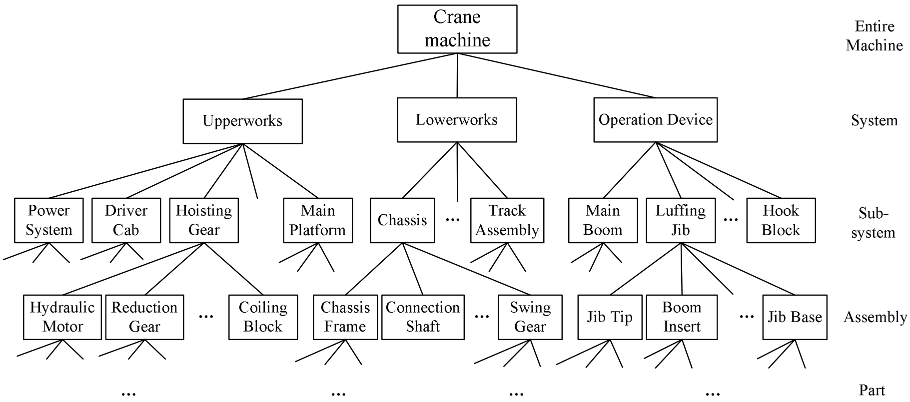

Fig. 3. The hierarchical structure of a crane machine

4.1 Determine the Functions of Crane Machine PSS

Customer value are collected through survey questionnaire and semi-structured interviews. The value elements are shown in Fig. 4.

Existing product (28 types of crane machine) and services (45 kinds of service) are analyzed to obtain the existing functions. According to the matrix in Fig. 2, some functions are abandoned. For example, the air conditioner is not needed in Indian, and headlight is not needed if the operating time is very shot. Some functions are added. For example, 24-hour rescue service, oil analysis service, and lending service are added to serve the customer. The family functions are as follows: core capability, module reliability, control technology, safety guard, operating mode, environmental protection and energy saving, cramped construction, operating temperature, construction guarantee, maintenance technology, maintenance cost, service professionalism, service timeliness, 24-hour rescue service, oil analysis service, and lending service.

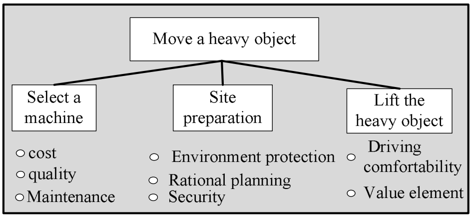

Fig. 4. Value elements of crane machine PSS

4.2 Modularize the Crane Machine PSS

The crane machine has been modularized. Thus we only need to divide service modules. Construct the correlation integration analysis matrix between the 45 services (see Fig. 5), such as hydraulic motor maintenance, chassis frame maintenance, operation training service et al. Every element in line i and column j in Fig. 10 represents the correlation between activity i and activity j. For example, the number 0.76 in line 2 and column 3 means that the correlation coefficient is 0.76. This number is the weighted sum of the function correlation, class correlation and process correlation coefficient. This matrix provides a basis for module partition. Activities with bigger correlation coefficient are more likely to be clustered into a module.

After module partition, 8 service modules are obtained: maintenance module, training module, lending module, operating condition analysis module, installation module, transportation module, oil analysis module and pre-sales consulting module. Each module has more detailed modules.

The basic module contains: power system, driver cab, hoisting gear, main platform, chassis, track assembly, main boom, pre-sales consulting module, training module, transportation module, installation module, et al.

The indispensable module contains: hydraulic motor module, auxiliary jib, maintenance module, lending module, operating condition analysis module, oil analysis module et al.

The optional module contains: remote control system, 24-hour rescue service, High pressure warning, the third winding engine, fuel preheating et al.

Company H assign these modules to different cooperators, and integrates these modular into a whole solution. After the new developed crane PSS was put on the market, customer feedback was gathered through questionnaires and interviews. The acceptance of the new solution by the users was very high, including comments that they would like the service to continue after the pilot test. Although the cost exceeded the budget, it can be accepted by the company. The practical operating results show that the selected solution is good.

	1	2	3	4	5	6	7	8	•••	43	44	45
1	1							0.58			0.6	
2		1	0.76									
3	1		1	0.4						1		
4				1								
5		1			1							
6						1						0.4
7	1						1					
8								1				
⋮					1				1			
43	1							1		1		
44									1		1	
45					1							1

Fig. 5. The correlation integration analysis matrix

5 Conclusions

As customer requirements become more complicated and change rapidly, platform design is introduced to improve the responsibility of PSS. An integrated PSS platform development approach is proposed in a collaborative environment. The main contributions are as follows:

(1) Platform design is introduced to develop PSS in a collaborative environment. The system integrator designs the PSS platform with basic module, indispensable module, optional module and uniform interfaces. The modules are designed by cooperators separately and integrated by the system integrator.

(2) An integrated PSS platform development approach is proposed based on existing product and service. Customer value is obtained by means-end type of model and Kano model. Existing product/service function is analyzed by axiomatic design and service blueprint. Module partition approach is used to divide PSS.

Future work will concentrate on PSS module partition. When the system become complex, the matrix that represents the interdependent relationship between components or service activities will be too huge to implement the corresponding clustering algorithms effectively. The complex network will be introduced to solve the PSS module partition problem.

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Transition Towards Product-Service Systems

Building an Ontology of Product/Service-Systems: Using a Maritime Case Study to Elicit Classifications and Characteristics

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Abstract. In recent years, the innovation strategy and development process entitled Product/Service-Systems (PSS), has attracted considerable attention from the research and industrial communities. The many contributions have come from various academic and professional viewpoints, which despite providing a rich view of PSS as a strategy, also leaves some confusion as to what actually constitutes a PSS. The definition of a PSS ontology could provide the basis for a more systematic knowledge gathering within the field and facilitate the application of integrated solutions within the industry. Ontologies provide an effective tool for a knowledge management process, due to their semantic capabilities, interoperability and extendibility. A PSS ontology for domain conceptualisation is proposed that captures the underlying end-user value and relates to existing PSS offerings. The PSS ontology is subsequently integrated into an ontology for the maritime sector, in order to allow for the identification of the PSS implementation opportunities within the industry. A maritime ontology can help the industry to document and reuse tacit knowledge while facilitating the implementation and value assessment of PSS solutions.

Keywords: Product/Service-Systems (PSS), ontology, knowledge base, maritime industry.

1 Introduction

In an ever competitive and globalised market, companies strive to enhance their competitive advantage, in order to survive and eventually expand. A viable strategy is to enhance the traditional product offering with service elements that foster customer loyalty and allow for increased product diversification. Product/Service-Systems (PSS) provide an integrated view on tangible and intangible elements of products, where products are considered equal to services, since both are means to satisfy customer needs [1].

Product/Service-Systems are regarded as a business opportunity for the shipping industry, where it is discussed that there is a growing demand from shipowners with respect to after-sales service [2]. One reason for this growing demand is that, due to

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current over capacity of the fleet [3], freight rates are low and it is currently economically unattractive to invest in new-builds. Since new vessels cannot be financed, focus is set on improving the performance of the current vessel portfolio and extending its economic life. A number of strategies can be followed that can reduce fuel consumption, increase availability and mitigate operational risks[3].

In light of the industry-wide challenge of fleet overcapacity, PSS can provide a novel alternative for shipowners to prolong the life-time of the fleet, reduce costs, enhance relationships with the supplier base and improve vessel tradability [2] [3]. In order to allow the transition to a service-centred economy, a wider understanding of the available PSS solutions and their associated value propositions must be communicated both to suppliers and the end-users – in our case the shipowners. These solutions must be able to adapt to existing business models and allow the involved stakeholders to communicate and share their views without ambiguity [4]. In this direction, ontologies can prove an effective tool to map domain knowledge, promote information sharing and increase information systems' interoperability [5].

The particular contribution of this paper is twofold. Firstly, a PSS ontology is proposed. The ontology provides a basis for the analysis of existing integrated service solutions within the maritime industry and connects PSS to key product/service solutions and their associated value. Secondly, a local ontology is built in order to explore the connectivity of the PSS ontology to actual business practices. It is shown that the exploration of PSS solutions is simplified, as the combined ontology can infer the total package of PSS offerings, as well as their impact on end-user value.

2 Literature Review

The potential benefits of PSS are well documented in the literature [6]. As companies evaluate PSS alternatives during the total life cycle of a product, a broader perspective is gained. Tukker & Tischner argue that this holistic approach is in itself a first step towards achieving better results [1]. In addition, PSS can create new profit centres and new partnerships with other businesses [7] whilst also providing incentive for the continuous improvement of the business, innovation in quality, and the satisfaction of consumer demand [8].

According to Lindberg & Nordin, a major challenge that companies face when transiting from a product-centred to a service-centred strategy is the difficulty in comprehending complex service offerings [9]. A knowledge-based decision making framework which describes PSS alternatives and their value propositions could promote such a transition. It would allow knowledge integration from the whole product life cycle phases and their associated services [10], systematic identification of customer needs and PSS concepts [11] and quick retrieval of knowledge to the strategic, tactical and operational levels of a company [5]. Furthermore, the PSS research community could also benefit from a systematic knowledge gathering exercise, encompassing the whole life cycle of services and products.

For the establishment of a common terminology and a reusable Knowledge Base (KB) on a subject or phenomenon, ontologies have proven to be an effective tool.

Ontology is a formal explicit description of concepts, in a certain domain, followed by the properties of each concept that describes various features and attributes and restrictions on these attributes[12]. A knowledge base is essentially constituted by an ontology, together with a set of individual instances of classes. Classes are concrete representation of concepts and are interpreted as sets that contain individuals[13].

Ontologies provide the basis for domain knowledge analysis, knowledge reuse, and allow domain knowledge to be separated from operational knowledge, thus also making domain assumptions explicit [12]. In this work, the need to include heterogeneous databases and describe dissimilar concepts using the same vocabulary was early recognized. In that direction, unlike traditional data models like UML class diagrams or entity relationship diagrams, ontologies provide methods for integrating fragmented data models into a unique model without losing the notation and style of the individual ones[14]. Compared to a database, an ontology can be better when the model consists of rich data, with many relationships that are often traversed [15].

In the literature, various ontologies have been proposed for product & service development. Shen & Wang [16] present a framework for understanding and conceptualising product centred services. A generic knowledge model for service conceptualisation is proposed, which enables knowledge sharing and reuse among the different stakeholders during service planning. Zhang et al. develop an integrated knowledge management framework for Product/Service-Systems [17]. It is argued that knowledge in product-related services allows manufacturers to improve products and an ontology is created, which links to meta-knowledge, such as documents, databases, and 2D CAD models. Annamalai et al. propose an ontology for top-level concepts of PSS. The aim of the ontology is "*to aid clarity to the top-level concepts of PSS which would help to communicate these concepts better between researchers and practitioners*". The top-level concepts in PSS are identified in collaboration with industry and validation is carried out in collaboration with PSS researchers [18]. Doultsinou et al. propose an ontology-based structure for manufacturing and service knowledge classification in their so-called knowledge reuse framework [10] . The proposed KB aims at understanding and documenting knowledge support requirements throughout the product life cycle. A number of recognised service issues that occur at different phases within the product life cycle are identified and integrated during the conceptual design phase.

Although past literature approaches provide a basis for systematic analysis of Product/Service-Systems, a number of issues remain unanswered. Existing knowledge bases do not focus on the actual service contents of existing PSS solutions, but rather aim at facilitating communication within existing value delivery networks. Furthermore, knowledge management of Product/Service-Systems is viewed purely from a supplier point of view and the end-user perspective on procurement of PSS is ignored. As PSS is widely acknowledged as being a co-development of value creation through concurrent production and consumption of a function [19], these unanswered issues are important to address in PSS ontology work, which we include in this paper.

3 Proposed Ontology Structure

In order to integrate the end-user perspective and evaluate the service contents of actual PSS offerings, an explicit formal specification of the underlying concepts in PSS must be initially established. Noy & McGuinness' ontology development methodology [12] was followed, in order to create an ontology for domain conceptualisation. The following steps were followed; in the order they are presented.

Determine the Domain and Scope of the KB. The scope of the KB is to explicitly describe the domain of PSS and explore the applicability of PSS solutions, by testing it in the maritime sector. In particular, the ontology illustrates the relationship between products, services and the network of the involved stakeholders during the product life cycle. The proposed KB further aims at describing the value in combined Product/Service solutions and depict the value proposition of existing PSS offerings.

Reuse Existing Ontologies. The developed KB has drawn elements from a number of proposed ontologies and information sources. Root concepts of PSS were extracted from [18]. The main classes that were included in the ontology were: Business Model, Product Service, PSS Life Cycle, PSS Need (and its equivalent class PSS Requirement), Stakeholder and Support Systems. Attributes of Value-in-Use were identified in [20], and the following classes were added: Ability To Source, Access, Administration, Contract, Convenience, Cost, Delivery, Detailed Analysis, Environment, Inventory Management, Knowledge, Offhire, Price, Proactive, Quality Of Equipment, Range Of Offering, Relational Dynamic, Responsiveness, Risk, Service Orientation, Support Systems, Traceability, Understanding Customer Business and Urgency. Furthermore, the developed KB made use of integrated offerings that were developed by the PROTEUS Innovation Consortium [3], in which the following classes were identified: Channels To The Customer, Spare Parts, Customisation, Packages, Education and Installation.

Enumerate Important Terms. A number of terms which are central to the field must be described. These terms are concerned with both the definition of Product/Service-Systems as well as their application in case studies. The main terms were identified in a highly cited review paper from the field of PSS [4] and included the following categories: Services, PSS, Requirements, Life Cycle Stage and Process. Furthermore, the PSS design framework was based on Transformation Models [21] from which the following terms were included: Material, Information, Energy, Effect, Input, Output, State, Transformation Process and Transformation System

Define the Properties and the Classes' Structure. There are several approaches for developing a class hierarchy [12]. In this work a combination of bottom-up and top-down approaches were followed, including the important concepts and distinguishing the most general classifications. The KB attempts to incorporate both the academic and the industrial perspective on the nature and application of PSS. To facilitate its structure and subsequent use, it consists of three mapping layers shown in Fig. 1.

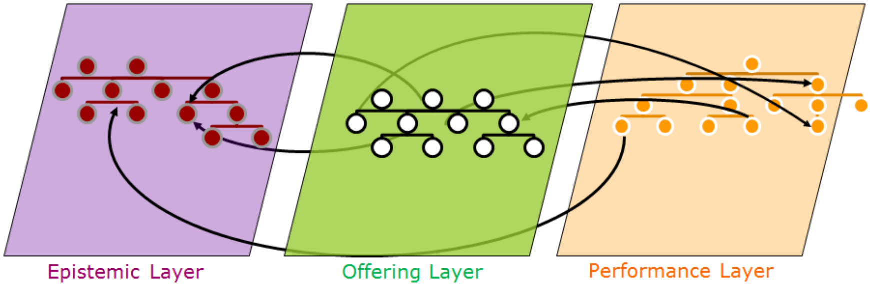

Fig. 1. PSS ontology layers and their connections

The epistemic layer is an abstract description of the PSS. The scope of this layer is to conceptualise the nature and the affinities between products, product life cycle, services, stakeholders, business models, requirements and the transformation process. Transformation is defined as the translation of inputs into desirable outputs in the form of material, energy and/or information [22]. The offerings layer is an explicit description of existing product/service solutions [3]. The scope of this layer is to enumerate existing integrating offerings and describe the synergies between them. The performance layer is a conceptualisation of the value that products and services entail for all relevant stakeholders. The scope of this layer is to explicitly define different types of customer and supplier value and bridge abstract value propositions to performance metrics. The individual layers were imported into the final knowledge model and relationships between the layers were established to connect the various heterogeneous taxonomies. For example, Product/Service Offerings were linked to their individual value offerings using the object property "increasesValue", while instances of products were linked to their associated PSS Offering using the property "hasPSS" and its inverse relation "isPSSOf".

Ontology Design Decisions. In developing the ontology a number of design decisions were made, regarding the structure of the KB. The ontology was developed in Protégé 4.3 [13] while elements of the ontology are named based on the CamelBack naming convention [13]. In order to cope with synonyms, the equivalent class concept was employed in order to link closely related terms [23]. Furthermore, in some cases, classes belonged to more than one superclasses (multiple inheritance) in order to cope with the ambiguity of terms and the difficulty of classifying some of them into a unique category. In the offering layer, offerings are modelled as classes and specific offerings as individuals that belong to these classes. These individuals in turn are linked in terms of their dependency on each other via the transitive [23] property 'isRequiredBy' and its inverse property 'requires'.

4 Case Study

Evaluation and update of the KB can be performed by applying it in a real problem and by discussing its structure with experts in the field [12]. In this work the particular case study stems from the maritime sector and focuses on Company A, a shipowner which is interested in procuring PSS solutions from external suppliers. The fleet of Company A consists mainly of tankers that transport clean petroleum products such as naphtha, gasoline, fuel oil and jet fuel around the globe. The company operates in the so-called “spot market”, meaning that its vessels do not have fixed schedule and are mainly chartered on a voyage-by-voyage basis.

In order to support PSS exploration within Company A, a local ontology – the Shipowner layer- is built in order to conceptualise the explicitly defined embedded knowledge within the company. The Shipowner layer was integrated in the overall PSS ontology to allow for information exchange between the layers. The main objective of the Shipowner layer was to gather tacit knowledge that was distributed among various departments within the company and explore PSS alternatives to existing business models. In this direction, seventeen semi-structured interviews were conducted with key people working on the technical and commercial operation of the fleet. Also, in parallel to the interview process, a number of external sources such as reports, business cases and databases were analysed. Through the interviews, the embedded knowledge was identified, which essentially is focused on the ship and its activities. Furthermore, the benefits and challenges for implementing PSS solutions in specific cases within Company A were discussed. Throughout the interviews, it was stressed that a tool which can illustrate the value proposition and trade-offs for different PSS offerings would facilitate their adoption.

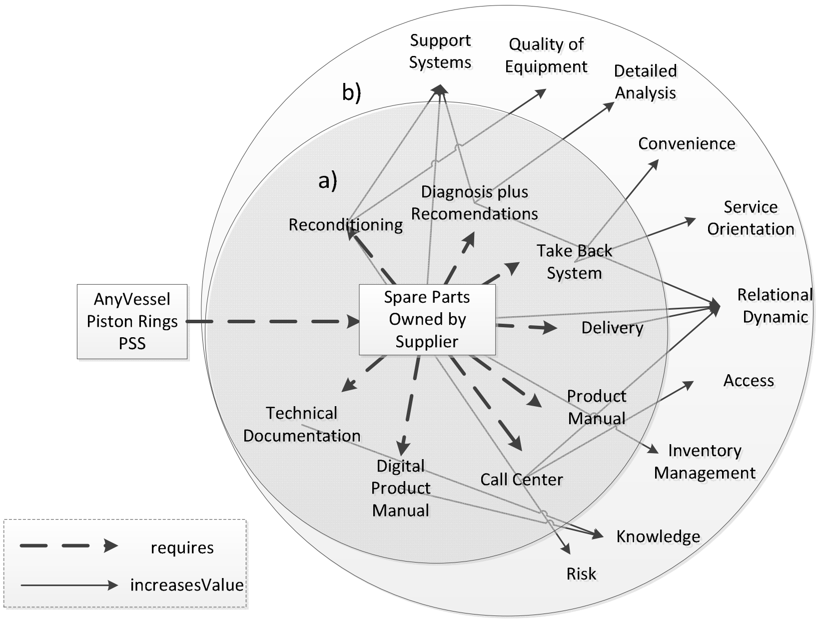

Fig. 2. Example of a PSS design using the developed KB. For a specific project (AnyVessel Piston Rings PSS) the designer picks the associated Service offering (Spare Parts Owned by Supplier), and the KB reasons on (a) the required offerings (shown within the inner circle) and (b) their associated value offerings (shown within the outer circle)”.

The integrated KB, which consists of the combined four layers (Epistemic, Offering, Performance and Shipowner layer), was used for PSS design. An application is shown in Fig.2, where piston rings for the main engine of a particular ship ("AnyVessel") are rented from a certain supplier. Company A can choose a PSS solution for a specific application in the context of its operations, and the KB automatically infers the additional PSS offerings that need to be procured as well as their value propositions.

5 Conclusions and Future Work

In this work a Knowledge Base for PSS conceptualisation has been presented. The KB builds on a growing expertise and interest in knowledge mapping and representation and is largely based on existing classes and concepts. It can provide a basis for PSS design and help evaluate existing integrated offerings in regards to their value propositions. The developed KB was applied in a case study from the maritime sector in order to show, in the context of knowledge representation, the KB's efficacy in helping a shipowner design PSS concepts and understand their benefits. Future work could expand and establish a representative framework for PSS design process using semantic knowledge bases. The overall framework can be compared to current customers' practices during PSS design in order to better describe its usefulness. It should be noted that the proposed KB is not intended to remain stable, as it is subject to scrutiny, refinement, changes in the structure, introduction of new classes and individuals and integration with other knowledge bases. Future research work could also include definition of quantitative instead of qualitative relationships and integration of the ontology with existing open-source knowledge bases that would provide a basis for semantic reconciliation within the field.

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Challenges and Opportunities in Transforming Laser System Industry to Deliver Integrated Product and Service Offers

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Abstract. Laser system industry is a complex network entity that includes laser component manufacturer, laser manufacturer, system integrator, laser job shop, laser process developer and end product manufacturer. Currently this market segment is predominately product-centric in which the common business model is to sell laser systems with two years warranty. However increasing competition within this segment is forcing some stakeholders to go further than the existing business model, and aim to build long-standing relationship between others. In this paper, the current structure and level of servitization in laser industries, the implications of higher levels of servitization for the various stakeholders of the industry, and the opportunities to develop and deliver higher levels of servitization are discussed. Analyses of semi-structured interviews with managers of laser system manufacturer and laser job shops reveal that any servitized solutions would primarily require the transfer of capabilities between various stakeholders.

Keywords: Servitisation, Product-Service System, Laser System, Stakeholders.

1 Introduction

Globalized economic pressures and competitive business environments are forcing industries to look beyond product-centered business proposition. Many studies have point out that manufacturing industries in developed countries need to compete on the basis of value delivered rather than on the basis of cost [1]. Servitization can be considered as a shift from selling products to selling an integrated combination of products and services that deliver value in use [2]. Product-Service Systems (PSS) are proven to add beneficial advantages in terms of increase in revenues, to establish closer relationship with customers, and act as a mechanism to understand interactions and product usages better [3]. Irrespective of these proven advantages, designing innovative servitized offerings is challenging, and the design process is often ad-hoc, and procedures are not well documented both in academia and industrial practices.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 127–134, 2014.

This situation is due to obstacles in transferring lessons learnt across varying industrial environmental conditions, and different stages of maturity levels in offered products and services. Also difficulties raised due to many stakeholders and organizations involved in value co-creation of servitized offerings. To bring cross transformational knowledge exchanges, there is a need to benchmark critical parameters involved in designing servitized offerings.

In this paper, we aim to generate generalized critical parameters involved in designing servitized offerings through undertaking a study in the laser system network. These parameters are based upon the detailed analyses of literature reported case studies results. The rest of this paper is structured in four sections: detailed literature summary on the case studies results from designing servitized offerings, research questions and methodology used, presentation of results, and discussion and conclusion.

2 Related Literature

Reviewing the existing literature, Baines [4] noted that there is a paucity of previous work that provides guidance, tools or techniques, that can be used by companies to servitized. There are many descriptive studies are required to understand this domain in-depth. To provide a focused review, only latest descriptive studies on success factors and challenges involved in offering integrated product-service solutions are summarized in this section. Martinez et al. [5] categorize the following challenges faced by a company while moving from being a product oriented organization to a product-service oriented organization: embedded product-service culture, delivery of integrated offering, internal processes and capabilities, strategic alignment, and supplier relationships. In continuation with this list, Stargård and Hassan [6] have identified comprehensive list of success factors to be considered in PSS development.

The identified factors are senior management clarification of strategic intent, cultural change management, teamwork culture, internal communication mechanisms, external communication mechanism, customer relationship, motivating breakthrough ideas, project core competency, cross-functional collaboration, cross-functional development, allocation of resources, training and education, knowledge management, customer satisfaction data, risk management, product positioning, portfolio of product opportunities, product functional content, knowledge of market potential, product service processes, product environment, development process, responsibilities of team members, concurrent development, internal task coordination, organizational readiness for sales, internal marketing and external marketing.

Durugbo [7] finds that technical requirements of competitive PSSs are best fulfilled in work systems that emphasize individual timeliness/ buy-ins, synchronous communications managed by strategic roles and tie-ins offered by service contracts. Baines [3] summarized that a shift in culture, contracting structures, governance, risk management mechanisms and financing systems will allow companies to deliver services while building their capabilities to innovate technology along the way. They noted that initial cost savings, on-going cost reduction, transfer of fixed costs into predictable variable costs, improved asset security and improved asset reliability are the priority factors for customers to be attracted in product-service offers. Vasantha et al. [8] noted that the critical productivity factors that define industrial product-service systems are performance, availability and reliability.

Ng et al. [9] proposed the three transformations needed for developing complex engineering service systems, namely: transform materials and equipment, transform information and transform people. For life cycle design, Masood et al. [10] classify uncertainties into the dimensions of engineering uncertainty, operation uncertainty, affordability uncertainty, commercial uncertainty, performance uncertainty and training uncertainty. Nordin and Servadio [11] identified critical issues during servitization using three main conceptual dimensions the organizational dimension (internal), the procedural dimension (hybrid), and the relational dimension (external). They studied these dimensions in terms of separating product unit from service units, shifting the manufacturer's mind-set, developing formal processes and procedures, generating new competences in terms of organizational and operational capabilities, creating strategic partnerships with suppliers, and to engaging with customer through learning interactions.

Although common themes such as internal processes, external processes, product and service characteristics and business elements are emerging as overlapped themes, the list of sub-factors within these themes are expanding and only few overlapping factors could be identified between studies. The primary reason for this divergence could be due to different market domains covered in every study. To bring convergence there is a need for comprehensive cross-sectorial case studies. However, many industrial sectors are not yet studied to undertake cross-sectorial case studies. One of the industries not yet covered is laser cutting manufacturing industry which is the focus of this paper. We aim to study the factors influencing to develop PSS offers in this industrial sector.

3 Research Questions and Methodology

In this paper, we aim to present answers for the following research questions:

- What is the current structure and level of servitization in laser industries?
- What are the implications of higher levels of servitization for the various stakeholders of the industry?
- What are the opportunities to develop and deliver higher levels of servitization?

These questions were answered by undertaking semi-structured interviews with managers of laser system manufacturer and laser job shops. Interviews were conducted with three laser job shop managers and two senior sales people of laser system manufacturers. In this paper, the core information collected from these interviews is summarized and presented. Figure 1 explains the network of three stakeholders, and their roles in the network. Primarily, Laser system integrator sells laser system to Laser job shop and End product manufacturer. End product manufacturer either outsource laser cutting jobs to Laser job shop or buy Laser system if the volume of laser cutting production is very high and have required capabilities to do laser cutting jobs themselves. End product manufacturer will post an open request for quotation across laser job shops if they decided to go with the outsourcing option. The key criteria chosen in outsourcing laser cutting jobs are delivery time and price.

So Laser job shop who proposes quicker time with lesser price will mostly likely to win the order. The next section answer the above mentioned research questions in the respective order.

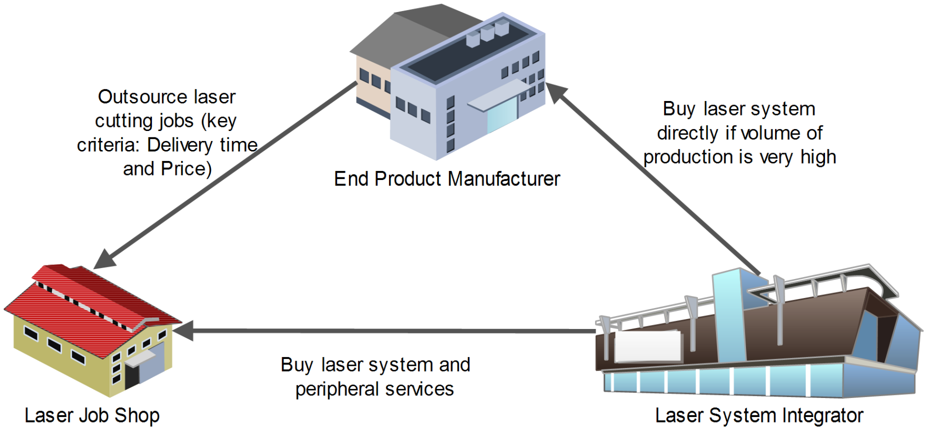

Fig. 1. Illustration of network between three stakeholders

4 Results

Current Structure and Level of Servitization in Laser Industries

Table 1 summarizes the current servitization level between Laser job shop and System integrator, and Laser job shop and End product manufacturer based on the criteria summarized by Martinez et al. [5]. Both these relationships have low level of servitization. The primary reason for this low level of servitization is that there is no relationship established between these stakeholders. This environment is primarily price-driven and there is no trust established between them.

Table 1. Identification of Laser Network's servitization level

Level of Servitization	**Laser job shop and System integrator**	**Laser job shop and End product manufacturer**
Value Basis of Activity	Mostly transactional based	Completely transactional based
Primary Role of Assets	Primarily asset ownership	Pay-per-use basis
Offering Type	Offered as Laser system plus peripheral services	Price driven environment
Production strategy	Mass production	Mass customization
Offering type	**Low Servitization**	**Low Servitization**

Although each outsourced job from End product manufacturer is driven by pay-per-job basis, and each job is different and manufacturing operation needs to be optimized for each setting, there is no relationship exist between Laser job shop and

End product manufacturer. The reason for this scenario is that laser cutting operation is now commoditized and it is no longer considered novel to improve manufacturing efficiency through laser operations.

Table 2. Rationale for (not) choosing the particular level of Product-Service offers

Product-oriented	Use-Oriented	Result-oriented
Most of Laser job shops prefer to buy and own laser system with specific period of warranty.	Only one of the four laser job shops interviewed mentioned that they are leasing the machine rather than purchasing.	Pay-per-use laser system model is not currently offered by System integrator. It was used initially only for market penetration.
Although good residual value of laser system is expected only up to 5-7 years, it can be used as long as 10-12 years.	Good residual value of the machine provides accuracy, less downtime, reliable, updated technology if any, and most importantly provides predicable running cost.	This offering is avoided by Laser job shops itself because they perceived that although it reduces initial investment, it has high financial risk and could be more expensive in longer run.
No major technology change is expected in near future.	Reduce initial major investment cost and ensure smooth cash flow. Upgrading old system is not a cost effective solution.	Also Laser job shops are nervous about this offering because they believe that System integrator could directly interact with their customers leading to their elimination in the network.
No restriction on Laser system usages and consumables used.	But placing a proper leasing contract is a challenge. Various terms and conditions did not match between Laser job shop and System integrator such as fixed insurance premium, place of return and usage of premium consumables.	System integrator apprehension about operator's misuse, and delayed and improper fault reporting.

Implications of Higher Levels of Servitization

The common business offering proposed by System integrator is selling laser system with two years warranty. System integrators have less competitive impetus to propose novel business offerings because this market segment is predominately dominated by only two integrators, and also laser job shops segment comprises only small percentage of their total business. System integrator also argues that since this market is price driven, there is no reward for faster service response time. However, System integrator do offers five year warranty replacement and buy-back option but without any uptime guarantee. Table 2 provides the rationale mentioned for choosing the particular business offerings than others.

Opportunities to Develop and Deliver Higher Levels of Servitization

The primary question emerges from this laser system network study is that, how can price-driven scenarios could be changed to relationship and trust driven industry? To find answer for this question, strengths and weaknesses existing within this network are analyzed.

The strengths of laser job shop are processing quickly on product design data, optimizing material usages, and efficient machine operation and material handling. The weaknesses are not having trained machine operators, lack resources to support data management for remote monitoring devices, and in remote location for some of their customers. The strengths of system integrator are services provided are generally excellent (e.g. next day service engineer visit along with well-equipped spare parts required, well networked service operations throughout the UK), and system failures are tracked well through error logs and failure causes identified 60% of the time. The weaknesses are less transparency in service operations leading to doubts for higher price for simple failure (e.g. replacing whole sub-system rather than repairing the particular component), and not well-versed with establishing suitable leasing contract.

End product manufacturer is a key stakeholder in this network and any system network modification should consider their business criteria as critical factors. Fast delivery time, less price, high quality, and local and friendly stakeholders are the critical requirements for End product manufacturer. Although End product manufacturer needs are important, the proposed solution should be win-win for all stakeholders. A new business model could be developed considering the three forms of customer engagement noted by Baines [3]: customers who want to do it themselves; customers who want us to do it with them; and customers who want us to do it for them. Considering these factors and engagement modes, a new business model is proposed which intends to build relationships between stakeholders. The proposed higher level of business model intends to build on strengths of each stakeholder and eliminate weakness though transfer of capabilities and resources. In this scenario the engagement mode "customers who want us to do it with them" is chosen because it avoids elimination of stakeholders in the network. Figure 2 illustrates the proposed higher level of servitization solution.

In the proposed model, Laser job shop move closer to a large and valued customer and provide the operators to run the surrounding laser cutting processes. The infrastructure and space could be provided by End product manufacturer. The laser system could be supplied by System integrator on a pay-per-use basis provided that a minimum payment is guaranteed and that risks can be finely calculated and shared between stakeholders. In this way, each stakeholder would share its expertise and resources. This servitized business model would cultivate long term relationships and ensure very competitive rates and immediacy of delivery for guaranteed volume of business. The strengths of this proposed business model are it takes into account the core capabilities of each stakeholder, and eliminates the drawbacks in the current laser system network. Similar kind of business model is noted by Baines [3] for emergent facilities practice where facilities are located in close physically proximity to the customers operations. However, the limitations of this model are it could lead to monopoly in Laser job shops and whiplash reduction in job shops, and also unassured whether service transparency (knowledge know-how) could be established by this network.

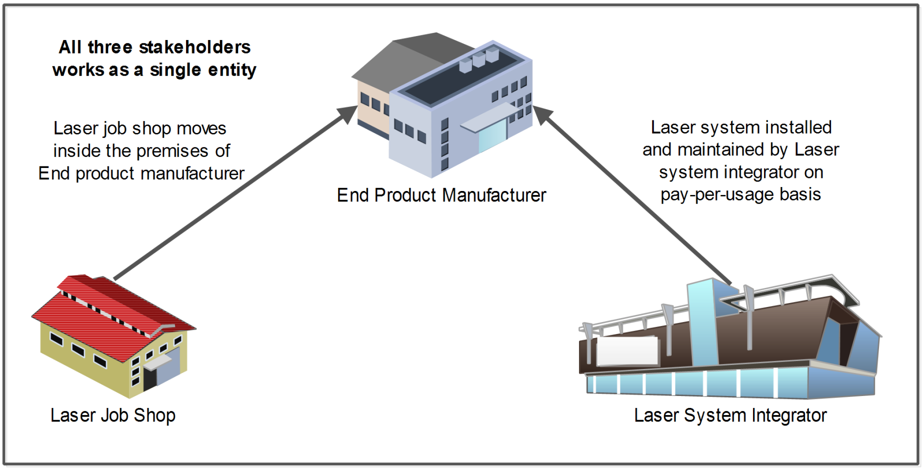

Fig. 2. A proposed new servitization model for the laser system network

Table 3. Critical factors influencing to develop higher level of servitization

Characteristics	Situation
Value definition	Price driven environment and not trust
Interrelationships	Transactional basis rather than relationship
Product maturity	Performance levels are achieved to required needs and drastic technology changes not expected soon. Product life is longer. Product upgrades are considered infeasible.
Service maturity	Services are advanced with immediate fault registration and causes identification. Advanced services are not appropriately rewarded. However transparency is a critical issue.
Market competition	Contradiction of competition between stakeholders. Laser job shops environment is highly competitive whereas System integrator environment is dominated by two key players.
Consumables usage	Many restrictions imposed on laser system consumables usage such as to use only premium gases.
Business contract	Establishing suitable terms and conditions between stakeholders are challenging.
Capabilities	Mismatch perceived with skills and resources such as operator’s skills.

5 Discussion and Conclusion

The foremost observation from this study is that "Pay-per-Use" business model and customization should not be considered as de-facto standards for higher level servitization model. The de-facto factor for higher level servitization model should be establishing long lasting relationships with stakeholders and delivering value-in-use to end customers. The list of factors that primarily influences to downgrade pay-per-use business model is tabulated in Table 3.

Although with above mentioned difficulties, it is possible to develop higher servitization model if focus placed on predictable cost and enables smooth cash flow for all stakeholders. The following servitization study on this sector will focus on possible influences of technology substitution on laser system by additive manufacturing.

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Towards a Framework for Analyzing and Evaluating Servitization Potential: Case Study of ENVIE Loire

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Abstract. For a manufacturing company, moving from selling a product to selling a function is a process called "servitization", leading to the suggestion of an offer oriented functionality that is more commonly called a Product-Service System (PSS). This process requires for a company to have a relatively clear vision of possible scenarios. Under the ServINNOV[1] project, we proposed after a deep analysis of the main researches on PSS a new approach to analyze the servitization potential. In this paper, we present our conceptual framework for identifying and evaluating the different scenarios and we illustrate the practical use of this approach using the case study of ENVIE Loire which develops remanufacturing activities.

Keywords: Servitization, Product-Service System, function-oriented business model, Tangible Value, Intangible Value, Envie Loire.

1 Introduction

In these previous years, the principles of service integration for manufacturing companies, and product integration for companies of the tertiary sector, respectively called “servitization” and “productisation”, are research themes or entrepreneurial initiatives that are increasingly being encountered.

Providing a client with functionality is not only based on a product, but also on a service package in order to present the client with functionality and insure its proper running. Products and services are two concepts that are both related in the same functionality offer, commonly called a Product-Service System (PSS).

The well-known examples of service economy business models are those of large companies: Michelin, Xerox, Rolls-Royce, … In order to successfully shift towards this new business model, many SMEs have to face up to two major questions:

[1] ServINNOV is a national funded research project, placed under the leadership of Henri Fayol Institute. With financing from the French National Research Agency-ANR and on collaboration with three research laboratories: COACTIS, G-SCOP, and PACTE. The project aims at studying one of the current changeovers of industrial companies from a production and innovation process essentially based on material goods to the integration of multiple service activities. http://copas.emse.fr/servinnov/

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1. The identification of the possible product-service offer, which product(s) and which related service(s) ?
2. The analysis of the profits and costs related to these different scenarios of servitization?

This is the context of our paper, in which we try to give clear answers to these questions by proposing a new approach to analyze the potential of servitization. In this paper, we present our framework and we illustrate the practical use of this approach using the case study of ENVIE, a company that delivers remanufacturing activities.

2 Service Economy and Servitization

Below, we briefly recall what we call service economy and servitization.

2.1 Service Economy

The first use of the term service economy was attributed to the architect and town planner Walter Stahel, and to the economist Orio Giarini, in 1986. They define it as goods or services optimization that consequently improve wealth management — goods, knowledge, nature [1]. The objective of service economy is not only to create, as large as possible, use value, but to ensure at the same time a sound consumption of raw materials and energy resources. The value of a product isn't just related to its physical components, but also and mainly related to its intangible elements that can improve the product's performance and can be a source to create value. If literature surrounding service economy isn't yet quite developed, a large theoretical field regarding Product-Service System (PSS) has emerged and developed since the fundamental work of Mont [2]. In fact, service economy can be considered as a particular model of a PSS offer.

2.2 Servitization

Product-service systems are defined as a "marketable set of products and services, jointly capable of fulfilling a client's need. The product/service ratio can vary, either in terms of function fulfillment or economic value" [3]. The development of servitization is relatively large, especially in industrial strategy. We will not go back to this set of work (a literature revue was done by Baines et *al.* [4], but we will focus particularly on developments that provide a pertinent base to identify servitization scenarios and their economic analysis.

2.3 Types of Product-Service Systems-PSS

Multiples classifications of PSS have been proposed. The most common classifies them into three types [5]:

1. Product oriented PSS: provide an additional service to the sold product (funding, maintenance, recovery at the end, training, etc.);
2. Use oriented PSS: the use of the product is sold, not the product itself (renting, leasing, pooling and sharing);

3. Result oriented PSS: the producer ensures the satisfaction of the consumer's needs, regardless of material products (low cost planning, installation management services).

As it can be seen in figure 1, Tukker [6] goes further and identifies 8 subcategories of PSS:

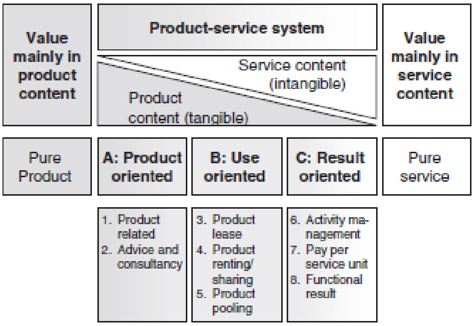

Fig. 1. Categories and subcategories of PSS ([6], p. 248)

Each of these categories groups models that present more differences on the economic scale than on the environmental one. We will focus here on the economic aspects, especially from the value creating perspective.

2.4 Elements of Value Creation by PSS

Tukker [6] proposes four "key economic elements" that allow the analysis and the benchmarking of the added value of the different types of PSS. These elements are presented below:

1. **Market value of PSS**: it can be tangible and/or intangible: the tangible value of PSS refers to the objective value it brings to the consumer (Resource, time and capital economy). The intangible value is subjective and therefore harder to estimate. It can consist of profits in terms of images, response to standards, etc.
2. **Production costs of PSS**: they include, of course, the traditional production costs, and take into consideration as well, when it comes to result oriented PSS, their inherent uncertainty. In fact, the PSS supplier in this case who engages on a result can run into penalties if the promised results are not met.
3. **The investments related to the production of** PSS: They not only cover at the same time the necessary capital needed for the production of PSS, but also the set of investments related to the company's transition and the modification of its organization.
4. **The capacity to capture value within the value chain**: today as well as in the future. This "capture" can be done for example by customer loyalty, or a rapid pace of innovation.

Based on these elements, we will present hereinafter our method that covers the set of PSS procedures and goes from the definition/creation of the need to its implementation.

3 Framework for Analyzing and Evaluating Servitization Potential

Based on the work of [7, 8 and 9], it was possible to obtain a holistic vision about some existent methodologies and to verify that a completed and globally accepted methodology does not exist. Thus, this research was guided with the aim to propose a new methodology for product-service systems. Under the project ServINNOV, and based on the analysis of previous literature, we proposed an analysis method for the potential of servitization (Figure 2). This global method consists of evaluating the difficulties and the opportunities that a company can encounter when developing a PSS system.

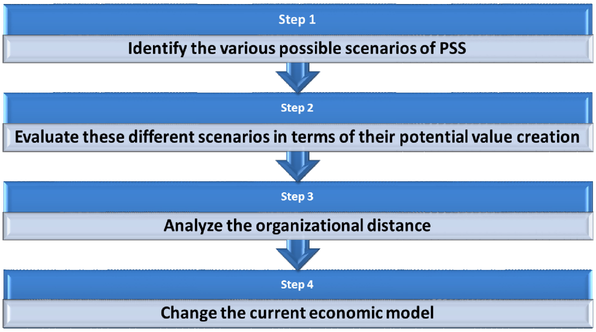

Fig. 2. Framework for analysis the potential of Servicisation

1. Identify the various possible scenarios of PSS: In fact, the first point of this method is to develop a portfolio of pertinent PSS scenarios, such as a large range of product-service systems that can be integrated in the company.

2. Evaluate these scenarios in terms of potential value creation: In this second step, the scenarios are evaluated based on certain indicators highlighted by Arnold Tukker [6] in his methodology: the tangible and intangible value for the consumer, risk provision.

3. Analyze the organizational distance between the current organization and the organization necessary for the provision of PSS: This third point is the analysis of the organizational distance of the company. To be able to shift towards this PSS portfolio, it is important to evaluate the feasibility of the scenarios. Baines and Lightfoot [10] explain that servitization is enabled by six elements: a strong leadership, informed and engaged customers, a platform for advanced services and benefiting people with humanistic skills-sets, readiness to exploit technology, a relationship-based strategic supply partnership. Based on these elements, we define organizational distance as the gap between the internal resources of a company and those necessary to its operation if its activity is modified.

4. Change the current economic model: Baines and Lightfoot [10] differentiate between the advanced services model and the base services and intermediate services model. For this one, in some instances this is quite straightforward such as when spare parts are paid for by customers at the point of collection, or when repairs are made on the basis of time and materials consumed and interim payments are made by the customer". (p. 74). The advanced services model can implicate a third partner: a financial partner who provides lump payment to the manufacturer and receives periodic payment for assets from customer. This is why we think that changing an economic model towards more services implies that the company must master its services offers even if it is not in the heart of its business.

In order to show the practical use of this method, we decided to use it on the case of Envie Loire. We willingly chose in this article to restrict the study of PSS to product and use oriented ones, even if the result oriented are the ones mostly used, but they are also more complex to develop.

4 ENVIE Loire and Servitization: Applying the Method

ENVIE Loire is a company that produces goods and services and positions itself in the competitive sale/maintenance sector of appliances. Even if its objective remains social, ENVIE is an insertion company through economic activity: the search for economic equilibrium is vital to pursue its social ambitions. However, in recent years, ENVIE's economic model was heavily challenged, especially with the emergence of hard-discounters in the appliances sector, and its financial results are in decline. In this context, the development of services and servitization appeared to ENVIE's managers as a potential field of diversification and development of its activity that is currently limited to sales of 4 large types of products: washing (washing machines, dishwashers), cold (fridges and freezers), cooking (ovens and stoves) and TV/PC.

4.1 Identify the Various Possible Scenarios of PSS

A deep analysis study conducted on the possible services for this company offered the director real elements to build upon. Therefore, in the end of 2012, the following scenarios were proposed to the director: (Table1).

Table 1. Possible service scenarios

				Washing	Cold	Cookng	TV / PC
Product-oriented services	Product-related service	S1	*Maintenance contract*	✓	✓	✓	!
		S2	*Material Recovery at the end of its life cycle*	✓	✓	✓	✓
	Advice and consultancy	S3	*Improving the manuals*	✓	✓	✓	✓
Use-oriented services	Product lease	S4	*Offer to lease with formulas more or less long term*	✓	✓	✓	✓
	Product renting or sharing	S5	*Made available materials in partnership with various organizations*	✓	×	×	×
	Product pooling	S6	*Using the materials simultaneously by users*	✓	×	×	×

✓ : Seems feasible ! : Seems complicated × : Seems infeasible

Table 1 shows a first analysis of the feasibility of these different scenarios according to the four categories of products. After the identification of these possible/realizable scenarios, we only focus in this paper on two scenarios: S1 and S4 that only concern the activity of washing.

Scenario 1 "The sale of a maintenance service for professional appliances": It is mainly a contract between Envie and a professional client — professional establishments, student residences, etc. In this type of contract, we were able to identify many adjustable parameters (the duration of the contract, the number of repairs, the number and type of preventive maintenance).

Scenario 4 "The sale of a renting service for washing machines": the studied scenario is the renting of washing machines produced by Envie. Currently, the machines produced by Envie are sold to households, but for this new activity, the targeted clients are either professionals such as hairdressers, or households who are interested in this type of offer.

It is considered as a first approach towards the integration of services at Envie, this procedure of servitization takes time to implement and must be carried out incrementally in order for it to properly function. Maintenance (S1) and renting (S4) can also be used as a reference for a potential development of other scenarios.

4.2 Evaluating the Different Scenarios Regarding Potential Value Creation

The table below summarizes the evaluation of the two chosen scenarios based on their value creation for the client (tangible and intangible), the cost for the company and the obstacles for ENVIE.

Table 2. Analysis and comparison of the two scenarios

		Scenario 1 : Maintenance	Scenario 4 : Renting
Value for the user	tangible	Increase the lifecycle of the product by replacing certain parts.	. Absence of financial costs for acquiring the device, . Pre-diagnostic telephone call and rapid intervention in case of breakdown, Repair and change of broken device . Recovery of product at the end of the contract
	intangi ble	None	Use of equipment without owning it or paying for its maintenance (client serenity when facing the unexpected)
Costs for the company	Tangible costs for the supplier	. Cost of movement of technicians (salaries, fuel, amortization and vehicle repairs) . Cost of establishing a follow up system of client interventions	. Eventual replacement (cost for purchase and stock), . Movement for installation, diagnostic, repairs, recovery, . Follow up of customer files and making appointments, availability of technicians in case of breakdown, Establishment of payment system and invoice management
	Risk provisi	None	. Managing the consequences of a deterioration (voluntary or misuse) of the equipment, . Risk of client non payment
Obstacles	For Envie	. Expertise regarding spare parts: which ones? Brands? . The intervention on parts is possible at home? Delays?	. Qualitative and quantitative procurement in material . Communication methods to advertise the renting offer . In case of problem, availability and reactivity of after sales services over the phone.

4.3 Analysis of the Organizational Distance between the Current Organization and the Organization's Structure Necessary to Deliver PSS

So, new process should be considered. The study conducted has led us to draw a map of the existing processes and the new ones that the company should develop:

1. **The prospecting process:** This is an administrative process, a research of clients for the service activity.
2. **Contract's progress**: Once the contract is signed, the payment process is launched, it depends on the fixed clauses during contract talks.
3. **Quality process**: The processes of the service activity are linked to performance indicators that are updated when implementing the activities.
4. **Procurement of parts process**: The parts are generally sent by the supplier to the shop within a period of 48h.

4.4 Shifting the Current Economic Model

A calculation tool was developed to test the different scenarios along with three subscenarios (optimistic, realistic and pessimistic). We sum up hereinafter, a part of the performed analysis on the scenario S1 (maintenance) with optimistic assumptions:

1. The fact that the number of contracts increases linearly by adding a contract each 3 months (15 contracts in March 2019).
2. Recruiting a technician is confirmed during halftime to support the shift towards 4 contracts at the same time starting July 2015.

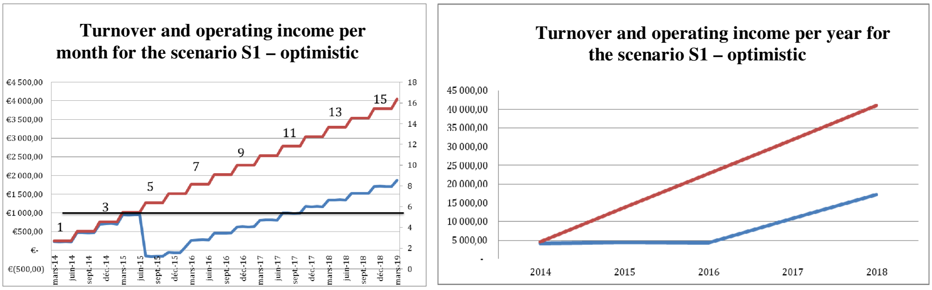

Fig. 3. Turnover and operating income for the scenario S1 – optimistic

With these graphs, we can see that the scenario is profitable because it generates a positive result during all the years of the considered period. Other scenarios were tested and analyzed and the main results are summarized in the conclusion.

5 Conclusion

Through this paper, we proposed an approach to analyze the potential of servitization which consists of identifying the different possible scenarios of PSS, evaluating these different scenarios based on their potential in term of value creation; analyzing the organizational distance and the strategic alignment of the company; and finally, changing the current economic model based on gaps identified in the previous step. We demonstrated its practical use on the case of Envie Loire. We then tested the other scenarios with the manager, this analysis showed various results:

- The difficulty for a small company to project itself in establishing services with steady means. The available means to create new services limits the number of potential clients (4 contracts at the same time)
- The development of associated services will quickly require the recruitment of a person dedicated to this activity, but this can really form a difficulty for a small company.
- Therefore, the scenarios position the services as 3% of the company's turnover, which is very little. These calculations were done based on a particular logic: take minimal risks, provide services with the existing resources with the potential of investing in additional means.

The company Envie henceforth has all the theoretical elements to know the impact of services on its organization but the development of these services can't be done without the will of the company's chief to take risks and without possibility of threatening the other activities of the company. This will require a real commercial development of services for new clients and the possibility to liberate time for the technicians to insure these services.

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Transition to Product Service Systems: A Methodology Based on Scenarios Identification, Modelling and Evaluation

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Abstract. The paper proposes a methodology to support the organisational shift towards product Services Systems. Its backbone is the evaluation of economic impact of such a shift. However, in order to efficiently accommodate organisational changes and include company specificities, other steps are required prior to evaluation. These are context analysis, scenarios identification and modelling. The novelty of the paper lies in (i) including organisational changes in the evaluation and (ii) managing the contextualization to company specificities.

Keywords: Product Service Systems, scenarios definition, economic performance, operational performance.

1 Introduction

The ever increasing customer specific needs coupled with increasing competition compel companies to continuously seek new business models. Among these are Product Services Systems (PSS) where customer demand is met by selling satisfaction instead of providing the product per se [1]. The transition from mere physical products to PSS can be seen as the evolution of product identity based on material content to a position where the material component is inseparable from the service system [2]. Goedkoop et al. [3] define PSS as 'a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models'. From this, it follows that key elements of PSS are product, services, actors and combination of products and services. The identification of the combinations that satisfy all stakeholders (i.e. network of players and customer) requires evaluation of different scenarios of product and service use, in a given industrial context.

This paper proposes a methodology to support the shift towards PSS by focusing on scenarios definition and evaluation. The rest of the paper is organized as follows: Section 2 briefly reviews literature dealing with the transition to PSS. Section 3 presents the proposed methodology. An illustrative case study is presented in section 4.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 143–150, 2014.

2 Supporting the Transition to PSS

2.1 PSS Transition Supporting Methodologies

Despite the large body of literature dealing with PSS, only a few authors addressed the question of how to shift to PSS [4]. For instance, the MEPSS (Methodology for Product Service Systems) project resulted in several guidelines supporting the shift to PSS. MEPSS provides plenty of workshop based tools intended to help companies build the PSS offer and evaluate it against sustainability criteria [5]. The mere economic evaluation is however not addressed by MEPSS. In the framework of the collaborative research project SFB/TR 29, Meier et al. [6] pointed out the importance of a solution space approach in the development of PSS rather than a single configuration. Such a solution space should be supported by a suitable organisation structure where roles are assigned to organisational units throughout the so called Industrial PSS Network. Dahmani et al. [7] proposed a framework for diagnosing the servitization potential of industrial companies from a decision point of view. Chalal et al. [8] addressed the transition to PSS at the operational level by analysing the impact of capacity management policies on the PSS performance, using simulation. Recently, Marques et al. [9] proposed a methodology for PSS development covering planning (i.e. preliminary PSS opportunities) to post-processing (i.e. preparing PSS to industrialisation) steps. Our study falls under planning and design phases of Marques et al. [9].

2.2 Requirements of PSS Supporting Methodologies

An outstanding challenge is to develop specific methodologies and tools that can provide guidelines for PSS implementation [10]. First, company strategy regarding PSS should be taken into account from the early design stages of the PSS. During the transition, companies must adapt their traditional organizational structures to cope with consumers and other stakeholders [4]. Second, it is important to involve all stakeholders in the PSS process [6] [11]. In fact, the development of the PSS recalls not only technological knowledge about products and services but also regulations and cultural backgrounds of the actors. Third, the economic viability of the PSS should be evaluated so as all stakeholders are well informed about the spins-offs and risks of the PSS. This multi-actor perspective in the decision making process has been often poorly addressed in literature. Finally, scenarios allows for putting together all pieces of puzzle: actors, products and services, thus enabling the evaluation. A scenario can be seen as a combination of product and services and actors involved. Each of the actors has a set of actions supporting the delivery of the PSS. The identification of the scenario is then a key element that shapes the organisation structure of the PSS and defines the responsibilities of the actors [11].

3 Proposed Methodology

This section describes a methodology to support SMEs transition towards PSS. Its steps are context analysis, usage analysis and scenarios prioritization, and scenarios performance evaluation (Figure 1). Steps 1 and 2 allow taking company specificities into account in a gradual way. The last step provides actors involved in PSS with good insights on the impact of the organisation changes required for delivering the PSS, through performance indicators.

3.1 Context Analysis

The context analysis consists in understanding company's industrial context and competition factors. To determine the specific PSS issues of a company, traditional tools such as the SWOT model can be used. Moreover, PESTEL is suitable tool for analysing the external macro-environment in which the company operates. Context analysis helps identifying relevant avenues to explore so as to shift from company's current offer to an integrated PSS one.

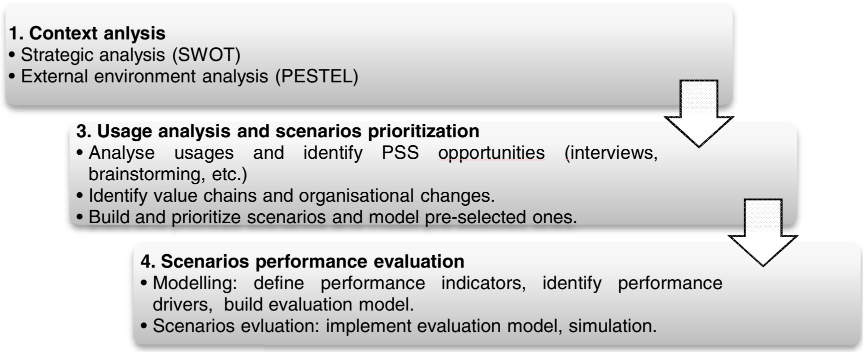

Fig. 1. Proposed methodology

3.2 Usage Analysis and Scenarios Prioritization

The objective of this step is to analyse different usages of the PSS offer in order to identify value creation potential for the customer and other stakeholders. To do so, it is necessary to characterize customer’s categories, their usages and needs in terms of goods and services and cross these usages with PSS opportunities. Afterwards, the PSS needs to be formalized by a progressive transformation of creative ideas into well-defined scenarios. These latter provides good insights about PSS value chain. Scenarios prioritization is based on involved actors experience and external factors such as regulations and customer culture. The main challenge lies in identifying activities required to deliver the PSS and assigning organizational actors to them. This task narrows the scope of the quantitative evaluation to a limited number of scenarios, thus saving time and money.

3.3 Scenarios Performance Evaluation

The rationale of this step is to build and implement a performance evaluation model to assess the viability of the identified scenarios in terms of economic and operational performances. To do so, this step consists of 1) defining performance indicators required by each of the actors involved in the scenarios, 2) identifying physical and financial flows that needs to be modelled in order to enable indicators calculation using simulation, 3) identifying performance drivers allowing for improving the viability of the scenario according to actors' points of view, and finally 4) implementing the indicators to evaluate the scenarios performance. Indicators provide information about the performance of the scenarios over different time spans (e.g. monthly basis: Sales cash flow ; PSS cash flow ; Production volumes ; Supply volumes; Inventory level ; Remanufacturing, yearly basis: Sales turnover ; PSS turnover ; Annual costs; Annual margin). Although this step provides insightful information on scenarios viability, drawing conclusions on which ones to go with is still the responsibility of decision maker.

4 Case Study

4.1 Context Analysis

The company under study has a business to business market in the field of quarry production plant. PSS opportunities concern a technical system and services using a laser video system to provide services for analysing physical properties of extracted stones. Market issues relate to the ownership of the product by customers, quality certification and potential of tough regulations. The internal strategic analysis underlines the viewpoints of different actors from executive committee. More important questions relate to 1) configuration of the offer and calibration of services associated and 2) understanding the internal required shift within the organization. Potential improvement areas of the current offer are quality analysis during the material extraction process and performance indicators monitoring.

4.2 Usages Analysis and Scenarios Prioritization (Qualitative Evaluation)

Various alternatives of the technical evolution of the product issued from several meetings with the company manager and staff. Afterwards, interviews with customers took place. During these interviews customers tell their point of view about strengths and weaknesses of current offer. Then interviewers collect customers' expectation with respect to a so called "ideal offer". Afterwards, the technical possibilities raised by the company and consistent with the client's objectives are proposed. Identification of different functionalities of the product constitutes is the foundation of the role assignment, which in turn leads to scenarios building. Table 2 summarizes the assignment process of roles to actors involved in the PSS delivery. First column represents the list of services (s1 to s6) and the main functionality ensured by the PSS, that is, analyse stone properties. Second and third columns depict the actors involved, company and customer, to which are assigned roles. Scenarios sub-columns define in which scenario are the roles executed. First scenario (1) refers to PSS contracts while second one (2) refers to sales of the mere product.

4.3 Scenarios Performance Evaluation

Figure 2 shows a simplified depiction of the modelled flows for the evaluation. Performance indicators that will be used for the evaluation are the following: PSS Turnover, Sales turnover, Annual costs, Annual margins, Remanufacturing, Supply volumes, and Inventory level. Performance indicators and drivers, and input parameters are depicted with boxes. Their dependencies are represented with arrows.

Table 1. Roles assignment in the case study

Functionality/services	Company		Custome	
	Role	Scenario	Role	Scenario
Analyse stone properties	Provide physical product ; Install Sell product Rent product	1,2 1 2		
s1. Remove dust	Supply components ; Deliver	1,2		
s2. Maintenance	Supply components ; Deliver	1,2	Use product	1,2
s3. Camera trouble	Supply components ; Deliver	1		
s4. Laser trouble shooting	Supply components ; Deliver	1		
s5. Monitoring	Deliver service	1,2		
s6. Update	Deliver service	1		

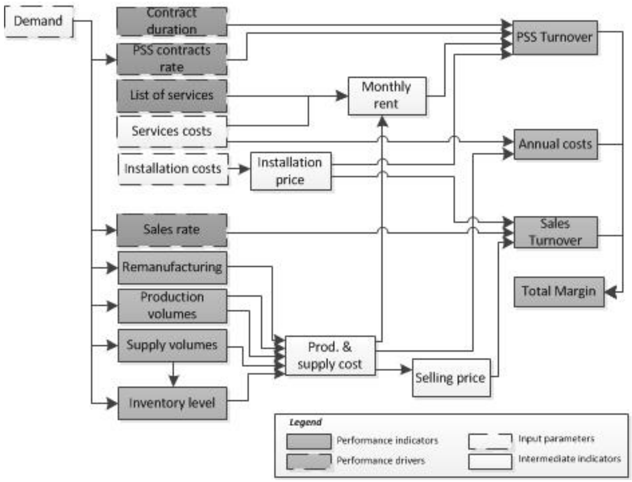

Fig. 2. Quantitative modelling

Main performance drivers are: Contract duration, Distribution of PSS and sales, and services included in the PSS contracts (i.e. content of service packages). As the distribution of PSS and sales is rather demand driven, the quantitative evaluation will only focus on contract duration and services included in the PSS offer. In order to analyse the impact of these drivers on economic and operational performance, we define two sub-scenarios as follows:

- Sub-scenario 1 (ss1): input variable is contract duration (cd) expressed in years, such that $cd \in \{2,4,6,8\}$.
- Sub-scenario 2 (ss2): input variable is services package (Pi), such that $Pi \subset \{s1, s2, s3, s4, s5, s6\}$. Accordingly, 4 situations are considered: $P1 = \{s1, s2, s5\}$, $P2 = \{s1, s2, s3, s5\}$, $P3 = \{s1, s2, s3, s4, s5\}$ and $P4 = \{s1, s2, s3, s4, s5, s6\}$.

An Excel based calculator is used for the simulation of the above scenarios. Data from the case company is gathered using interviews and internal reports.

Underlying assumptions of the simulation are as follows:

- A1: A unit of the demand is a PSS contract or a physical product sale.
- A2: The demand is increasing with 20% each year.

- A3: Demand is equally balanced between PSS contracts and sales.
- A4: Simulation spans over 10 years.
- A5: Services package is fixed at $P1$ in ss1 simulations.
- A6: Contracts duration is fixed at 2 years in ss2 simulations.

Contract duration impact analysis. Figure 3a shows Turnovers evolution according to contract duration. Sales Turnover does not depend on such a duration, which explains that it is depicted with only one curve. An interesting result is that the longer contract duration, the higher is PSS Turnover. This can be partly explained by the reduction of installation costs which are needed when a new contract is started. It can also be seen from Figure 3a that Turnover is increasing from year 1 to 10, which is explained by assumption A2. PSS Turnovers are more sensitive to demand increase than Sales Turnover. For example, about 20% of increase in the demand leads to an increase of PSS Turnover of 6 and 8 years contracts (1000K€) twice as much as Sales Turnover (500K€). Total variable costs have typically the same trend as Turnover. When examining Cash flow evolution during first year (Figure 3b), it is apparent that company faces a deficit during first months when offering PSS contracts. This deficit is mitigated by sales Turnover; however cash flow is still negative. This can be explained by (i) the fact that total costs exceed both PSS and Sales Turnovers, and (ii) the 3 months term of payment. Cash flow indicator is likely to compel company to seek financing so as to cover the deficit. In order to check the impact of contract duration on operational performance, we also use remanufacturing indicator. Figure 3c shows remanufacturing volume according to different contract durations. It points out that PSS starts to bear fruit in terms of remanufacturing, as from third year. This is expected because minimum contract duration is 2 years. Moreover Two years contracts allow for more remanufacturing, since they correspond to the highest product turnover rate.

Services packages impact analysis. Figure 3d shows the evolution of sales turnovers according to the number of offered services. An expected result is that sales turnovers and total costs increase with the number of services. Services costs are quite similar, thus the sensitivity of sales turnover is almost the same to all services (1000K€/year). In a short term perspective, increasing the number of services seems not to be interesting for the company. It could however increase customer loyalty and, thus generate economic value in the mid and long terms. Figures 3e and 3f examine the impact of services offered on the supply volumes and inventory level, respectively. Figure 3e points out an increase of the supplied volumes of components with the increase of services offered. This makes sense as most of the services consume components (e.g. maintenance, camera troubleshooting, etc.). This induces an increase of the inventory level, which is evident from Fig. 3f. These two indicators underline the need for a possible adaptation of the supply and storage capacities of the company, when implementing PSS. According to estimates of costs incurred by these adaptations, decision makers could choose to go ahead with investing more in services or simply offer small packages of services. Such a decision depends also on customer willingness to pay since the more services are offered, the more customers will pay.

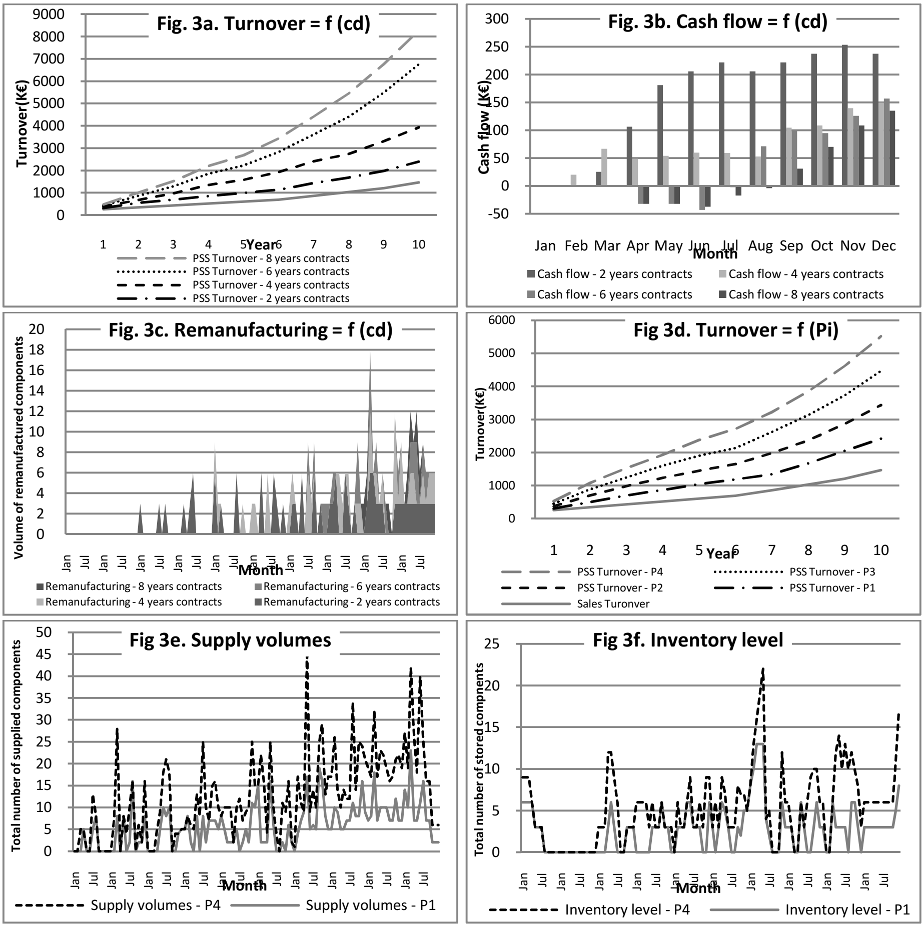

Fig. 3. Simulation results

The above results provide more insight on the PSS scenario from different perspectives. However, final decision about scenario viability still requires decision maker experience which could help prioritizing the indicators. For instance, customer willingness to pay is likely to has an important weight in the decision making process.

5 Conclusion

The proposed methodology allows for supporting the shift towards PSS through context and usages analysis, and scenarios definition and evaluation. The design of the scenario is a key element of the methodology because it summarizes creativity efforts and usage analysis into a set of scenarios. This qualitative analysis is completed by a quantitative analysis which relies on evaluation using performance indicators and simulation. The evaluation provides more insights on scenarios viability with respect to economic and operational indicators. The case study did not, however, highlight the multi-actor aspect considered by the methodology. This can be further investigated using another case study where different actors are involved in the PSS delivery. Furthermore, the methodology can be generalised by enabling the possibility to adapt the performance indicators to specific industrial contexts. Another interesting improvement avenue is the integration of environmental evaluation. This helps not only evaluating environmental impact of the PSS but also identifying possible correlations or trade-offs between economic and environmental performance of the PSS.

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Service Orientation in Collaborative Networks

Enterprise Collaboration Framework for Managing, Advancing and Unifying the Functionality of Multiple Cloud-Based Services with the Help of a Graph API

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Abstract. Nowadays, the proliferation of cloud-based services (CBS) has revolutionized the way people communicate, connect, share and eventually conduct business. Large and small and medium enterprises often adapt to this era by providing their core competence through an API. The present paper aims at describing a solution that manages, advances and unifies the functionality of the various CBS under a common framework that is being developed as a coherent graph API. Since the task of handling the evolution and complexity of the CBS API lifecycle is high, the framework is accompanied by a tool that creates a community of enterprises and developers actively engaged both in the usage of the Generic Graph APIs, but also in the update and improvement of these initial APIs.

Keywords: Web APIs, Cloud-based Services, Generic APIs, Graph API, Social Enterprise, User-centric API Framework.

1 Introduction

Since the early nineties, there has been an explosion of web pages as well as of web services. The era of the web is here with many enterprises trying to adapt and transform their businesses. Each enterprise develops its own approach to expose its services / APIs, and other companies that need to consume such services have to adjust to their requirements. Even though such an approach might have worked in the early days of the Internet, nowadays that there are thousands of available APIs, it is getting harder and harder for enterprises to keep track. For that reason they have dedicated departments only for this purpose. Even though some approaches for common practices and standards have been discussed and proposed during the years, nothing has been yet monetized to its full potential. Some of the most popular approaches are RAML [1], Swagger [2], WADL [3] and API blueprints [4]. One emerging approach worth mentioning is the Hydra [5,6], which tries to build a common description language for web hypermedia APIs utilizing the toolkit extracted by JSON-LD and semantic web.

In this paper, we describe a methodology to gather APIs from various cloud-based services that are important for enterprises, expose a common graph API for all of

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them, and provide documentation and a mocking tool to test before actually implementing their applications. Companies are given the opportunity to design, implement and verify their own APIs on top of this unifying API. In order to verify that such a framework is sustainable, we have enhanced it with a community orientation in order for companies and individual developers to directly interact with the framework, and improve it.

The whole methodology was designed and implemented as part of the OPENi EU funded project. Targeting the needs of end-users and application developers, OPENi realizes its vision for user-centric, cloud-connected applications by providing:

- To Mobile Application Users: a personal cloudlet, a single location to store and control their personal data and to realize a novel application experience, by being able to keep their user generated content and data in the cloud and further make it available across different applications on different devices.
- To Developers: an open API framework to build applications that can seamlessly integrate publicly available cloud-based functionality and content and to expand the provided API functionalities, according to their needs, with respect to the Cloudlet owners' privacy.

In section 2 of the present paper, we give an overview of the domain of web APIs and the problems that enterprises face. In section 3, we present the core methodological steps that we followed and in section 4, we describe in detail the whole approach of the framework and how this is beneficial, goingbeyond the current state of the art. In the final chapter, we conclude with a brief overview and the next steps.

2 Problem

There is an increasing discussion around the API Economy, referring to the increasing availability of APIs and making data accessible to third parties [7]. As of 1 May 2014, Programmable Web contained a listing of 11,365 public APIs [8] and is still continuously growing. Building over others' solutions puts many risks and dependencies on a business, with the main problem being that any changes or discontinuities may put more effort in tracking changes in an API, and updating an interface to it. The more dependencies there are with third party APIs, the more complex it becomes for an enterprise to handle. Some APIs are quite stable, like Twitter API reaching only Version 1.1 by 2013 [9], but with major changes in their methods too. Other services have been undergoing major changes for years, like Facebook that only recently has promised that each new API version will be supported for two years [10] and will give developers 90 days of migration; but still the version 1.0 is considered quite unstable to be supported under this plan. Some other APIs have been completely discontinued, like the TESCO API [11]. Under this growing and important business of APIs, the instability and maintenance of interfaces has become a major issue for every developer and more generally for every enterprise that builds interfaces with multiple external data resources as outlined by Jun Li [12]. Thus, a layer of abstraction that will combine multiple API resources, put them under a unique API and govern any API changes can be the solution to this growing uncertainty. A nice similar approach by Tanaka [13], even though it focuses on a slightly different point, it also outlines the importance of web APIs in the enterprise and why mashups are crucial in the industry.

Another major issue, especially for community-based businesses, is to develop early on an active community, which will provide a platform with unique content of high quality. Existing platforms have created closed silos of content, creating the hazard of a fragmented, closed world as Christian Bizer stated [15], [16]. In some cases also, some platforms have followed blurred lines towards their adoption with copyright issues, like YouTube was built over proprietary video content, Pinterest is based on copyrighted pictures that its users upload or Flipboard was based on content retrieved and filtered by common RSS feed resources. Thus, a common way to access users' data, wherever these are (e.g. their personal storage, Facebook, Instagram, Dropbox etc.), just by authorizing an application to access them, would solve the "cold-start problem" for many digital solutions. At the moment, the central point of reference, content authorization and identity management is Facebook for third party developers. A platform that would allow enterprises to build and reach collaboratively a community of users, by extending it with data structures and business capabilities not imagined before but also without locking this content for specific companies, would solve this problem in the modern world. Such notions have already been discussed in detail by Zhong [14], by explaining the complexity that such systems can carry and by proposing a methodology of how this could be handled.

Last but not least, even if there are best practices and standards about designing APIs, there are no industry-specific APIs guidelines or standards. For example, the Facebook Graph API has evolved to an industry standard in social media applications, something that sooner or later Twitter followed, but there is no best practice in e-shopping solutions. An interoperable platform can become a central point of reference and connectivity for every new API that rolls out, and if built around an open community mentality, it may reduce the costs of maintaining the web of APIs. As part of the state of the art analysis we conducted, we identified that numerous companies have built their whole business model around helping other companies designing and building better APIs. In this paper we go beyond the state of the art, designating a framework that semi-automates all this procedure in a sustainable manner.

3 Methodology

One of the major targets of OPENi is to offer an open API framework that is capable of interoperating with third party services, abstracting the integration challenges to a single open standard. To do that, the following procedure was followed:

1. Extensive analysis of Cloud-based Services with regard to usefulness, popularity, range of functionalities and used technologies. The availability of an API is considered a prerequisite for a service to be considered for integration.
2. Categorization of Cloud-based Services, upon studying similar categorization proposed by developers' reference portals as well as the categorization adopted by the biggest mobile apps marketplaces.
3. A set of Generic APIs (i.e. Activity API, Media API, Products & Services API) was created and specified based on the identified categories. These

Generic APIs will handle interoperability with any cloud-based service, abstracting the integration challenges to a single open standard without losing important service features.

4. Investigation of ways to ensure the sustainability of the Generic APIs, offering the means to enhance them, thus increasing their added value for enterprises that choose to utilize them.

From this last step the need for a new Platform, the API Builder, emerged, envisaged to tackle the following challenges:

- *Easy, semi-automatic integration of changes in CBS*: In today's rapidly evolving landscape, new Cloud Based Services are certain to appear and existing ones will possibly alter their APIs as referenced by Dig and Johnson[17], as well as by Fokaefs [18]. A platform like the API Builder, that aims to offer an abstraction of the various APIs and their partial integration into new unified ones, would lose its advantage without a mechanism to handle such changes. Alterations may appear at any level of the Cloud Based Services' ecosystem, including minor/major changes to or discontinuation of existing services, extension with new methods and appearance of new CBS.
- *Documentation*: When incorporating services provided by multiple platforms, the need to study and understand all the different APIs can be a very frustrating and time-consuming task. Therefore, the existence of an inclusive documentation for all the services in the same consistent format was considered to be of great value for the developers and enterprises.
- *Flexibility*: Not all enterprises need to offer the same services and thus not all are in need of the same API. Even without considering the possible changes in the underlying APIs, the need to extend, customize and build on top of it is evident and should therefore be accounted for.
- *Avoid duplicate effort*: The size of the market targeting the Cloud Based Services has led to the appearance of numerous products and services that utilize these 3rd party APIs, many of which required the development of similar middle components. Developers and thus enterprises would greatly benefit from a platform that allows the designation and re-use of already designed and/or implemented components, discouraging investing effort to duplicate existing work.
- *Lack of user pool*: Despite the boom of applications exploiting the CBS, many fail to establish their role in the market. The API Builder, as part of a large platform with an existing user pool, usage statistics and clear predefined privacy settings can offer new opportunities to the application developers.

Having a different API for every object would require more clients to be implemented, more calls within the platform and would ultimately increase the complexity of using as well as sustaining such a platform. To this end, graph modeling was selected as the more suitable and intuitive approach in order to properly handle the enormous amount of information that needs to be stored and also the need to dynamically extend and update the underlying schema. That is why all the OPENi created meta-model follow the Linked Data paradigm. The schema.org vocabulary has been actively indexed in a way that every API and all of its objects are mapped by a one to one relationship to a vocabulary entry.

4 Approach

Figure 1 High Level Architecture depicts the API Builder's role within the OPENi ecosystem.

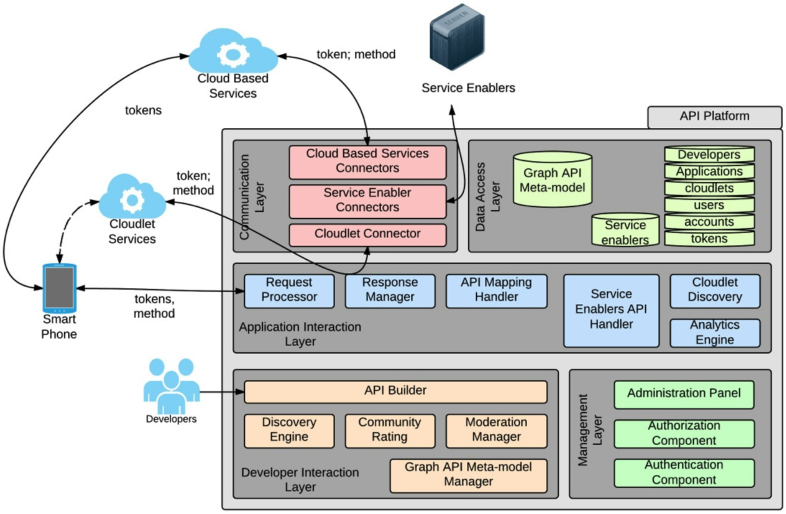

Fig. 1. High Level Architecture

As already explained in the Methodology section, it is important to sustain the Platform and make it viable. Changes are not always easy to trace automatically and for that reason the API Builder is designed as a collaborative tool for developing APIs.

The OPENi APIs provide a number of objects and methods. Changes can be handled at object, method and CBS levels, in the following ways:

- Object Creation: Everyone participating in the Builder can create new object schemas. In order to provide full flexibility, every OPENi object, either part of the initial corpus or created inside the API Builder can be used as part of another object.
- Method creation-customization: Each participating enterprise can add, remove and rename fields from existing methods as needed or even combine methods, essentially creating new ones.
- Semi-automatic integration of changes in the CBS APIs: Minor changes in a 3rd party API could be handled through the method creation and customization functionalities. For large-scale API changes, a separate mechanism should be made available to enterprises that includes code submission, review and integration phases. Similar effort has been undertaken by Taheriyan [19], trying to create a semi-automatic way to map web APIs.
- Support for integration of a new CBS: As the Cloud Based Services are part of a rapidly changing market, new services may emerge. Hiding the unnecessary complexity from the enterprises is a key feature of the API Builder, but the

integration of a new CBS is not expected to be provided as a fully automated process by the API Builder. To integrate the API of a previously unsupported Cloud Based Service, separate changes will be required including code submission to the OPENi repository, additions to the documentation and extension of the underlying graph schema. Excluding any of these steps will leave the OPENi platform in an inconsistent state. To avoid that, the API Builder should provide developers with an intuitive interface that guides them through the completion of the necessary steps, enforcing the correct procedure flow, while in the background checking if the proposed changes should be made in the underlying model.

To achieve efficient exploitation of the provided functionalities which are aggregated from the OPENi cloudlet platform and from 3rd party APIs, enterprise developers are in need of sufficient guidance. That is why extensive documentation is provided through the Builder's UI for all the exposed services.

The Builder greatly depends on its community of developers to actively participate and take advantage of these mechanisms in order to keep the API framework up-to-date, functional and intuitive. As pointed out by Pankowska in [20], the authority of a collective community increases sustainability. For that reason, the API Builder is designed to offer a number of social networking functionalities.

It should be noted that although sharing objects and methods within the community is strongly encouraged, an enterprise might choose not to disclose its work. However, the envisaged collaboration network is expected to help developers deliver the required product in less time which ultimately translates into profit for the enterprises. The collaboration mechanisms are adopted for two more reasons.

First, any API that exists in the platform is also exposed for validation as well as feedback to the community. If a useful component is implemented, it is expected to gain high score and thus be more easily detected and re-used, which can serve as a first level of duplicate effort avoidance. To further empower this methodology, a recommendation system is used for suggesting objects and APIs to a developer interested in building a new application on top of the OPENi ecosystem [Figure 1].

The second reason is related to the smoother adoption of applications that interact with the API Platform. Since developers reuse the schemas that others have used, some data conforming to the first schema probably already exist in some users' storage (cloudlet). That way, the new application can directly utilize this data, as far as this is allowed by the user's privacy settings. Within the OPENi Framework, clean privacy rules have been of primary importance and users' data are stored and treated with respect to the desired level of privacy. It would thus be easier for users to trust these applications, as they are guaranteed to follow well-known practices concerning data privacy.

This can prove to be essential for the community of applications, because especially in the early stages a large community of users cannot be ensured. With the proposed procedure this is not important since we facilitate reusing preexisting information and do not allow for silos of data within the framework.

Enterprises could also benefit from the provided API usage statistics in order to gain insights about the utility of the implemented APIs but also their popularity which could disclose new trends.

5 Conclusions

A paradigm shift in enterprise-centric design of business applications is emerging based on the proliferation of APIs that play a pivotal role in a thriving API ecosystem by unlocking latent value in data and information of cloud-based services. With the purpose of supporting easy integration of a broad spectrum of existing cloud-based functionality in a platform-independent way, a framework supported by a tool has been shaped. This framework takes into account the various usages that companies may find for interacting with the CBS and the needs of those when coming to collecting information for analytics or in general collecting information. Those issues when coming to providing a generic method for interacting with existing APIs as well as handling the data privacy issues and all the complexity that comes from interconnecting privacy restrictions at different layers and portions of data, have been delivered in this framework. A step further is also taken by providing a community of developers collaborating with the enterprises in creating APIs and dealing with the complications.

The OPENi platform provides an added-value approach that aims to tackle the diversity of the above-enumerated challenges. Its architecture and implementation are both motivated by the research challenges addressed in this paper. It is a place where enterprises and developers can confidently cooperate into constructing better APIs by improving the developing API lifecycle and reducing the privacy complexity issues as well as the tracking changes effort.

As next steps, we are going to have a deeper integration with hypermedia API description standards, enhance interoperability with enterprise systems and validate our approach in the domains of advertising, shopping and personal data management. As an ultimate goal, it would be favorable to have each API provider to have their API described directly within this framework and improve it with any new changes.

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Orchestrating New Markets Using Cloud Services

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Abstract. This paper examines the needs of SMEs for services that enable the key business functions required. Through a series of semi-structured interviews with 30+ SMEs, it is concluded that the services required varied in importance depending on the size and stage of development of the SME. As a result, the key IT requirements for operations in SMEs were developed and a suggested list of cloud-based applications to deliver them through a city cloud service was derived. A good initial point for these Cloud services is to provide a set of common services for SMEs to utilise that enhance collaboration capability. This paper presents the architecture of a set of cloud services that can, via a City Cloud, enhance and boost economic activity in the City Cloud region. Significant elements of the architecture have been tested and key results are presented.

Keywords: SMEs, Business Processes, Cloud Services, City Clouds, Business Clouds, New Markets.

1 Introduction

Within the field of Information Technology (IT), every so often a new approach appears which promises to change the way businesses operate and function. Cloud Technology is possibly such an approach. This wide ranging paper brings together a number of ideas to propose a novel model for orchestrating new markets and driving economic growth in a region

Cloud computing has been defined as “a model for on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.” [1]. Over six hundred articles that discuss cloud services and their applicability have cited this definition. Using a terminology more suitable to small businesses, this research understands Cloud Computing as a new general-purpose Internet-based technology through which information storage and IT services (applications, network and bandwidth) are provided to customers in a “pay as you go” model. Cloud Computing can allow SMEs to focus on their core business rather than worrying about applications, server updates, computing issues and IT maintenance. This paper is split into two main areas of investigation:

1. How does the use of different business applications vary with the size of the SME (section 2);

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 161–168, 2014.

2. In a Smart city cloud, what other applications would be required to enhance economic growth (section 3&4).

A number of projects such as the EU Platform for Intelligent Cities (EPIC) or the joint EU and Japan "Cloud of Things for empowering the citizen clout in smart cities" (ClouT) have been undertaken. Yet rarely is there a focus on using The Cloud to enable and enhance the SME economic activity in a City region. A few cities such as Honolulu (USA), Edmonton (Canada), Geraldton (Australia) have implemented city cloud services but have not focused on enabling SMEs. Dongying in China is building a City cloud computing platform as a government/business model. However, the business aspect is largely focused on the Oil industry supply chain. This lack of focus on SMEs seems to be a major oversight to the authors. It is SME skills/capability and the business activity they enable in a region that services larger businesses and thus helps fund other services such as transportation, energy and health. There are many cloud service providers advertising their cloud applications to SMEs to help them run their business processes. Various approaches are described in the published literature [2] to guide SMEs on either the preparation to migrate to a cloud platform or the implantation of cloud services in their business. These services, however, do not emphasise the benefits from increased collaboration that would arise if all the SMEs in a region used similar business applications.

In the new and fast growing area of Smart Cities and their application of cloud technology, a discussion theme on how cloud services could be used as a utility to support a wide range of SMEs and drive collaboration and economic growth is necessary. More crucially, such services could enable and extend the business collaborations on which SMEs increasingly depend [3]. The ability by SMEs to lower cost but easily access additional capability and address new opportunities via the cloud would be a key driver of economic growth. SMEs aggregating capability through collaboration can open new markets and better satisfy local ones. This issue is discussed and a cloud model is suggested for a cluster of regional SMEs.

2 SME Functionality Requirements

Primary and secondary research was conducted to identify the ICT application requirements of micro, small and medium SMEs.

If the value-adding activities of an SME are identified, suitable cloud applications can be matched to the value activity. Adoption of IT services in the value chain by SMEs has been discussed by several researchers such as [4-6]. Research done by [7] summarizes the ICT usage by SMEs in fulfilling their business value activities. Their results are shown in Figure 1. Bharati *et al.*, [5] emphasises more on the firm size as a factor in adoption of ICT tools by SMEs in their value adding activities. Many researchers [8, 9] have discussed that technology adoption varies according to firm sizes. They discuss that the smaller the firm, the less likely for it to adopt complex ICT tools such as ERP, SCM and CRM. However, there are a few researchers who oppose it. Several authors have stressed that firm size is not a reason for varied technological adoption between firms [10-12]. To validate whether firm size does or does not matter in technological adoption between firms, the authors conducted semi-structured interviews with a sample of SMEs in the West Midlands region of the UK. The interview results are summarised in Table 1 which identifies the business capability required and the extent of usage by company size. The results align with the literature discussed earlier except for CRM. It was also confirmed that the more complex the ICT tools the less likely they are to be adopted by micro SMEs. It may be concluded that all SMEs need similar IT tools but the degree of application of the IT tools depends on the firm's size.

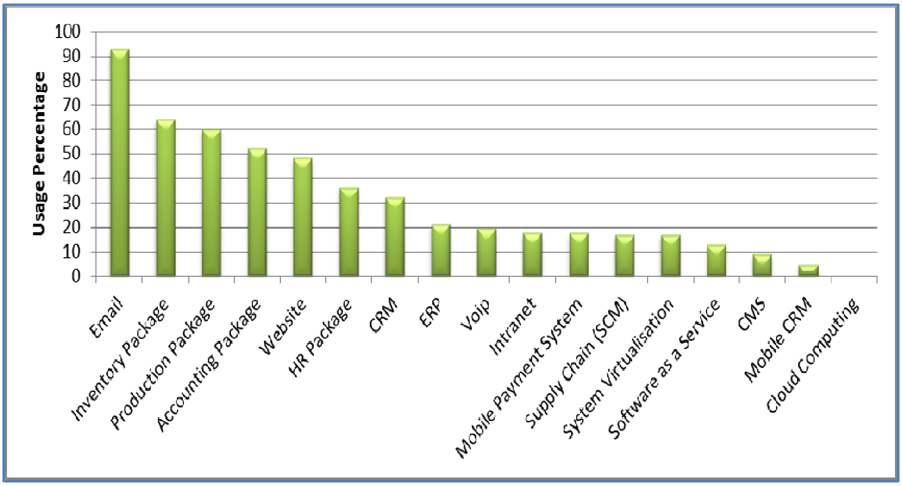

Fig. 1. ICT usage in SMEs (sample size 300)

Table 1. Business Process corresponding to the value activity based on SMEs size

Business Process	Value Activity	Usage in Percentage
Accounting and finance	**Firm Infrastructure**	**Medium (100%) Small (92%) Micro (69%)**
Website, e-Commerce, CRM	**Marketing and Sales**	**Medium (78%) Small (64%) Micro (70%)**
Production Planning, Inventory Management, Knowledge management, ERP	**Operations**	**Medium (67%) Small (40%) Micro (31%)**
IT Asset Management, Application Development	**Technology Development**	**Medium (67%) Small (50%) Micro (44%)**
Human Resources	**Human Resource Management**	**Medium (67%) Small (25%) Micro (11%)**
Supply Chain Management	**Inbound & Outbound Logistics**	**Medium (33%) Small (42%) Micro (22%)**
Electronic Procurement	**Procurement**	**Medium (67%) Small (20%) Micro (11%)**
Communication, File Sharing, Email, Data Storage & Backup, Database	**Others**	**Medium (92%) Small (74%) Micro (74%)**

3 Collaborate to Compete

Seth Godin [13] shared this insight: "*The dramatic leverage of the net more than overcomes the downs of the current economy. The essence is this: connect. Connect the disconnected to each other and you create value*." The issues for connection for a cloud architecture were summarized into four categories by [14] and are listed below:

- Interoperability of data between different applications should be allowed inside a single cloud environment
- Exchange of data between applications across different cloud providers
- Software programs should be able to connect and integrate data between multiple cloud environments
- Migration of cloud application and data from one cloud provider to another.

This proposed model is taken to next level where Internet Service Providing (ISPs) SMEs, which develop IT solutions, and SMEs that need IT solutions are brought together onto a single cloud platform. This provides a market for both ISPs and application consumers to operate their business on a single platform. The principle of developing applications by SMEs for SMEs that use this platform are supported by [15, 16]. This requirement justifies why "Google Apps for Business" applications were recommended for SMEs. Google "Apps for Business" links Application users with application providers in a common framework as required by the Open Cloud Manifesto. Such architecture makes collaboration between SMEs technically easier, but by itself does not provide business drivers to increase collaboration between SMEs. To overcome the incompatibility issues shown in Figure 2a and to provide the business drivers to increase SME collaboration, the authors propose a framework where the IaaS and PaaS are standardized by using a single IaaS and PaaS provider. The suggested architecture will be hosted by a city or a regional cloud and supported by a network of IT and human services to drive business activity through enabling collaboration.

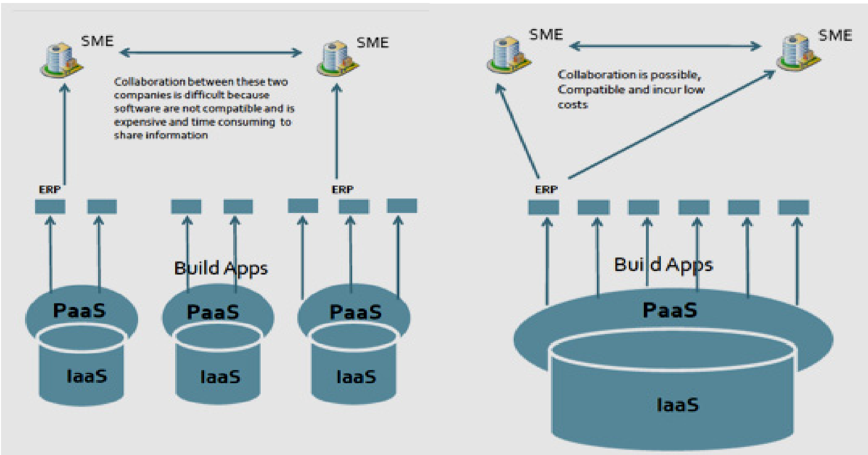

Fig. 2a **Fig.** 2b

Fig. 2. Open City Cloud Model

One key conceptual and business change required to make this happen is to describe business in a different way. Typically businesses describe themselves by the products they make and thus the sectors they are active in. For the last ten years the authors have been testing the benefit of SMEs describing their competence and capability instead, and having that validated by an independent body. Figure 3 shows an example company description that lists among other things, the processes, machinery and skills a SME has. A full list for many companies can be seen by searching the directory at www.wmccm.co.uk. Fig 4 show a view of a group of such rated companies in a City region based on their core competencies. The resulting business benefits and thus drivers for collaboration from providing such descriptions for a group of companies are (based on experience with our regional portal):

1. City Capability visible to the World increases business opportunity for individual SMEs – in our experience 3-5 times more business enquiries.
2. Common set of Business Apps eases/increases local collaboration
3. Business Operating Costs Lowered – switch capital costs to revenue costs
4. Entrepreneurship Success Rate increases – Out of 97 start-up business assisted there was an 84% survival rate four+ years later.

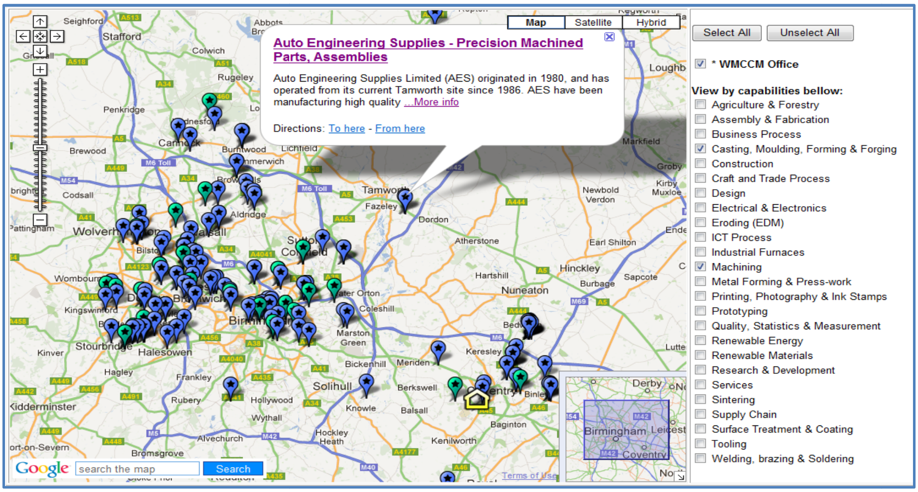

Fig. 3. Competency Map for Casting, Moulding, Forming and Forging capability in WMCCM

4 Orchestrating New Markets

The architecture described above achieves benefits by lowering the cost of access and enabling and driving collaboration through improved visibility and access to higher value business opportunities.

The authors have developed and run a portal (www.wmccm.co.uk) for SMEs in the West Midlands region of the UK to help test some of the concepts discussed. The Portal provides services to help business attract more business opportunities, and to partner in order to address these opportunities. The key enablers to this are:

1. Providing a trusted description of what these SMEs CAN do. This does not mean listing their current product and services, but listing the key processes and machinery they have and their level of expertise in utilising them. Most other SME business portals list the products.
2. Providing a feed of higher value tender opportunities.
3. Providing a partnership formation function to quickly form partnerships to address the high value tender opportunities based on capability and cultural fit.
4. Provide secure online collaboration spaces for partnerships formed.

The current system has a SME membership of about 12000 and these SMEs win business of the value of the order of 6Bn Euros each year. The success rate of new ventures supported through the Portal is significantly higher, for example 84% of new ventures still operating four plus years after their formation.

The authors can also identify a number of additional services to support the City Business Cloud model. These include business benchmarking and improvement services to drive SMEs performance improvement, access to tender and tender bid support services, and access to a local Experts register. The full architecture of common business services to be provided by a City business cloud based on the authors experience would be as shown in Figure 4.

With the addition of the proposed architecture to the open cloud for SMEs discussed previously, the authors can see a business environment where:

1. The City's budget can be spent with local SMEs, because local businesses can now collaborate to provide scale/capacity and full capability. Normally these types of tenders would go to national businesses, many of whom are not locally based.
2. Benchmarking reports would allow SMEs to assess their processes against best practice and drive performance improvement.
3. External access to the capability of the city's SMEs would draw in extra business opportunities (our experience with the WMCCM portal suggest 3-5 times more).
4. Substantial opportunities for import substitution would arise, through the orchestration of capability to address opportunities in the region and in other regions.
5. Local expertise would we captured through a experts register, that would include retired people and would act like a City Knowledge base.
6. SMEs move into new markets based on their capabilities. An example is a local car seat making business that is now a major supplier of body piercing jewellery. The common capability is the ability to bend and join wire precisely.
7. Collaboration with other City clouds in regions with complementary markets is eased. For example WMCCM companies are in a region with major automotive industry support capability, other parts of the World have major automotive assembly industries but little support industry e.g. Port Elizabeth in South Africa.
8. We expect emergent behaviours and business models arising from the environment created, which are largely unanticipated. For example a "broker" class of intermediary may well arise that orchestrate capability using the city business cloud to address new business opportunities. (Our experience from WMCCM).

This represents the current state-of-the-art in SME enablement through a city cloud in the authors opinion, based on their ten years of experience with the WMCCM system,

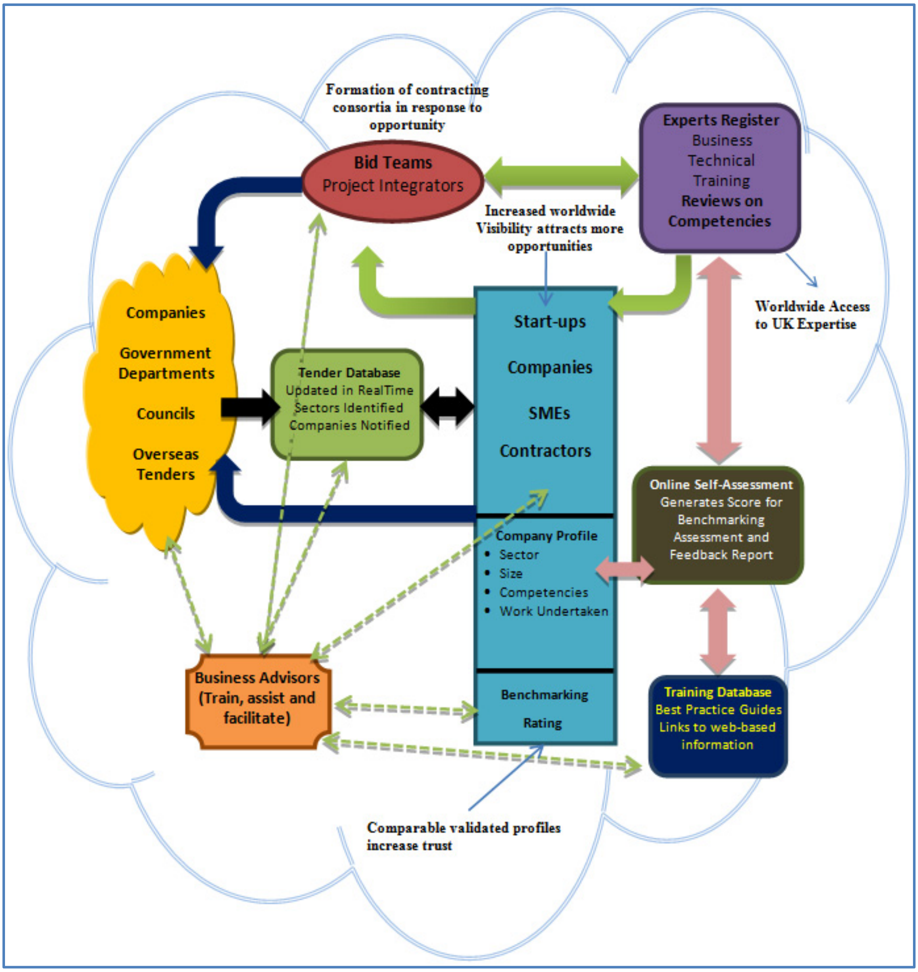

Fig. 4. Architecture for a Smart City Business Cloud

discussions with a number of cities looking to implement city clouds and recent experience of working with Inner Mongolia University and the Singapore A*STAR research organization where efforts to map and monitor business capability are underway.

5 Conclusion

This paper builds on and integrates a number of concepts derived from literature and practical experimentation. The benefits of collaboration to SMEs in order to increase their higher value capability and capacity, is key focus. Barriers to collaboration can be many but a key one is often incompatible systems. This is a major problem as they often do not have the IT skills or financial resources to address this. This paper identifies the core functionality needed by SMEs as they grow and suggests a set of cloud application that are best suited to help them grow through collaboration. A group of

SMEs using common systems within a cloud business support architecture, as suggested in Figure 4, can power economic growth in a City cloud. This has been partially tested by a regional portal, the West Midlands Collaborative Commerce Marketplace (www.wmccm.co.uk), where 12000+ SMEs win business worth more 6Bn Euro. A key feature of such a service is a focus on capability not on products, as is normally the case. Through combining capability, SMEs in a City cloud, can address new higher level opportunities, and create new local capability. As an example WMCCM generated a capability to build toilet modules for railway carriages when none existed in the region previously. Further research with WMCCM, Singapore and in Inner Mongolia is being undertaken to validate the full model.

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An Innovation Model for Collaborative Networks of SOA-Based Software Providers

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Abstract. Software industry has become a very important sector, mostly comprising SMEs. New ICT paradigms have arisen to face new challenges of the economy, namely the Service-oriented architecture (SOA). SOA has the potential to leverage SMEs to new degrees of competitiveness. One of the most relevant drivers for that is innovation. However, SMEs use to be very limited in their resources, and both innovation and SOA are complex, costly and risky. This paper presents preliminary results of an ongoing research towards developing an innovation model that relies on collaboration, enabling software/SOA providers to work as an open network and hence to jointly carry an innovation out. This is important as SOA/software/services sector is very different than manufacturing, to which most of the innovation models are devoted to. The proposed model also identifies the most relevant supporting issues that should be taken into account along the innovation and collaboration processes. The model is presented as well as its rationale. Final considerations about the work are presented at the end.

Keywords: Collaborative Networks, Innovation, Software Services, SOA.

1 Introduction

Software industry has become nowadays a very important sector. One of its characteristics is that its companies are by far composed of micro, small and medium sized enterprises (SMEs). In Europe, for instance, there are more than fifty thousand SMEs within the ICT sector [1]. SMEs, however, use to have enormous difficulties for engaging general assets to feasibly invest on innovation, infrastructure, growth, training, development and supporting professionals with acceptable risk [2]. Therefore, it is crucial to develop competitiveness models that can allow ICT companies to take advantage of more recent ICT and organizational trends in a sustainable manner.

A number of more recent ICT paradigms have emerged with the potential to leverage that. This paper deals with SOA (Service Oriented Architecture) paradigm. SOA has introduced a new outlook on systems design, development, integration and servitization, provided under a number of architectural, accessing and software business models. In the SOA vision, all system's features are seen as independent and self-contained software modules – called software *services* – that jointly form virtually

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a single logical unit to create products and processes. There are some technologies for implementing services-based systems, being *web services* the most used one [3].

Reports anticipate a SOA market of $15 billion dollars in 2019, involving an increasing number of emerging enterprises and variable business models [4]. In spite of its potentialities, SOA *per se* does not guarantee companies sustainability, so other aspects are required. One of them is innovation. Rosenbusch et al. [5] and Li et al. [6] point out that software innovation is a key aspect to increase SMEs competitiveness.

However, SOA projects are complex, risky, costly and unique, impacting companies (both customers and providers) at many dimensions [3]. SOA deployment also demands several complementary issues that are often provided by partners from larger ecosystems, depending on general business requirements and existing local (at customers and/or providers place) ICT supporting infrastructure and legacy systems.

Therefore, if SOA is intrinsically complex but on the other hand it is a clear trend in terms of business sustainability, how innovation can be leveraged and supported ?

This paper exploits the premise that SMEs of SOA software services providers can mitigate such barriers if they collaborate more intensively with each other. By SOA providers it is meant companies that develop and own (web) services and supporting software services that are able to be composed into more aggregated SOA solutions.

Collaborative Networks (CN) has arisen as a prominent paradigm and supporting foundation to implement strategic alliances grounded on more intense and fluid collaboration among organizations. Its essentials relies on allowing organizations to keep focused on their skills and aggregating competencies and diverse resources with other organizations – so creating networked organizations – in order to offer products with higher value to meet businesses in a better way [7]. This strategic decision can endow them with the possibility of innovating together, developing novel or gathering existing services and solutions from other companies to more effectively and flexibly attend to new/more demands and wider markets. This can provide more valuable and innovative SOA assets for variable customers regarding an increasing need of customizations while ROI and services reuse are maximized [8].

Nevertheless, working collaboratively is not simple. Companies are heterogeneous and autonomous, so their different strategies must be accommodated and interoperate regarding their different priorities and trade-offs in terms of acceptable risks, trust and benefits [7]. Therefore, how can SOA providers innovate collaboratively?

It is important to highlight that a SOA/software product has many differences when compared to manufacturing sector/product, like e.g. development stages and methodologies, supporting constructs, physical deployment, SLA treatment, software quality, and product contracting, access and usage [9]. Yet, development processes also have particularities when a SOA project is carried out collaboratively [10].

A sort of networked-based innovation models have been proposed by many authors. However, none of them are devoted to SOA/software sector and whose services' providers are autonomous SMEs that can participate in all phases of the innovation process, collaboratively and as a network, sharing benefits, costs and risks. Besides that, most of models are very abstract, without providing more detailed processes and even less for a collaborative SOA scenario.

This paper shows preliminary results of an ongoing research which aims to contribute to face this gap, presenting an innovation model that deals with those general requirements. It has been conducted as a research-action, qualitative, deductive and applied work, strongly grounded on literature revision.

The paper is organized as follows. Section has introduced the problem and research goals. Section 2 presents the review of basic foundations. Section 3 presents a review of the state-of-the-art in the tacked problem. Section 4 presents the proposed model. Section 5 provides a summary of the achieved results and next steps.

2 Basic Concepts

This section presents a much resumed description of some of the main core theoretical foundations that have been used in the conception of the proposed innovation model: *innovation models; collaborative networks,* and *governance*.

2.1 Innovation Models

Literature presents several definitions for innovation. This paper adopts the OECD definition, as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [11]. It is of interest of this paper to focus on the *product/good* type of innovation.

By innovation model it is meant the general conceptual construct that helps an organization and its actors to carry out an innovation (adapted from [12]). The literature presents an extensive set of innovation models. In essence, they basically describe the main phases and general processes necessary to carry an innovation out along and typically via a so-called *funnel*, namely: selection and/or generation of ideas, concept development, concept evaluation/selection, concept design and specification, implementation and exploitation (adapted from [13]). The intention is that these processes can be instantiated and particularized for any domain and case.

Innovation models have evolved from linear models to network and open models, which can go back and forth through each phase (*stage*). Evaluation actions (*gate*) use to be added between each stage so releasing or not the process continuation. Processes can be performed sequentially and/or work in parallel. Different actors can be involved along the innovation process' stages, being intra-organizational members or external partners, and even customers [14].

Regarding this paper's goal, two innovation models are of particular relevance: the *Network* and *Open* innovation models [12]. Roughly, the Network model considers an open environment composed of companies prepared and willing to work on an innovative idea when it comes up. Processes and operating rules are set up accordingly. Open innovation focuses on a new logic based in openness and collaboration. It has been often adopted by large corporations that have the innovative idea reasonably well clear and looks for some complementarities and added value in some processes or product's parts. This can come from established partners or from wider ecosystems.

2.2 Collaborative Networks

CN is a general concept that embraces the diverse manifestations of collaboration among organizations. This involves the structure, behavior and evolution dynamics of networks of autonomous entities that collaborate to better achieve common or compatible goals [7]. Two of them are of particular importance in this work: VO

(*Virtual Organization*) and VBE (*Virtual organization Breeding Environments*). Generally, a VO can be defined as a temporary alliance formed by autonomous and heterogeneous organizations that join their complementary core-competences and resources to attend to a given demand, dismantling itself after all its legal obligations have been accomplished. During its lifecycle (*creation, operation, evolution* and *dissolution*) new members can get in and existing members can get out from the VO.

VOs are mostly originated from long-term alliances, namely a VBE. A VBE in turn formally groups organizations aiming at primarily creating VOs with the most adequate partners in a more agile and trustful way, thanks to enough pre-conditions as well as basic and common operating rules for collaboration which are set up when its members get into it [7]. A VBE is classically seen as a closed world, not supporting at all larger and open digital business ecosystem, i.e. a scenario where other VBEs, other CN, independent actors and even selected customers might be involved in to cope with a joint software business. Adaptations in the VBE concept towards handling that more ample scenario have been proposed, as the *Federation* concept [8].

Having in mind the envisaged collaborative innovation environment, this paper focuses on how SOA providers SMEs belonging to classical or extended VBEs can form a VO to jointly innovate.

2.3 Governance

Governance in Networked Enterprises can be defined as "the definition of rules, criteria for decision-making, responsibilities, and boundaries of actions and autonomy for the involved actors. It is created by the own set of organizations to regulate itself. The fundamental role of governance is not managing, but rather to delimitate the management. Actors can use their knowledge within the defined governance framework in way to help organizations to best reaching their common goals [15].

During the collaboration life cycle companies share assets and sensible information. However, they are independent enterprises and have their own business strategies, creating a complex and intrinsically conflicting operating scenario. Therefore, it is extreme relevant to properly govern that in way to minimize conflicts among all the involved actors and hence the risks for achieving the innovation goals.

Networked enterprises governance have to consider two dimensions: one related to the coordination of the economic activities, and another one to the network structure and the coordination of its activities [15]. The essential rationale of these dimensions is that the market, the given business and power (in a broad sense) influence directly the way a network should execute, monitor and manage its processes and all related information, and hence on how it should be internally organized to correctly and efficiently respond to that.

In the CN perspective, a VO embraces different partners, with different roles and so rights and duties, according to the business' profile, VO life cycle and the VBE-like/network's principles, bylaws and rules. This should be regulated by the VBE-like and VO governance models [16].

Regarding that the focus of the proposed model is on the innovation processes, the issue of IT or SOA governance [17] is seen as very important but treated at another level, orthogonally along the second funnel's process (see next).

3 State of the Art Review

SLR (*Systematic Literature Review*) methodology [18] was applied to support this review. It involved the *IEEExplore, ACM,* and *ScienceDirect* scientific databases, collecting papers written in English and published in journals and conference proceedings in the period Jan 2000-Feb 2014. This task was complemented with some *ad-hoc* searches over the Internet. It also comprised a search at *CORDIS*, the EU research projects database. A special attention was put on trying to identify the ones which dealt with SMEs and the software sector.

Any work has been found out after the search which dealt with the envisaged open *and* networked-based innovation model *and* devoted to SOA & software providers. On the other hand, 5 papers and 6 projects presented more useful insights for the proposed innovation model, its processes and constructs.

In terms of papers, in resume, Du Preez et al. [13] have devised an innovation model for products and general services (i.e. not for *software* services) identifying the most important required macro processes. Berre et al. [19] have proposed supporting languages to express the value delivery and services chain for the general area of services. Hoyer et al. [20] have stressed the obstacles that SMEs face when collaborating towards jointly handling e-business transactions as well as some important constructs and issues to support that collaboration. Belussi et al. [21] have proposed a framework and typology to understand the services (but not software) innovation as a wider and multidimensional evolutionary process, thus helping to better realize the amplitude of the services concept. Li et al. [6] have proposed a model driven collaborative development platform for SOA-based e-business systems. However, they neither focus on supporting innovation nor performing that development within a network.

In terms of EU projects, *BIVEE, ComVantage, IMAGINE, CoVES, Laboranova* and *PLENT* [22] have tackled innovation at different perspectives and levels, fundamentally devoted to manufacturing sector, some considering the open innovation model, some don´t. Anyone has applied the network innovation model and/or more directed to software or SOA sectors.

4 Proposed Innovation Model

4.1 General Requirements

In general, the envisaged innovation model intends to endow groups of SOA-related and supporting software SMEs (belonging to a federation-like ecosystem) to carry an innovation out towards providing a (SOA) software (product) solution to attend to a given request. In order to devise the model and processes, this general vision was decomposed into more specific requirements. Such requirements were elicited considering the various foundations and literature review roughly mentioned in the previous sections. The general requirements currently considered are:

1) Companies are autonomous and geographically dispersed SMEs;
2) Companies are SOA software services providers;
3) The ‘product’ is a SOA-based software, composed of several existing web services, or of web services that need to be developed from scratch or as newer/different versions;
4) A SOA solution can be either a unique software for a given customer or a more general solution that can be further configured to customers;
5) Different companies own services or are in charge of developing such services;
6) This ownership should be protected and duly accounted;
7) Each active web service and its supporting infrastructure/interoperability can be developed / provided by one or by some software companies or ad-hoc supporting partnerships;
8) Companies can come from different, wider and open digital business ecosystems. They can belong to one or more long-term alliances, or can be completely independent companies;
9) Companies that will participate in the innovation process should be properly selected;
10) Companies may participate along the entire innovation process and software development life cycle, depending on the agreed roles, rights and duties;
11) This participation, the stage in that, and the decision power should be coordinated and regulated according to the given business/innovation needs and general constraints;
12) Companies may/can/should enter to, operate in, and exit from the collaborative innovation network in different moments and number of times, both in the normal operation of the network and when problems, changes or severe conflicts take place;
13) The innovation process and companies’ performance should be managed and measured, and web services quality should be certified.
14) The innovation process can be triggered both on customer request and prospectively (by one or more federation’s companies). This can have the aim of attending foreseen new businesses, or of coping with initiatives to improve an existing SOA ‘product’ or part of it;
15) Regarding the intrinsic nature of software services development process, there is not a simple progression, being often necessary going back to earlier stages to overcome difficulties or need for revisions.

4.2 Basic Rationale

The model’s structure takes the “classical” macro processes proposed by Du Preez et al. [13] into account (section 2.1) since they can comprehensively embrace the general processes considered as necessary for the envisaged model. Processes’ names and sub-processes were however adapted to better reflect their core role regarding the intrinsic nature of SOA/software development processes and life cycle (which are different than e.g. the manufacturing sector and its processes, as depicted in [9]).

The ecosystem is not completely open so interested companies need to have some degree of preparedness to be part of it as well as they need to respect some common collaboration/operating rules and ethical principles, as proposed in e.g. [7].

Regarding that SOA and supporting software providers have web services assets and related expertizes, it is important that the interested ones can have the possibility to propose ideas as well as to participate in discussions and initial analyses. Once the idea is approved then selected companies can carry the innovation out. It is important that all necessary expertizes can be joined, covering the diverse dimensions involved in software innovation, such as legal, financial, commercial, technological and software engineering. This should consider not only the innovation development itself but also the *after sales* phase as SOA products require further assistance and maintenance of several types and intensities.

Regarding the OECD's chain-link model [11], the proposed innovation model is focused on the development of the (SOA) product itself, from the initial ideas exchange to its final delivery. It assumes that market analysis and prospection have been done as well as the decision for being a (total or hybrid) SOA-based product solution has been taken. Yet, that the distribution of the SOA product (in the case of local deployment) and sales/after sales related issues can be up to partners other than the ones involved in the innovation development itself.

4.3 The Innovation Model

The model is showed in Fig 1. It also uses the abstraction of the funnel to represent the multiple ideas going through evaluation phases in a process of funneling and filtering (from left to right) so that only the approved ideas go to be developed.

Inspired in a large cleaning supplies multinational case (although with a different purpose), the classical one-funnel model was split into two funnels. This means that the whole innovation process is performed along two sequential but somehow decoupled macro phases. Whilst the first funnel aims at last to support the discussion and selection of the best ideas and the definition of the respective members of the innovation network (i.e. a VO), the second one aims to indeed develop the selected innovation(s) inside the formed VO(s). Processes and nature of discussions, type of knowledge, information flow, type of responsibilities, etc., are intrinsically different in each funnel. Regarding that, the innovation behaves more like as *network* type (see section 2.1) inside the first funnel and more like as *open* innovation type in the second funnel. In terms of governance model, while the *all-ring no-core* and *buyer-driven* models [23] [24] tends to largely prevail in the first funnel, this tends to be more *core-ring with coordination firm* and *information-driven* in the second funnel, although much dependent on the current business rules.

In both funnels the innovation can move forward and backward. However, this tends to happen much more frequently in the first funnel due to the natural not so structured way of exchanging more abstract and business ideas towards more concrete plans. On the other hand, this tends to be more controlled in the second funnel, based on the results evaluation performed in the intermediate gates (illustrated as "vertical lines" separating the processes within the funnels) to decide if the whole process can go on or not (in broad terms). Therefore, in general terms, it can be said that a more human-driven approach tends to predominate in the first funnel (using techniques like *Design Thinking* and *Canvas*); and a process-driven approach tends to prevail in the second funnel, where the (software) development process is usually better defined and more structured. The entrance and exiting of partners to/from the second funnel is much more fluid than on the first one, whose composition is basically formed by the federation's members. As such, there are different notions of budget, time and human resources allocations, of IPR constraints and legal issues, of governance policies, the role of research, the involvement of existing or the creation of spin-in and spin-offs to exploit intermediate or different facets of the final outcome, and the involvement of customers, experts and external supporting entities in each funnel.

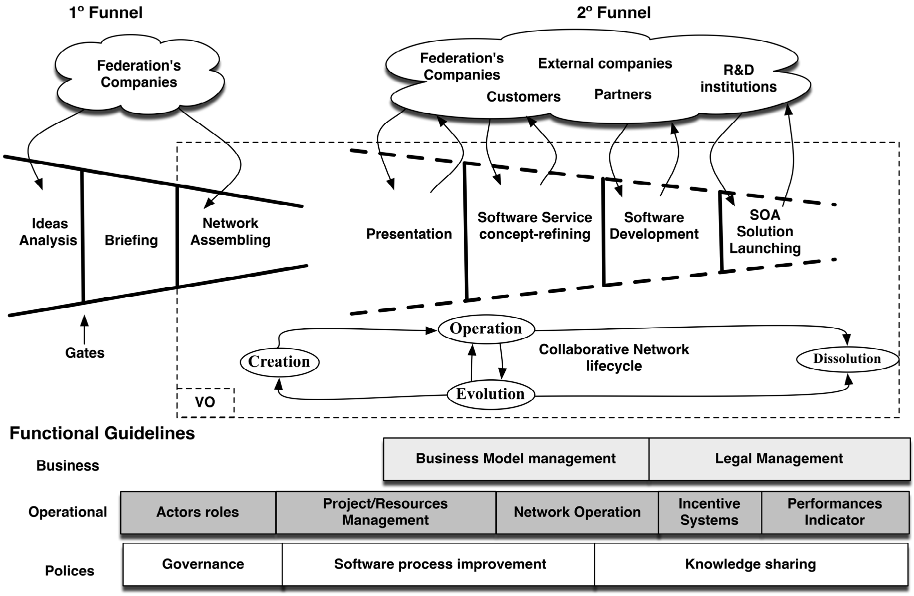

Fig. 1. The proposed Innovation Model. Source: authors.

Very briefly, the processes are the following:

First funnel

1) Idea Analysis: one (or group of) company from the federation can propose a joint innovation to the federation's committee (usually comprising multidisciplinary persons), which will firstly evaluate the idea's potential. At this moment the idea is presented shallowly.
2) Briefing: the idea is now detailed presented, describing the necessary technologies, potential partnerships, estimated ROI, foreseen market, etc.
3) Network assembly: formation of the VO that will carry the innovation out. It includes since partners' search and selection till negotiation, VO governance model setting up, revenue mode, specific contract signature, and metrics.

Second funnel

4) Presentation: a complete project plan and ICT technological analysis are conceived and the business model is eventually refined. This is done by the involved companies' managers (the VO innovation committee) helped by some external actor (from inside or outside the federation) depending on the VO governance model. It also includes issues of IPR and ownership, accounting, and knowledge gaps in the VO and in the federation.
5) Software-service conceptualization: it refers to the idealization of the SOA solution, the required services to be composed and their expected QoS and

trustworthiness, analysis of existing (observing different versioning and multi-tenancy aspects) and to-be developed or to-be wrapped services, integration / interoperation / orchestration needs regarding required communication and general and individual execution services infrastructures, UML modeling and Use Cases, mockups, etc. Actually, the essential important goal of this process is to check the envisaged SOA feasibility from the technical perspective.

6) Software development: this process basically deals with the same issues tacked in the previous step, but at a very detailed level. It includes the services coding themselves (with variable software development methodologies), their truly integration and final verifications. It covers the SOA/services life cycle development [9], but with the many particularities when the SOA project is developed by a group of companies [10].
7) Service launching: this last process is the less well defined as it is very dependent on the business, on the contract and its term, target customers and associated general legislations, access mode (e.g. local deployment, ASP or SaaS) and definitive running infrastructure. Therefore, this should be all "configured" before finally delivering the SOA product to the 'client' who has requested the innovation.

There is a decision-making step (gate) between each process, so one process only starts if the previous one has been approved after its analysis. This analysis is done adopting agreed and common criteria, a mean to support transparency and trust building among the VO members and other involved actors. Each gate has specific criteria and metrics. Processes can be audited and all relevant knowledge can be stored. All this is defined in the federation and VOs' governance models.

An underlying construct in the proposed innovation model is the *VO life cycle* (see section 2.2). Its importance is twofold: i) knowing more precisely where the VO is created, operated and dissolved; i.e. being aware of in which processes a VO can change its configuration, including partners entrance/withdrawing and their respective roles; ii) helping partners in the VO management as this requires additional processes for each VO phase other than innovation or software engineering related. These processes have different complexities and demands different efforts, costs and supporting methods from the VO members [7].

4.4 Functional Guidelines

Functional guidelines (FG) correspond to supporting aspects that should be considered by network members along the collaborative innovation. It is a construct not presented in other innovation models. They represent methods, techniques, tools and foundations that are required at the different phases of the whole process at different levels. Ten main FGs have been identified as a result of an inductive method over a number of works on innovation from the literature review (e.g. [25] and [26]).

FGs are grouped in three categories, which act at three levels of the innovation process. FGs themselves are positioned within these different levels. Briefly:

- *Business* level: it embraces the FGs related to the innovation commercialization, in more particular: business model management (elements to guarantee that the innovation results are aligned with the defined business model), and legal management (to guarantee that the innovation results have been developed and are aligned within the required legal framework, respecting contracts, IPR and services ownership).

- *Operational* level: it embraces the FGs to support the "daily" operation of the innovation development, in more particular: the actors management (to guarantee that all the involved actors will consider their rights and duties according to the governance model); Project/Resources management (it supports the usual issues related to manage the innovation process as a project, including associated human, financial and material resources); Network operation (it is also related to the governance model, adapting the power and structural elements of decision-making as long as the innovation process goes on); Incentive systems (issues to guarantee the correct application of incentives to collaborate in the innovation also regarding productivity and adherence to the project's goals); and Performance indicators (selection and application of adequate indicators to correctly measure and manage the performance of the project, individual services, partners and the innovation itself).
- *Policies* level: it embraces the FGs related to general relations among the VO, the VO with other actors (internal or external to the federation), and with customers. In more particular: Governance (rules and models to set up how the innovation will be done and managed); Software process improvement (models, standards, specifications, practices, IT and SOA governance, and methodologies to guarantee the right way of developing software and services); and Knowledge sharing (to guarantee that the necessary information and knowledge - of all types - to support the innovation are properly shared, that lessons can be learned, etc.).

These FGs and their placement along the innovation process should however be seen here as a reference. Therefore, regarding the particularities of the given ecosystem in terms of e.g. existing culture, type of customers, adopted business models, and regional/national/international accounting and legal frameworks and associated requirements, they can support processes in a different way and can have different degrees of importance. New FGs can also be added for given instantiations.

5 Final Considerations

This paper has presented preliminary results of a research which aims at conceiving an innovation model devoted to support collaborative innovation among SMEs of SOA software services providers towards a SOA solution.

The proposed model has been developed in the light of Collaborative Networks, enabling SMEs to work as a network, so sharing costs, risks and benefits. A Virtual Organization (VO) represents the group of SMEs that jointly carry the innovation out. One of the underlying assumptions is that they should come from an ecosystem of ICT companies, which should have some preparedness to collaborate and that share common principles and operating rules.

However, quite few works have dealt with collaborative innovation targeting networked SMEs and anyone looking at the software services sector and related products. Besides that, most of the innovation models that have been proposed are directed to manufacturing, a sector very different than the SOA/software sector.

Collaborative innovation has the potential to leverage SMEs of software and, in more particular, of SOA providers, to new degrees of sustainability. This ascends in significance as SOA represents one of the most powerful ICT drivers and future directions but at the same time brings lots of complexity to software projects. The proposed model represents a contribution to mitigate this problem, helping networked companies in conducting a joint innovation. This is supported not only via a more intense software services assets reuse, but also permeating the network with a fluid participation of external actors.

The proposed model also identifies the most relevant supporting issues that should be taken into account along the innovation process and the VO life cycle. To be highlighted the governance issue, fundamental to guarantee the correct evolution of a given innovation as long as it progresses, regulating partners' roles, rights and duties. This mitigates conflicts among companies and hence the innovation risks. Such issues, taken as functional guidelines in the proposed model, helps companies to allocate proper resources and be aware about different levels of complexities along the collaborative innovation SOA life cycle.

Regarding the particularities of software/SOA sector, the nature of the innovation process, and the fact that companies should work in a network, the classical innovation funnel was adapted and split into two sequential but decoupled funnels. The first funnel works more under the network innovation model and the second under the open innovation model. The innovation flow can move forward and backward in both funnels and, per definition, partners can be involved in many steps and with variable intensities along the innovation process.

This innovation model is focused on SMEs of SOA providers, and not to traditional software developed internally (although eventually in a distributed way) by one company. Yet, it is not devoted to Internet-oriented companies niche that develop small apps-like software applications typically on their own.

Collaborative innovation and even less collaborative software innovation and SOA are recent topics and most of SMEs are still giving the first steps towards that. As such, the adoption of this model by SMEs of SOA-based companies tends to also follow a natural maturity process, an obstacle largely pointed out in the literature on collaborative networks but for which a number of supporting methodologies have been proposed and implemented.

Next steps of this research include the verification of the model and its elements close to a real cluster of ICT/SOA providers already identified for further refinements. The final evaluation of the model is expected to be performed via a working group and structured questionnaires (Expert Panel technique) to be applied close to a cluster of real of ICT/SOA companies placed in the South of Brazil. Refinements on top of the work of [10] in terms of detailed processes and practices to develop SOA collaboratively is a task also planned to be done, besides the conception of an implementation guideline of the model.

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Service Orientation in Demand-Supply Chains: Towards an Integrated Framework

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Abstract. Offering customer-centric value through dynamic and networked capabilities is a strategic need in the current business environment. This strategic need can be met by a Service-Oriented Demand-Supply Chain (SODSC) concept. Various direct and indirect notions in different contexts have been developed about SODSC concept. However, the lack of integration between these notions can easily lead to confusion. This paper aims to counter this confusion by providing a framework for structuring various related notions and explaining them through illustrative cases. Based on a cybernetic system approach, the service-oriented value, partnership and control aspects of SODSC have been investigated respectively. On the basis of a distinction between demand and supply chain perspectives, two distinct dimensions of service orientation have been explored in each of the aspects. The resulting integrated framework, visualized by three related two-dimensional matrices and illustrated by real cases, offers the possibility to characterize and analyze the various SODSC notions.

Keywords: service orientation, partnership, control, demand-supply chain, framework.

1 Introduction

The current business environment is characterized by empowered customers and globally networked suppliers. In this environment, the offering of customer-centric value through dynamic capabilities is a strategic issue. This strategic issue has led to the development of new dominant logics, especially in the marketing and operations management contexts [1]. Service-Dominant (S-D) logic as a new paradigm that emphasizes customer-centric value creation has changed the conventional marketing nature from transactional to relational [2]. Also the necessity to provide integrated and life-cycle based product services combinations, rather than single products or services, has transformed the traditional stable supply chains to adaptive supply networks [3]. This means that service orientation in demand and supply chains can be conceived as an essential requirement to survive in the current business environment.

The importance of service orientation in the demand and supply chains has led to the development of various related notions such as S-D logic [1, 2, 4] Product Service

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System (PSS) [5], Industrial Product Service System (IPS^2)[6], service enhanced products [7] and solution management [8]. Although this variety of views and notions helps to understand the different aspects of service orientation, the lack of integration between them can easily lead to confusion. To deal with this confusion, in this paper we apply the Service-Oriented Demand-Supply Chain concept that is reflected by SODSC. This concept addresses the differences between the responsibility of demand chain and supply chain activities for service orientation [9]. It reflects the necessity of integration of these activities as well. Based on the SODSC we aim to develop an integrated framework that enables to bring together different related notions.

In this paper, to deal with the complexity and confusion of diverse notions related to SODSC, we distinguish between different aspects and different perspectives (i.e. demand chain and supply chain) of SODSC. The different aspects will be explored separately through a cybernetic system based representation of SODSC. This representation of SODSC includes respectively the service-oriented value, the partnership, and the control of SODSC. This kind of logical reduction of complexity helps to position different service-oriented notions in literature in the integrated framework. The resulting integrated framework, visualized by three related two-dimensional matrices, is illustrated by three real cases. The proposed integrated framework along with the illustrative cases enables recognition of different conceivable service orientation transitions. This integrated framework also enables the analysis of the characteristics of a particular organization and its demand-supply chain from the service orientation point of view.

In the next section, the cybernetic system based representation of SODSC is introduced. The distinct aspects of SODSC result from this representation. Also the distinction between supply and demand chain perspectives is illustrated. These aspects and perspectives shape the basis for an investigation and positioning of different service-oriented notions. Subsequently, the three main aspects of SODSC, i.e. service oriented value, partnership and control, are investigated separately in the third, fourth and fifth section. The sixth section provides a discussion on the results of the investigation. The final section concludes the paper and proposes the future research steps to be made.

2 The Approach for Structuring and Explaining SODSC

As stated before, we will apply cybernetic based system theory to investigate different aspects of SODSC. System theory is based on the idea that basic principles are common to all systems, independent of the area of science to which they belong [10]. Regarding the multi-disciplinary nature of service orientation [11], these basic principles of system theory, enable development of an integrated view on the different aspects of service orientation. System theory also provides a terminological setting that is useful to overcome misunderstandings related to the usage of different terms in different contexts.

A system is defined as “a set of interacting or interdependent components forming an integrated whole” [12]. System approaches can be characterized based on the level of complexity [4], but can also be classified as physical, mathematical and cybernetic models, according to the similarity and the degree of abstraction [5]. In comparison with other system approaches, the cybernetic approach is suggested to be used in complex contexts [4]. So with respect to the complex nature of SODSC [13], this approach of system thinking provides proper possibilities to deal with complexity.

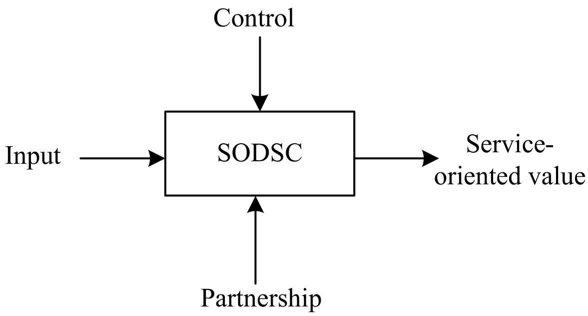

Fig. 1. The cybernetic system based representation of SODSC aspects

To encounter the complexity and confusion in SODSC, a cybernetic system approach reduces the SODSC to its logical aspects. In line with previous research that has developed system based representations of supply or demand chains [14, 15], we distinguish different aspects of SODSC, see Fig. 1. SODSC can be considered as a system that provides a specific type of output for customers (what) through supportive mechanisms (how) under a certain type of control (why). The clarification of these mentioned aspects leads to a better understanding of SODSC. So, firstly the service-oriented value is investigated as the output aspect of SODSC. The clarification of different dimensions of service-oriented value, as a core concept in SODSC, facilitates the exploration of service orientation in the other aspects. Secondly, the impact of service orientation on the supportive mechanism aspect in demand-supply chain is investigated. Taking into account the networked nature of SODSC, partnership is explored as the key supportive mechanism aspect. Finally, the characteristics of the control aspect in the SODSC are examined. Since in the networked business environment the main focus is on the strategic alliance/partnership [16], the most important input in our model are the partners that are going to participate in a networked business. So taking into account the partnership as the main supportive mechanism in our model, we don't have to investigate the input aspect separately.

Besides the cybernetic system based reduction of complexity, we also distinguish between demand chain and supply chain perspectives on service orientation. Based on the value chain framework [17], the demand chain perspective focuses on the marketing, sales and customer relationship management activities. The supply chain perspective focuses on inbound logistics, operations and outbound logistics activities. The demand chain perspective responds to the necessity for understanding, creating and simulating customer demand [9] and can be recognized as the value creation or the value obtainment system. On the other hand, the supply chain perspective includes all the supply processes to fulfill the customer demand [9] and can be called the value delivery system.

By using of foregoing distinctions, we will characterize different service-oriented notions in the three main aspects, respectively: service-oriented value, service-oriented partnership and service-oriented control. In each aspect, in accordance with the distinction between demand and supply chain perspectives, two dimensions of service-orientation are considered as well, i.e. value obtainment and value delivery. Consequently three two dimensional matrices will be developed in the next sections to investigate the various SODSC notions.

To explain further the characteristics of SODSC notions through the proposed matrices, three real-life illustrative cases will be described. For this purpose, we have chosen three cases of service orientation in the ICT industry. The first case is about Microsoft that has experienced a noteworthy shift from being a supplier of software for IBM personal computers, to a provider of customer-centric products and services through its huge service ecosystem [18]. The second illustrative case of service orientation is the IBM Rational solution for Collaborative Lifecycle Management (CLM) [19]. The CLM is an extensible platform that helps to integrate different related products and services across the software life cycle. The last case is about Accenture's cloud platform that offers integrated hybrid IT solutions [20]. This platform is founded on the integration between different products and services that are provided through different service ecosystems. Each of the mentioned cases describes a different type of service orientation transition that will be discussed based on the proposed framework. This case based illustration can be conceived as the primary step for showing the applicability and generalizability of the proposed framework.

3 The Service-Oriented Value Aspect of SODSC

The investigation of SODSC depends on a clear understanding of the service-oriented value. Different notions in marketing, operations management and information management contexts have led to confusion about the service oriented value. In our approach, we distinguish between these notions based on the supply chain and demand chain perspectives. On the basis of these two perspectives, two different dimensions of service-oriented value can be recognized in literature as well [21]. The first dimension of service-oriented value, i.e. from a demand chain perspective, is established on the basis of customer interaction to create value. The second dimension of service-oriented value, i.e. from a supply chain perspective, is established on extending capabilities of a supply chain to cover the broader requirements of customers through adding new services to the core products of a supply chain.

The first dimension of service oriented value focuses on the interactions between suppliers and customers rather than the ability of a supply chain to provide an extended range of products and services, see Fig. 2, vertical axis. Within this dimension, the emphasis is on the customer centric interactions that shape the value. Within this dimension, the service orientation is reflected by the customer centric definition of the value. This dimension emphasizes the more prominent role of a customer for obtaining the value. It suggests that value is always determined by the customer as value-in-use, whether in direct interaction with the supplier or in indirect interaction through goods in use. Within this dimension of service orientation, value lies not in building more features into products and services such as mentioned in the integrated product services, but in providing more and varied opportunities to consumers for co-creating personalized experiences [22].

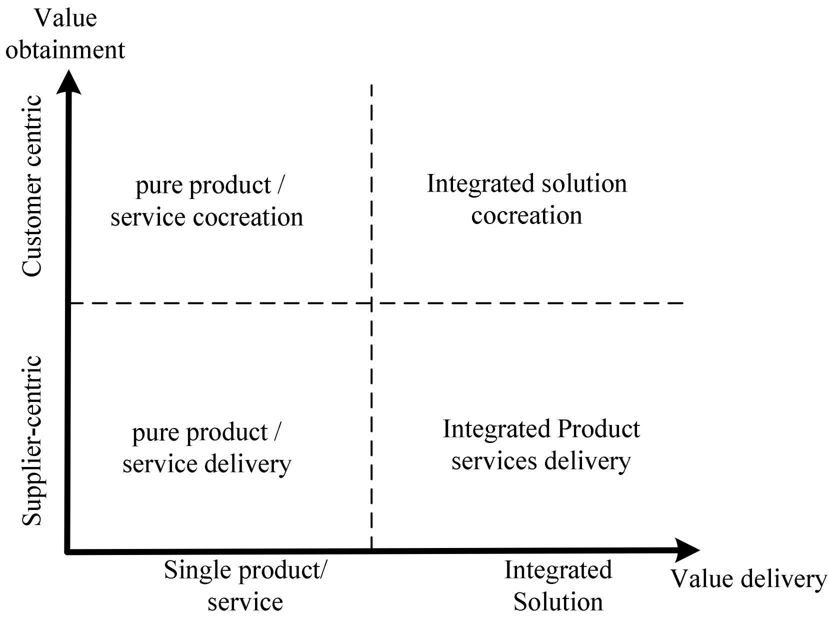

Fig. 2. The characterization of service-oriented value

The second dimension, i.e. the supply chain perspective on service orientation, predicates the ability of a supply chain to deliver new services in addition to the core offerings of a supply chain, see Fig. 2, horizontal axis. This type of service orientation is a supply chain transition from delivering pure products or services to delivering integrated product services packages. This transition is inevitable for companies in mature industries due to the need for higher customer value. Two most important strategic directions that lead supply chains towards the offering of integrated product services can be described as respectively:

1- Time based extension of provider responsibility: from product/service delivery towards product lifecycle management (PLM);
2- Risk based extension of provider responsibility: from output oriented towards result oriented responsibility;

Both mentioned dimensions of service orientation, can be considered as customer orientation approaches. However, the first dimension responds to customer orientation through value obtainment activities, whilst the second dimension realizes it through value delivery tasks. The combination of both dimensions leads to offer integrated solutions for customers [23]. It means that offering integrated solutions requires customer-centric interactions as well as the ability of providing integrated product services.

The characterization of the service-oriented value, see Fig. 2, can be illustrated by the cases introduced in section 2. Microsoft's evolution from being a supplier of software for IBM personal computers to co-creating through independent developers, who interact with end users, can be considered as service orientation from a demand-chain perspective (i.e. the value obtainment dimension). The IBM's CLM product that supports the entire software development lifecycle from requirement to deployment through integrated and collaborative tooling can be seen as the service orientation in supply perspective (i.e. the value delivery dimension). Also the Accenture cloud platform, that supports hybrid IT solution cocreation through customer interaction with different ecosystems, is an illustrative case for integrated solution cocreation (i.e. the ultimate combination of value obtainment and value delivery dimensions). These illustrative cases show that the proposed distinction between the two dimensions of service-oriented value enables the characterization and the interpretation of service-orientation in real-life business situations.

4 The Partnership Aspect of SODSC

The partnership aspect in our cybernetic approach to SODSC, see Fig. 1, describes the alliance of stakeholders to provide service-oriented value. In line with the two distinct dimensions of service-oriented value, i.e. from the demand and the supply chain perspectives, two different dimensions for service orientation of the partnership aspect of SODSC can be recognized. The customer-supplier relationship dimension, established from a demand chain perspective, underlines the role of a customer as an active actor in partnership models that support the customer interaction for value co-creation. The supplier-supplier relationship dimension, established from a supply chain perspective, emphasizes the suppliers' own relationship to aid delivery of integrated product services. These two different dimensions for the characterization of the partnership in SODSC are shown in Fig.3.

The customer-supplier relationship dimension, see Fig.3, due to its marketing origination, emphasizes the costumer involvement in value creation rather than the partnership between suppliers [24]. This dimension is in line with the customer empowerment trend in the marketing context. Customers can engage in dialog with suppliers during each stage of product design and product delivery. This form of dialog should be seen as an interactive process of learning together [25]. Customers as active actors to co-create value can take different roles such as co-designer, innovator, marketer and socially responsible actor [26]. In this way, the service ecosystem and value network [27] notions have been developed to address new types of partnership. In the service ecosystem, a customer as an active actor coproduces service offerings, exchanges service offerings, and co-creates value [1]. This means that in a value network the supplier-supplier relationship is the subordinate of customer-supplier relationship. In other words, in a value network the customer as a value co-creator determines the suppliers' requirements to respond the customized value.

On the other hand, the supplier-supplier relationship dimension, see Fig. 3, takes into consideration the partnership characteristics that enhance transition from pure products or services towards integrated product services. Delivering result-oriented product services that supports the availability of the delivered value in its whole life cycle requires a strong collaboration between suppliers. Also delivering integrated product services, which is customer oriented in its nature, requires more market sensitiveness in the supplier-supplier relationship. This collaboration between suppliers that can be adopted based on the customer needs to deliver customized integrated product services can be characterized as an adaptive/agile supply network [28, 29].

With respect to the characterization of service-oriented value (Fig.2), partnership mechanisms to support the cocreation of integrated solutions might be characterized by both customer-centric as well as adaptive. This is reflected by the combination of two dimensions of service-oriented partnership in Fig.3. This type of partnership supports a flexible and dynamic collaboration to respond to the emerging opportunities originated from customer involvement in value creation. The dynamic and opportunity based partnership to deliver the cocreated integrated solution, can be handled through a collaborative value network, see Fig. 3.

In line with the foregoing section, and for a further clarification of the two dimensions of service orientation based on the partnership aspect, we again address the three cases introduced in section 2. Microsoft Partner Ecosystem that supports the co-creation of customer-centric products and services around the Microsoft technologies can be considered as an illustrative case of a value network (i.e. the customer-supplier relationship dimension in Fig.3). In this ecosystem that consists of 640,000 partners, members interact with customers independently to provide customer-centric value [18].The CLM of IBM can be delivered as a whole package or fragmented parts of the integrated package based on the customer requirements. So the relationship between the suppliers of the different elements of CLM should be adaptive (i.e. the supplier-supplier relationship dimension in Fig.3). The Accenture cloud platform for the co-creation of integrated solutions might be able to coordinate between suppliers in different value networks. It means that the partnership aspect in support of the Accenture cloud platform consists of the different value networks as well as the adaptive relationship between the suppliers who are members of different value networks (i.e. the combination of the two dimensions of service-oriented partnership in Fig 3). These three cases indicate that organizations pursuing a particular direction for providing service-oriented value require a particular type of partnership characteristics.

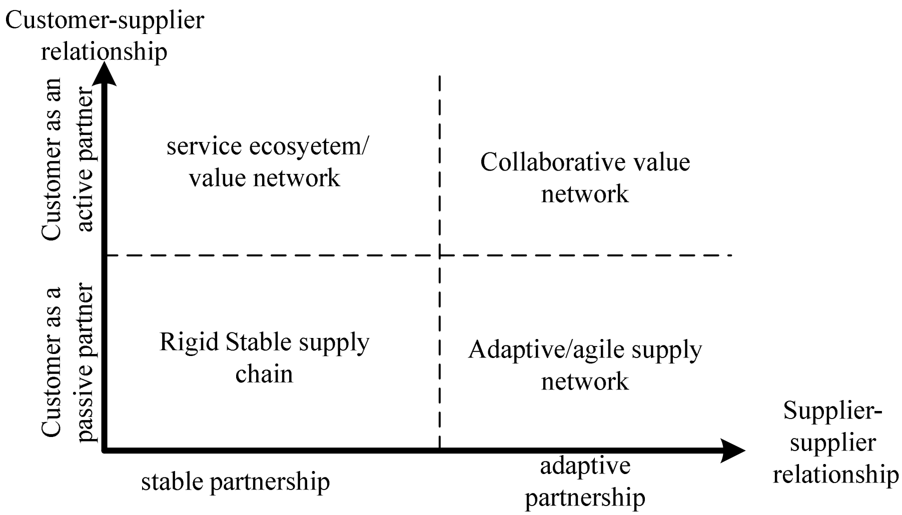

Fig. 3. The characterization of the partnership aspect of SODSC

5 The Control Aspect of SODSC

Following the distinction between service orientation in demand and supply chain perspectives, two different dimensions can be addressed of the control aspect as well. These two dimensions are presented in Fig.4. Where from a demand chain perspective, the control focuses on the handling of customer-supplier relationship, from a supply chain perspective the control focuses on the coordination between suppliers. The main priority of the first perspective is to lead the system towards a better obtainment of customer satisfaction, where the second perspective emphasizes more efficiency and responsiveness in the delivery process.

The service orientation in the customer-supplier relationship control dimension addresses the shift from a transactional approach for value obtainment towards relational dominant logic (See Fig.4). The transactional approach as a pre-dominant logic for value obtainment is product-oriented and can be seen as trying to get the customer fitted to the product. The transactional approach for the value obtainment focuses on customer attraction, e.g. through controlling '4Ps' (Price, Product, Promotion and Placement) as the most important variables for the value obtainment [30]. However, the relational value obtainment proposes a different approach that is customer-centric rather than product-oriented. The relational value obtainment emphasizes customer experience rather than customer attraction. The customer experience-centric control is based on customers' commitment, trust, satisfaction, communication, and the seller's customer orientation [31].

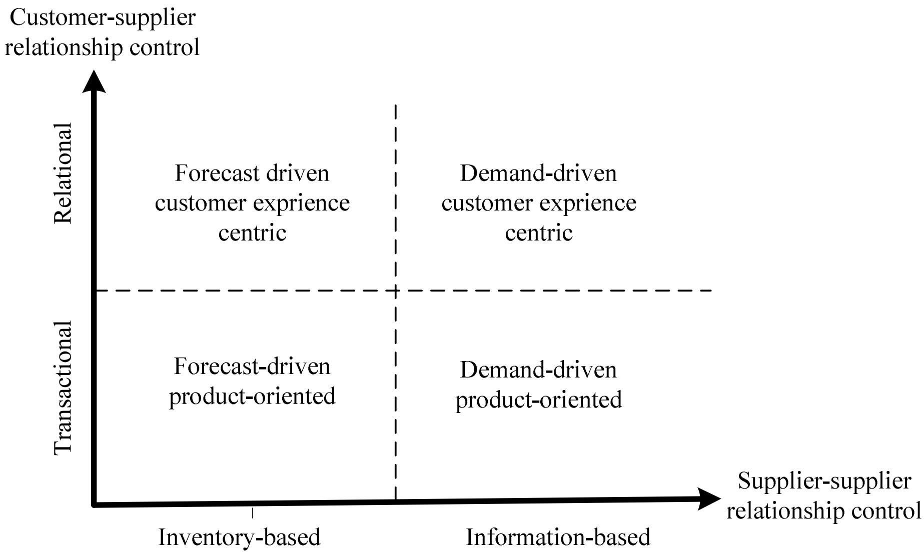

Fig. 4. The characterization of control aspect of SODSC

The second dimension in the control aspect of SODSC describes the coordination between suppliers to provide integrated product services (See Fig.4). According to the corresponding dimension in the service-oriented value and partnership aspects, the focus of the control aspect in this dimension should be on the handling of agility and flexibility. Handling the agility requires a market sensitiveness capability in the control aspect to understand and respond to the real demands of customers [29]. This leads the control of the relationship between suppliers from forecast-driven to demand-driven. The demand-driven control, which is based on the real customer demand, requires a real-time access to information. So while the conventional suppliers' relationship control is inventory-based, the service-oriented supply chain control is information-based. This means that the demand-driven control is established on the information that is de-coupled downstream as far as possible. So the real demand information can penetrate into the whole supply chain.

By combining the two mentioned dimensions of service orientation of the control aspect (See Fig.4) it can be concluded that cocreating integrated solutions through a collaborative value network requires control characterized as relational and information-based. In this case, the control aspect of a system is responsible for handling the relationship between the customer and all the potential suppliers in order to obtain the most fitted value, as well as to organize the suppliers to deliver the obtained customized value. In this case control should be able to manage customer-supplier interactions through open dialogue and social interactions and also to coordinate the whole supply chain to deliver the obtained customer centric value. This means that control in the collaborative value network should be capable of handling real time integration between value obtainment and value delivery, (See Fig.3). In this case, the dynamics of supplier-supplier relationships originates from the customer experience (that is obtained through customer interaction control).

In accordance with the previous sections, the characterizing control aspect in SODSC can also be recognized in the three cases introduced in section 2. It can be conceived that the control aspect in the Microsoft ecosystem through an extended and deep relationship with a broad spectrum of customers can obtain customer-centric values for offering new propositions. While, it seems that IBM's CLM should be able to coordinate between different suppliers to handle different and dynamic demands that are requested by customers. Accenture's cloud platform, being able to offer customer-centric integrated solution, should be capable of tracing and obtaining value from different service ecosystems, as well as a dynamic coordination between suppliers to deliver the customer-centric value.

6 Discussion

The proposed framework for SODSC contributes towards solving the confusion related to the usage of various notions of SODSC. The distinction between the three different identified aspects of SODSC enables an investigation of a broad range of notions in the literature in a structured way. Also the recognition of two different dimensions in each of the three aspects clarifies the different aims of service orientation in the marketing and manufacturing contexts. S-D logic and "service system" notions, which have emerged as the most important scholarly marketing debates in the last decade, emphasize customer-centric value obtainment. While notions such as IPS[2], PSS, and service enhanced products, that originated from manufacturing and operations management contexts, address the shift from pure product manufacturing towards integrated product services delivery. This type of extreme distinction helps to get a clear understanding of the main focus of the different confusing notions.

The proposed framework can also be used to understand potential transitions of organizations aiming for service orientation. Service oriented organizations, as well as networked businesses, can position them in the proposed framework. Since the three proposed matrices address different aspects of a SODSC, there is a logical dependency between them. Based on this dependency, selection of a particular direction of service orientation at each aspect requires pursuing the same direction in the other aspects. We give three examples to clarify this dependency. First, organizations that based on their strategy are going to focus on customer intimacy as their main service-orientation theme [32], should be able to handle value networks through relational customer experience control, see the left top cell in the matrices proposed in Figure2, Figure3 and Figure 4. Second, organizations that focus on integrated product services delivery competences should be able to manage agile supply networks through demand-driven control, see the right bottom cell in the matrices proposed in Figure2, Figure3 and Figure 4. Third, innovation based organizations in the service-oriented context, willing to co-create new services to offer integrated solutions for customers, should be capable of managing a collaborative value network through customer-centric and demand-driven control, see the right top cell in the matrices proposed in Figure2, Figure3 and Figure 4.

7 Conclusion

In this paper, through a cybernetic system based representation of SODSC, the three main aspects of SODSC have been investigated, i.e. the service-oriented value aspect, the partnership aspect and the control aspect. This investigation has resulted in three two-dimensional matrices which form together an integrated framework to address the different SODSC notions and views in a structured way. This integrated framework enables to recognize different types of 'real-life' service orientation transitions. The paper also addresses the first steps towards a validation of the integrated framework, i.e. by illustrating and explaining service orientation transitions of three 'real-life' cases in the ICT industry.

Although the proposed integrated SODSC framework is based on literature research, analysis and logical reasoning, and the positioning of the real-life cases shows its usability, more case study research is recommended to validate, strengthen and enrich the framework.

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Engineering and Implementation of Collaborative Networks

Implementation and Operation of Collaborative Manufacturing Networks

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Abstract. Collaborative networks of manufacturers, suppliers and even customers are an emerging trend in global manufacturing. Higher flexibility, shorter time to market and economic as well as technological synergies create value and strengthen the market position of such virtual enterprises. The ComVantage framework already provides a sophisticated technical approach for dynamic collaborative manufacturing networks based on semantic data, mobile app orchestration, business process modelling and sophisticated access control. This article discusses the services and processes that are necessary to implement and operate a virtual enterprise using the ComVantage framework. It identifies services and service providers, and proposes an infrastructure and a tool environment for the ComVantage approach.

Keywords: Virtual enterprise, collaborative manufacturing network, mobile interaction, semantic data, co-operation, co-creation

1 Introduction

In order to master the competition in a global market, companies do not only have to operate more efficiently, they further need to be much better cross-linked among each other. Moreover, agility in terms of networking and process execution is important [1]. The execution of business processes across organizational boundaries as well as cross-linking data sets of collaboration partners are key success factors and initiate the

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transformation of isolated individual companies towards an integrated, agile virtual enterprise. Resulting Collaborative Manufacturing Networks (CMN) may also include customers in order to leverage co-creation and co-production of customer-oriented products and services.

By definition of Barnett, et al. [2], a virtual enterprise is based on a temporary alliance of several businesses. It takes advantage of a market opportunity and dissolves, when it has passed. A virtual enterprise does not have own major resources but consists of the resources and core competencies of the individual partners. The European research project ComVantage, which is funded by the European Commission within the Framework Programme No. 7, has the goal to develop a software architecture as well as a working prototype of a distributed infrastructure for virtual enterprises [3].

From a business perspective, the most important question to be answered is which positive impacts on the business can be created with the implementation of a CMN based on the ComVantage infrastructure, and which additional expenses and dependencies must be taken into account on the opposite. Synergies during implementation may result from jointly used business services and the reuse of shared resources. Additional expenses may be incurred by the necessary provision and harmonization of data and services for the network as well as by coordinative work within the network. Most collaborative activities further create dependencies that must also be considered. In this paper, a process for the implementation and operation of a CMN is presented, which maximizes synergies, minimizes dependencies and clearly allocates and structures the necessary activities. The process thus minimizes business risk and ensures a structured design and operation of the network.

2 State of the Art

Having clarified a generalized definition of a virtual enterprise and its purposes, the interpretations and implementations of collaborative working environments are very heterogeneous Alone among publicly funded research projects, there are several projects in the field of co-operation and co-creation.

The project ADVENTURE for example has the goal to create a framework that provides tools to combine factories in a pluggable way to manufacture a particular product which consists of a high number of components from different suppliers. Core element of the three layer architecture is the central 'Dashboard portal' as the user interface for all for monitoring and managing purposes [4]. GloNet as another example follows a service-oriented approach with a novel framework for automated software service composition in a complex multi-stakeholder service scenario for product life cycles. Therefore, they provide mechanisms to model or compose software services via business processes and combine them with the product. The resulting product model will become available in a 'Business Services Provision Space' via web services as product-related information and services during its life cycle [5]. In contrast to product or service related virtual enterprises, BIVEE's Virtual Innovation Factory (VIF) focusses on an innovative co-creation space with an ultimate goal to transform existing production processes and organizations into new ones as a following step to the Open Innovation paradigm by Henry Chesbrough. Based on collaborative and social network tools the idea moves through a flexible life cycle, called 'Innovation Waves', allowing to cover the whole flow up to production [6].

A core aspect of a temporary virtual enterprise is their life cycle, which can be basically subdivided into the five phases of Initiation, Partner search, Process design, Execution and Dissolution as it was done by Shamsuzzoha and Helo [4]. Another common aspect is the usage of software for collaboration and communication to establish Collaborative Manufacturing Networks (CMN). They have an integrated end-to-end Information and Communication Technology (ICT), formalized (business) models and a shared knowledge space, based on Web 2.0 technologies. Therefore, the network provides their partners a cloud based platform for overall operational processes, like security access control and communication, as well as certain software tools to align their own business processes, data and background systems within the shared processes and data in the CMN.

3 The ComVantage Framework

The ComVantage project aims at developing a software architecture and a technological foundation of generic enablers for operating a virtual enterprise. The project will provide means to evaluate the business impact and will prove the suitability of the approach in three different use cases. With respect to the challenges addressed in the introduction, the following key concepts characterize the ComVantage software architecture:

First, a *decentralized approach* is required in order to address the specific requirements of virtual enterprises. The ComVantage approach supports individual and local instances of a collaboration hub for each network partner. Figure 1 illustrates an exemplary CMN setup containing two partners. Each collaboration hub offers a Domain Access Server as single point of access to local datasets and a couple of local data sources. The decentralized collaboration hub concept enables each partner to keep full control about their valuable business data. Furthermore, the single point of access paradigm for each collaboration hub ensures that applications can be developed independently of specific data sources and are decoupled from their heterogeneous data models. SPARQL and JSON/RDF are used as standardized interface technology between all components of the architecture to achieve high interoperability and flexibility. However, collaboration partners are not forced to run and maintain their own infrastructure, but can use shared collaboration.

Second, *semantic data harmonization* based on RDF and Linked Data principles is used to realize the single point of access paradigm of the collaboration hub. Whereas data models (as ontologies) will be stored directly in RDF (in Triple Stores), legacy systems need to be integrated by the use of Linked Data adapters (see Figure 1). These adapters perform a mapping from legacy data (e.g. from a relational database model) to a uniform data model based on RDF for each collaboration hub. While the mappings will be defined at design-time, the extraction of data may occur at run-time in order to avoid the persistence of redundant semantic data that need to be kept in sync with the original legacy data. Additionally, a multi-tiered access control approach was developed. Cross-domain authentication, physical separation of data in views and SPARQL query rewriting based on role-driven policies ensure that unauthorized access in a setup of collaboration and inter-organizational access to information is prohibited.

Third, collaboration scenarios are driven by the execution of *inter-organizational business processes* to realize a cross-domain product value chain. Especially in the manufacturing industry, business processes may be very complex. On the other side, the personnel on the shop floor needs intuitive and usable mobile IT support. ComVantage has developed the Industrial App Framework that allows the orchestration of limited-purpose mobile apps to App Ensembles which support complex and inter-organizational workflows. A pool of Generic Apps can be used to accelerate the user interface development. These Generic Apps can be adapted to specific use cases and automatically orchestrated to App Ensembles using a business process model.

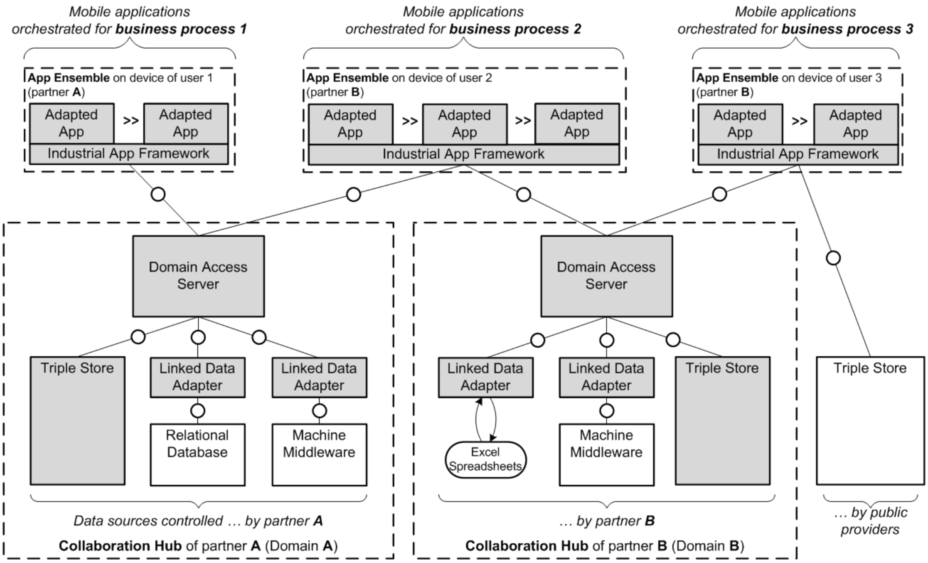

Fig. 1. The big picture – Exemplary setup of a CMN with two partners and ICT infrastructure including mobile apps, collaboration hubs and data sources

4 Implementation and Operation of a ComVantage Network

4.1 Overall Process

In general, implementation sub-processes are categorized into collaborative processes where all partners have to jointly create a common result, shared processes that are done by an internal or external provider for all partners, and company internal processes that have to be done by each partner individually. Collaborative processes require coordinated work and joint decisions by all partners. Shared processes are equal for all partners and thus have only to be done once. The results can be shared resources or services. Company internal processes do not require collaboration. The results feed into the CMN. It is obvious that company internal processes can also be outsourced. However, the main difference to shared processes is that there are no synergy effects besides the joint use of (external) competencies.

The ComVantage overall implementation process consists of seven sub-processes, which are done sequentially in three phases. In the first phase, the common business processes (BPM) and roles (RM) are modeled. These are collaborative sub-processes, where joint decisions must be made. In the second phase, ontologies and apps are developed that are necessary to implement the BPM and RM. These are shared processes whose results are shared by all partners. In the third phase, each partner provides datasets for the developed ontologies and creates an Access Control Model (ACM) based on the RM to secure the provided data. In parallel, app ensembles are orchestrated based on the BPM, ontologies and apps. The app ensembles provide the datasets to authorized users according to the underlying BPM and are thus the final result of the entire process. All sub-processes are scalable. Individual activities may be omitted and the tools may be selected according to the actual requirements.

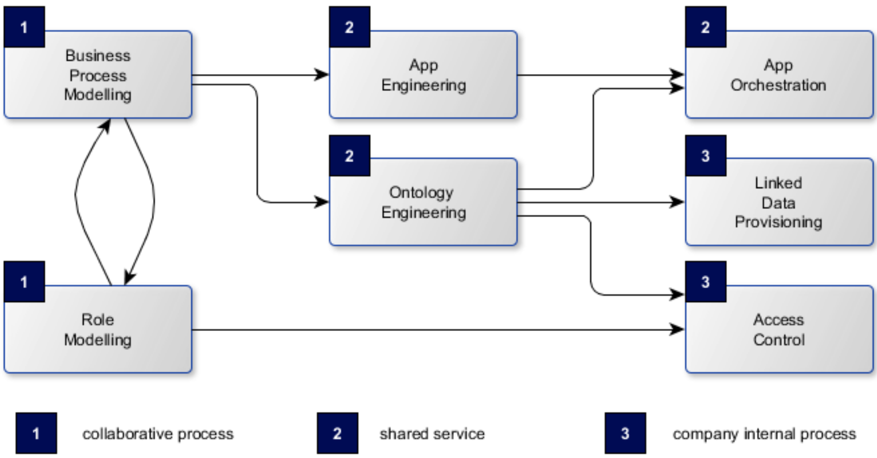

Fig. 2. Seven Steps towards a CMN – The ComVantage implementation process

4.2 Role Modelling and Business Process Modelling

The Business Process Modelling phase is traditionally tightly coupled with Role Modelling. For the hereby presented approach it is essential that role assignments use machine-readable representations so that the semantic relation between a process task and its performing role is preserved beyond the modelling phase, for example through a model serialization. To achieve this, the ComVantage approach relies on a meta-modelling platform [7] and an RDF serialization vocabulary discussed in more detail in [8], with a proof-of-concept collaborative modelling tool hosted by the Open Model Initiative [9]. The modelling tool implements the iteratively evolving ComVantage modelling method, whose meta-model specifies the semantic links that can be created by modelers (usually as inter-model hyperlinks) and can be externalized for RDF queries in order to enable the later phases of the ComVantage implementation process (e.g. App Orchestration).

Business process modelling is a well-established approach, however there is a diversity of tools and languages to support it – some of them coming from standards, others from commercial tools. Popular approaches aim at high reusability across domains, therefore high abstraction levels that do not retain any domain specificity and are not prepared to collect requirements. The ComVantage approach provides the possibility of assigning, to each process task, domain specific resources and artefacts: mobile apps requirements, robots, product parts etc. Therefore, the meta-model underlying the business process modelling phase integrates with explicit associations the following facets: a) Process motivators (the trigger of a virtual enterprise – a customized product order, a service, a temporary market opportunity); b) Processes (the actual control flows triggered by the process motivators and possible acting upon them – the case of production processes); c) Process participants (liable entities or assets). In this last class, there are business or individual roles (liable entities described as a business network or organizational chart), required mobile apps (with functional capabilities) and access means (queries indicating the kind of access and endpoint required to perform a process task). Each task of a business process model can be explicitly linked to all these types of participants, hence enabling the collection of requirements around each specific process (by querying the process model serialization). These requirements can feed into the App Orchestration and Access Control phases in the following ways. First, App Orchestration deployments can read the Diagrammatic Orchestration Model – a usage precedence graph describing which apps are required for a selected role, and in which order. This model is derived automatically from the business process model by graph transformation means (details in [8]). Second, the Access Control phase can collect the queries assigned to process tasks – they are queries that should be enabled by the policies of endpoint owners, for the specific roles linked to the same tasks.

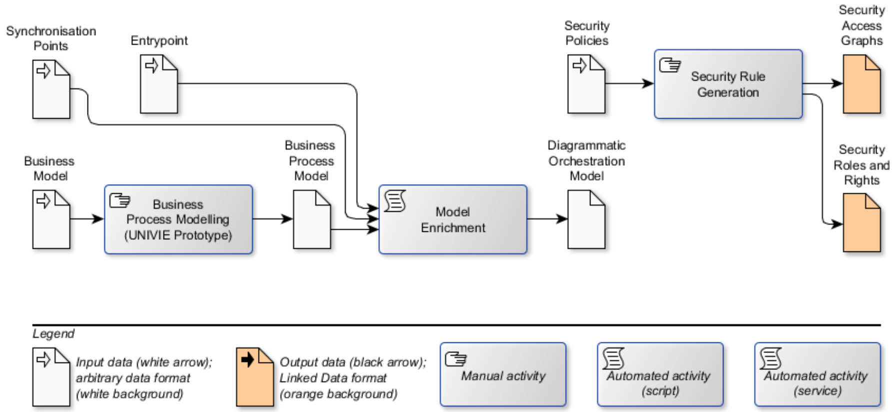

Fig. 3. Role Modelling and Business Process Modelling. Activities may be manual or automated. Data may be formatted as Linked data (orange) or not (white). Input and output of the entire process marked with arrows.

4.3 Ontology Engineering

In order to design the ontologies that serve as terminologies and data structures for the applications, several ontology engineering methodologies [10, 11, 12, 13] were considered, and the Enterprise methodology developed by Uschold and King [14] was selected, since it provides sufficient guidance to provide the ontology engineers with a clear process without requiring disproportional overhead. This methodology suggests the following phases: 1. Identifying the purpose; 2. Building the ontology, with steps a) Capturing, b) Coding, and c) Integrating existing ontologies; 3. Evaluation; 4. Documentation.

The first step can essentially be completed before the start of the CMN and laid out in the business plan. For step 2a, interviews with domain experts from the application partners have to be conducted to determine the essential terms of the corresponding domain and their relations. Step 2b can be performed with the help of the Protégé tool, generating RDFS or OWL ontologies based upon these terms. In order to integrate existing ontologies (step 2c), terms from popular ontologies are used where this is possible, e.g. the FOAF and vCard ontologies describing persons and their addresses or the GoodRelations ontology for prices and other costs. Links to DBpedia entities should also be included if appropriate. Step 3 involves using the developed ontologies within the respective application areas and evaluating them with respect to usability, clarity, and consistency. The final step is performed by documenting the developed ontologies in text documents and by using the rdfs:label and rdfs:comment properties within the ontologies themselves. In order to also enable non-experts to perform basic ontology operations, the OntoSketch tool [15] was developed, which allows for refining existing ontologies by domain experts using a graphical editor.

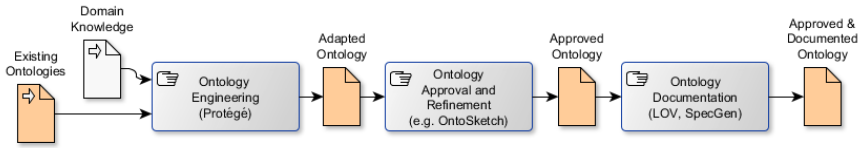

Fig. 4. Describe the domain – Ontology Engineering

4.4 App Engineering

During the App Engineering phase (illustrated in Figure 5) the set of apps required for the network's business processes is created. If an app repository already exists it is first checked for apps that can potentially be reused in the business processes. Then, existing conventional apps, e.g. document viewers or messaging applications, are identified in order to integrate them during the subsequent App Orchestration phase. For all other app requests in the business processes, such as specialized data views or tasks that manipulate the Linked Data graph, new apps may be developed.

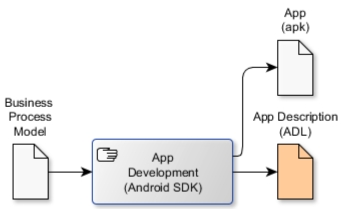

Fig. 5. App Engineering

Any app that shall be used must be formally described in the developed App Description Language (ADL). The ADL is a domain specific ontology for modeling an app's characteristics essential for collaboration. Besides conventional meta-data such as operating systems, supported screen sizes, languages, etc., the ADL supports modeling the app's abilities, input and output data, and entry points. The entry points are essential for forming an app network, the modeled inputs and outputs allow for inter-app-communication. The abilities are later used to match apps to activities in a business process model.

4.5 Linked Data Provisioning

The main task of the Linked Data Provisioning phase (illustrated in Figure 6) is to generate, distribute and supply the CMN with the information necessary for the common business models. Sources of information can be, among others, Excel sheets, XML files, and proprietary engineering or control systems. The information has to be modeled with the approved ontologies in order to be useful for the CMN.

The Ontology Engineering phase delivers the meta-models of the information which is necessary for the shared business cases. Afterwards, the sources of this information (existing legacy systems or already Linked Data stores) can be identified. Linked Data adapters may be provided for this data if this information is not already present as Linked Data. The adapters use the approved ontologies from the Ontology Engineering phase to transfer the legacy data into Linked Data taking domain specific knowledge into account. If the update rate of the legacy data is rather low, simple automated model transformations can be applied which provide a RDF output for an information entity as input (e.g. a single Excel file). Various frameworks (e.g. Jena for RDF support) and application interfaces (e.g. Enterprise Server for Comos) may support this task. The RDF file is then stored in a triple store (e.g. Virtuoso) which offers access via SPARQL. If the update rate of the data is rather high (e.g. the provision of process values), a service may provide direct access to the necessary information as Linked Data. Some dynamic adapters provide a local SPARQL endpoint (e.g. XLWrap, D2RQ) whereas others only provide data via a REST web interface as Linked Data.

Usually, the majority of the data provided by the partners is only loosely coupled. Hence, a link discovery and generation process between different datasets may generate additional links, which will also be stored in the Linked Enterprise Data cloud. A final validation of the RDF datasets is mandatory to ensure the reliability of the information provided in the cloud. This step can be done with tools, which may perform a RDF validity check, check the instances against the used ontology or common best practices, or even check against specific defined rules. Finally, collaboration networks need information about available datasets, their structure and content. Therefore, documentation is added to all datasets, which itself can be modeled as Linked Data by using for example the VoiD vocabulary.

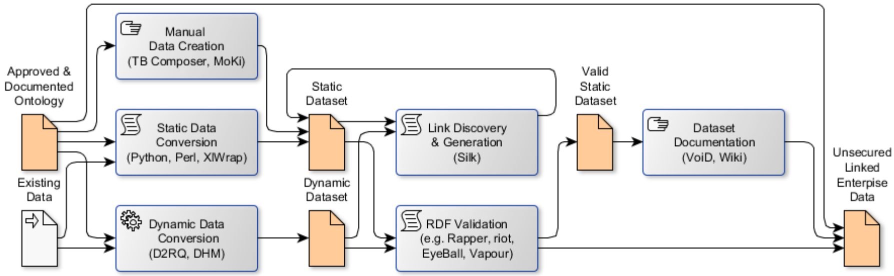

Fig. 6. Breathe life into the CMN – Linked Data Provisioning

4.6 Access Control

The main aim of the Access Control phase is to create an Access Control Model (ACM) based on the roles modeled (RM) to secure the information published as Linked Data. For the provisioning of trust, the ComVantage approach complements traditional XACML role-based multi-domain access control models, including SAML authentication, which are useful to control the access to dynamically changing Linked Data information, with innovative SPARQL query rewriting capabilities based on data views to address the security needs of mobile inter-organizational information sharing. The goal of the SPARQL rewriting process is to create queries that return the same results as the original queries except for those answers that contain restricted information. For this purpose, the security framework includes conditions to the original SPARQL query so that all the information requested is included within the set of information that the user is authorized to access taking into account its role, which has previously been modeled as explained in Section 4.2. In order to achieve this objective, this SPARQL rewriting process relies on the organization of the original RDF data in a set of Views with different access types (*canSee* or *canUse*) for the different user roles (see Figure 7).

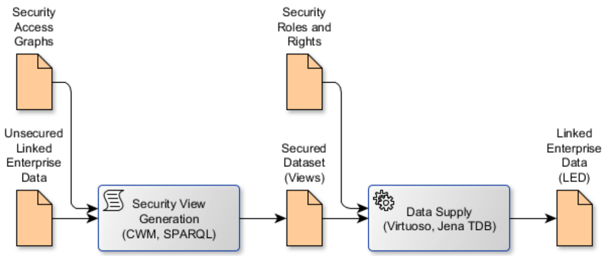

Fig. 7. Secure the Linked Enterprise Data – Establishing Access Control

The ComVantage security approach does not just guarantee that the access to the information remains secure, but it also has to ensure that the information published as Linked Data is just modified and updated by the users that are authorized to these tasks. For that purpose, SPARUL templates previously approved by the data owner are assigned to different user roles who will be allowed to modify and update the original Linked Data and the defined data views accordingly.

4.7 App Orchestration

The App Orchestration phase shown in Figure 8 takes results from the Business Process Modeling phase, the Ontology Engineering phase and App Engineering phase and leverages them to create App Ensembles that are used to view and operate essential aspects of the CMN (details in [16]). They constitute the network's front end and provide means to view and manipulate the information contained in its Linked Data graph. App Ensembles are sets of Apps that are interconnected in a meaningful way to fulfill mobile support requests in business processes. They facilitate the correct switching between apps and automate the exchange of information between them. To create an App Ensemble, appropriate apps for the business process must be selected from a repository. This is accomplished by comparing requirements stated in the Diagrammatic Orchestration model (which is derived from a business process) to the app's abilities formalized in their respective App Descriptions (using the ADL). Then the apps are adapted to the data structure of the CMN. This is accomplished by assigning SPARQL templates to the apps which adhere to the networks ontologies. SPARQL templates are SPARQL queries with placeholders that fit the network's information structure and provide necessary data to the apps. Using SPARUL the templates are also employed to manipulate the Linked Data graph. In the third step, connections between the apps are established by analyzing their entry points defined in the App Descriptions. The information from the three orchestration steps is joined into a Semantic Orchestration Model and serialized as RDF.

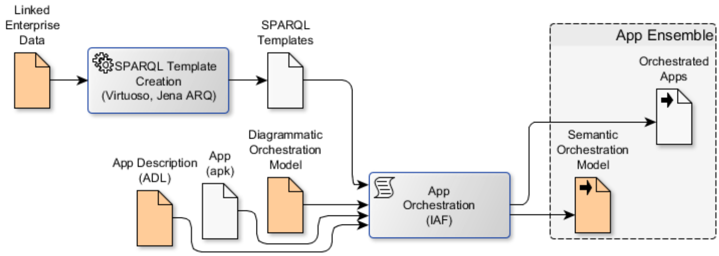

Fig. 8. Bring it to the users – App Orchestration

Installable binaries of all Orchestrated Apps together with the generated Semantic Orchestration Model form an App Ensemble. It is deployed to a mobile device where it can be loaded and executed using the ComVantage App Management Component that interprets the Semantic Orchestration Model.

5 Progress Beyond the State of the Art

Both technologically and administratively, the ComVantage approach addresses the challenge to generate a verified added value through the CMN early and with scalable effort. This takes into account that CMN may differ significantly in terms of size and composition, and in terms of its business objectives. The process has therefore been designed to generate as few dependencies between the partners of the CMN and resolve necessary dependencies as early as possible. Thus, the implementation costs and risks are minimized. On the other hand, the process achieves maximum synergy in joint activities. It is clearly defined which results can be reused and what activities can be outsourced to service providers. Moreover, the process is scalable. Activities can be omitted if not required, tools can be selected depending on the actual requirements of the CMN. Finally, the presented process is iterative. Since the implementation of a new CMN and the modification of existing CMN are based on the same process, the CMN can be continuously adapted to the current requirements.

The presented process has been implemented and validated in the context of three use cases in the areas of commissioning of production lines, customer-oriented production and maintenance of process plants. Both the composition and size of the CMN (from micro-company to large enterprises, including customers) as well as its business objective (acceleration of engineering processes, maximization of customer-orientation, and optimization of operation and maintenance) have been varied across the use cases. It has been found that the presented process scales well with respect to both factors. At the same time it became apparent that the flexible use of manifold tools was arduous. Also, some activities were not yet sufficiently supported by appropriate tools. A (modular) integration of the proposed tools in an integrated development environment (IDE) and the development of appropriate tools should therefore be a focus for future activities.

6 Conclusion

In this paper, the processes, tools and outcomes have been presented that are necessary to implement a ComVantage collaborative manufacturing network (CMN). It has been shown that the overall process strives for minimization of dependencies, maximization of synergies and great scalability of all sub processes. In the next phase of the project, suitable integrated engineering tools will be designed to better support the processes described in this paper. These tools will be directly built upon the technologies and concepts of the ComVantage framework and thus promote the feasibility of the ComVantage approach to CMN in industry and business.

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The Sensing Enterprise: Towards the Next Generation Dynamic Virtual Organisations

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Abstract. In today's dynamic and volatile global environment, established legacy concepts such as Virtual Organisations (VOs) need to be evolved to enhance their agility in order to promptly adapt to changes. This paper proposes the use of the Sensing Enterprise concept and properties, supported by the paradigms of the Internet of Things, Cyber-Physical Systems and Future Internet Enterprise Systems, as an essential enabler towards the advancement of the current 'dynamically created' VO concept towards a Next Generation of agile and genuinely Dynamic Virtual Organisations (DVOs), displaying awareness, perceptivity, intelligence and extroversion. The properties and benefits of the Next Generation 'sensing' DVO are defined and then illustrated in a scenario that typically requires utmost agility and dynamism.

Keywords: Virtual Organisations, Breeding Environments, Sensing Enterprise, Internet of Things, Collaborative Networks, Disaster Management.

1 Introduction

In the context of increasingly competitive global environments in market and society, enterprises and organisations are often compelled to take on project opportunities requiring competencies beyond their individual resources and knowledge. As a result, organisations become so-called Collaborative Networked Organisations (CNOs) that act as 'breeding environments' (BEs) for Virtual Organisations (VOs) [1]. VOs are temporary associations between BE members, created in order to bid for, win and complete projects requiring resources and know-how above those available in any BE member alone. However, in an increasingly volatile market and society environment, successful VOs are required to become dynamic and agile, i.e. to constantly perceive changes and adapt to them in a timely manner.

In this paper, the authors argue that the new 'Sensing Enterprise' (SE) concept, supported by the paradigms of the Internet of Things [2], Cyber-Physical Systems, [3] and Future Internet Enterprise Systems [4], is able to assist in the evolution of current VOs and dynamically created VOs within a VO Breeding Environment (VBE) [5], towards a next generation of genuinely Dynamic and agile VOs, hereafter referred to

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as ‘Dynamic VOs’ (DVOs). As a result, DVOs will be able to sense and promptly adapt to changes in their environment during their entire lifecycle.

A brief review of current research in the SE area is followed by defining the capabilities of the future SE. Next, the SE paradigm is applied to the current VO concept so as to transform it into a genuine DVO. Finally, the practical application of the new DVO concept is exemplified through a case study in disaster management - an environment that would greatly benefit from higher levels of dynamism and agility, present in the next generation DVOs.

2 The Sensing Enterprise

As the economy and society is becoming increasingly networked and digital, there seems to be a need to redefine the notion of enterprise[1], especially as new social and technology tools are provided by recent advances in new research paradigms, such as Internet of Things [2], Cyber-Physical Systems [3], Future Internet Enterprise Systems [4] and others. Such paradigms facilitate the pervasiveness of the enterprise, blurring its traditional boundaries to the point where internal and external stimuli (coming from within and outside of the enterprise) cannot be distinguished. As pervasiveness implies a federation of processing capabilities and knowledge resources, the new paradigms will also make collective intelligence more accessible and coordinated.

In an attempt to reconsider the notion of the enterprise, the FInES cluster [6] has identified so-called *Qualities of Being* as properties of the future enterprise as being humanistic, community-oriented, cognizant, people-centred, inventive, agile, environmentally aware, and ‘glocal’ (with local and global perspective). An enterprise displaying the above properties becomes a so-called Sensing Enterprise (SE).

The SE is also described as “an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness” [7]. In fact, it is not characterised only by awareness (as the term implies), but also by decentralised intelligence. This does not only concern collaboration in decision making, but also purposefulness evaluated in its environment. Thus, an SE is in fact a social enterprise, sometimes also described as ‘liquid’ to suggest its pervasiveness.

The ‘liquid’ character of the SE is supported by the anticipation that sensors will become a commodity in the future [8]. Thus, the ownership of an enterprise on the sensors will not necessarily restrict other organisations to provide value-added services, based on observations of these sensors. Santucci et al. [ibid.] point out that “the Sensing Enterprise will be a sort of radar in perfect osmosis with an ecosystem of ‘objects’ supported by several private area networks and delivering in real time a wealth of unstructured data, not only more data but also new data”.

Presently, the main technical obstacle for ‘de-solidification’ of the conventional enterprises is the ‘verticalisation’ of the existing technical solutions, e.g. Cyber Physical Networks - the trend of manufacturing devices initially customized to the specific applications. This leads to application silos with fragmented architectures, incoherent unifying concepts, and as a result, a lack of interoperability.

[1] The terms ‘enterprise’ and ‘organisation’ are used interchangeably throughout this paper.

2.1 The Sensing Enterprise Capabilities

In terms of technical architecture, the SE is considered as a system-of-Cyber Physical Systems (CPS) where these CPSs do not necessarily operate within the boundaries of the enterprise, nor even in its domain of interest or operation. The SE will also encompass the CPSs owned and governed by the other enterprises.

In order to access, combine, use and act upon the extensive, multi-dimensional, multi-modal data (now at the disposal of the enterprise), an SE needs to maintain the capabilities to seamlessly sense this data, perceive its meaning, make decisions and articulate a response (whether this articulation refers to acting (actuating), requesting the additional data, transferring an information to another enterprise, etc.). The stimulus for this cycle may originate from within or outside the enterprise and within or outside its domain of interest.

The cycle above can be explained in terms of semantic interoperation of two enterprises. Note that hereby, the term 'enterprise' is used in this explanation only to illustrate the ownership on the specific CPS, which one enterprise could exploit. In order to illustrate this cycle, we extend Sowa's [9] formal definition of semantic interoperability of systems; thus, an enterprise S is semantically interoperable with enterprise R, if and only if the following condition holds for any stimulus p that is articulated by S and sensed by R: For every statement q that is implied by p in the enterprise S, there is a perception of p, namely q', in the enterprise R that: (1) is implied by p in the enterprise R, and (2) is logically equivalent to q (see Fig. 1.).

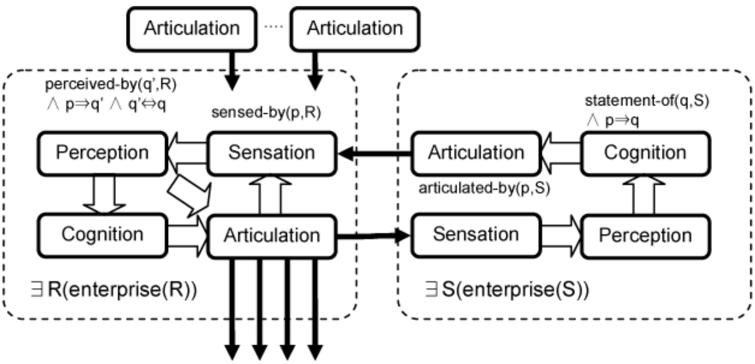

Fig. 1. Illustration of the interoperable SE

Based on the assumptions above, we identify awareness, perceptivity, intelligence and extroversion as the key capabilities of the Sensing Enterprise [10].

Although the core concept of SE does not distinguish between the internal and external stimuli, there is a need to separately consider the self-awareness and environmental awareness of one SE. While the latter is crucial for exploiting the pervasiveness of one SE, the former is relevant for maintaining its multiple identities (e.g. towards suppliers and customers, but also on web or a social network). The pervasiveness of an SE extends the conventional domains of interest of an enterprise (e.g. typical channels for detecting new business opportunities). Hence, now one has to consider not only the functional environmental awareness, but also the universal one concerning observations of any stimuli, even from unknown and unanticipated sources. When arbitrary stimuli are taken into account, it becomes important for the enterprise to achieve the capability to perceive any stimulus, be it multi-modal, multi-dimensional, discrete or continuous. Perceptivity is a capability of an SE to assign a meaning to the observation from its environment or from within itself. Then, based on the perception, the SE should be able to decide on the consequent action. This decision is a result of a cognitive process, which consists of identification, analysis and synthesis of the possible actions to perform in response to the “understood” observation. The intelligence also encompasses assertion, storing and acquisition of the behaviour patterns, based on the post-agreements on the purposefulness of the performed actions.

The last desired attribute of an SE, extroversion, is related to the willingness and capability of the SE to articulate the above action/s and demonstrates the SE’s business motivation and/or a concern about its physical and social environment.

3 Towards Next Generation Dynamic Virtual Organisations

3.1 Virtual Organisation Evolution

The development of VO and VBE management models, methods, systems and tools [11] addressing challenges in CNOs management, supported by the progress in Information and Communication Technologies (ICT) [12], is on-going given the dynamic environments in which organisations exist. Thus, ‘first generation’ VOs were created from an ‘open universe’ of organisations considering a number of important factors in the process so as to quickly and reliably establish an interoperable environment between trusted partners. This approach was limited by the possibility of rapidly finding a set of suitable partners that best fit a collaboration opportunity and quickly configure them into a VO. ‘Second generation’ VOs called for a more effective VO creation process [13] to enable having dynamically created VOs in response to the requirement to capture short-time windows of collaboration opportunity. Therefore, VBEs (as ‘nesting’ environments) emerged in order to increase the preparedness of organisations towards rapid configuration and creation of VOs by negotiating in advance a set of cooperation agreements and common operation principles, interoperable systems and ontologies [13].

Nevertheless, market dynamics have made collaboration opportunities not only short-time windows, but also collaborative projects with evolving features induced by the fluctuations in the continuously changing environments that may surround a VO collaborative project operation. This calls for a ‘third (next) generation’ VO type, with an emphasis not only on a dynamic VO creation process, but also on VO’s ‘agile’ behaviour during its lifecycle. A third generation, truly dynamic VO (DVO) would be capable to recognise and promptly react to changes in the environment during its operation, and therefore survive and even thrive on change. This organisational behaviour matches that of what has been described above as the ‘Sensing Enterprise’ [7], on which authors believe DVOs should be based on.

3.2 Next Generation Dynamic Virtual Organisation Properties

During the last years, advances in ICT have been facilitating more effective, agile, flexible and trustworthy collaborative environments and networks, enabling organisations to collaborate and negotiate, systems/services to adapt and interoperate, information to be exchanged and retrieved, and resources to be discovered and shared [14]. In this context, organisations need to acquire new *Qualities of Being* [6] (see Section 2) which are strongly related to the properties that define an SE*:* aware, perceptive, intelligent, and extroversive. Authors propose the adoption of these properties for the next generation VOs (DVOs).

Thus, a genuine DVO must display *self-awareness* and *environmental awareness* capabilities in order to cope with dynamic and sometimes turbulent market conditions. *Self-awareness* is related to the capability of the DVO or DVO partner to sense a phenomenon or event within itself; for example, the DVO should be able to forecast, based on its own internal performance a possible need for re-engineering during its operation and proactively react with the required changes/adaptations to maintain the time-, cost- and quality frames constraining its mission/goal. *Environmental awareness* is related to the capability of the DVO or DVO partner to sense a phenomenon or an event from its environment, extended by the capability to receive messages from its environment; for example, to detect an external driver or inhibitor in the market and/or society that may trigger an internal DVO change process to take advantage of the driver or mitigate the risk of the inhibitor.

A second important Next Generation DVO property would be *perceptivity* as the capability to assign a meaning to an observation internally or in its environment and decide on possible action - for example, real-time continuous monitoring, assessment and adjustment aiming to sustain DVO efficiency.

The third property of a Next Generation DVO would be *intelligence*, as a capability encompassing assertion, storing and acquisition of behaviour patterns (best practices), based on post-mortem analyses in regards to the purposefulness of the past performed actions; for example the use of past DVOs heritage (experience and other assets) for improving future or current DVOs operation performance.

Fourth and last property that a Next Generation DVO would need to exhibit is *extroversion,* related to the willingness and capability of the DVO or DVO partner to articulate its actions in case of a request or need for change (e.g. VO evolution); for example, a DVO partner willing and capable to change its position in the DVO topology or modify the initial role, rights and responsibilities assigned to it, or a DVO capable of reconfiguring, rescheduling, reallocating or optimising the resources involved in its operational plan.

4 Case Study: Dynamic VOs in Disaster Management

The increasing rate and intensity of natural and man-made disasters demands more than ever effective prevention, preparation, prompt response and recovery from catastrophic events. Governments worldwide respond to this challenge by putting in place various disaster management policies, departments, agencies and organisations providing emergency management and services. Typically however, such organisations display a high organisational diversity due to their complex historic, traditional, geographical, cultural and political environments. In addition, there is a plethora of other participants (e.g. non-governmental organisations, volunteers etc.) that need to be included in the disaster relief effort. These factors significantly increase the complexity involved in cooperation.

The collaborative operation of emergency services is often promulgated at state, national and international levels (e.g. [15-18]). However, such directives alone have proven insufficient, bringing about increased response times, sub-optimal cooperation on the ground and even dispute as to who, where and when is 'in charge'[19].

In order to address these issues, previous research has argued for and modelled the establishment of so-called 'Disaster Management Collaborative Networks' (DMCN) as strategic alliances of governmental and non-governmental organisations which are aimed to act as BEs facilitating the *prompt* establishment of Disaster Management Task Forces (DMTF) and Disaster Response Teams (DRT) in order to handle complex search, rescue and/or relief mission [20].

The models previously proposed relied on the dynamically created, second generation VO paradigm; while this approach improves response times and cooperation, it does not address well the degree of autonomy and interoperability required of the DMTFs and DRTs during operation on the ground. Independence and resilience are crucial in emergency situations where some response teams may fail, with the rest of the teams having to promptly reorganise or find replacements (with or without BE/DMCN assistance) in order to recover missing functionality; this would require prompt, ad-hoc interoperation with potentially new partners [21]. Response teams should also be able to perceive and promptly adapt to changes to their operating environment, to ensure the safety and efficiency of their partners and of other teams.

4.1 Sensing, Agile Disaster Management Task Forces and Response Teams

It is hereby argued that the previously defined DVO concept featuring 'Sensing Enterprise' properties could address the shortcomings of the previous models.

Thus, *self-awareness* (perceiving a phenomenon or event within itself) would help DMTFs and DRTs to continuously monitor the status and performance of their human, software and hardware components (e.g. monitoring the vital signs of team members, functionality of equipment etc.). *Environmental* awareness would enable the task forces and response teams to sense events and receive information from other sources in the operating environment - e.g. data from wireless sensor networks (WSNs) or other teams and compensate for fluctuations, within pre-determined limits. This capability, currently restricted to a functional aspect (i.e. matching pre-determined interests of the team) could be subsequently evolved to *ubiquitous (universal) awareness*, enabling the team to receive and interpret messages beyond agreed interests and formats. This would allow a heterogeneous set of response teams to interoperate seamlessly and share data essential to their mission and safety.

The *perceptivity* of the Next Generation DVO concept employed in disaster management would allow the DMTF or DRT to assign a *meaning* to an internal or environmental observation and decide on possible action; for example, location information provided by an internal GPS sensor combined with radiation, temperature etc. readings from the environment (e.g. via a WSN) would create a percept that may lead to certain action (proceed, evade, etc.). Should the envisaged action be beyond predetermined autonomy level, contact the DMCN or BE for mission reconfiguration.

In disaster management, a timely, suitable response is crucial in saving lives and property. Therefore, the DMTF/DRT decision to act based on a percept must be based on a cognitive process, consisting of identification, analysis and synthesis of the possible actions to perform in response to the understood observation (i.e. the percept). Therefore, the DVO-based agile response teams must also possess *intelligence*, possibly in the form of a knowledge management/expert system that would provide possible actions based on rules established by using disaster management best-practice, previous disaster response actions and outcomes and importantly, by externalising relevant human tacit knowledge. The DMTF/DRT would become a learning organisation that constantly learns, stores, and improves its response to external challenges in an agile manner.

The social effect of *extrovert* DMTFs and DRTs, materialised by transparency towards other teams, disaster relief participants (e.g. community, non-governmental and faith groups, etc.) and general public would bring significant benefits. In large scale catastrophic events, trust and communication are paramount in an effective response and minimising negative effects [19, 22]. Often, in a disaster situation, the population self-organises in novel and efficient ways; response teams must tap into this resource and use it to optimize their operations; for this to happen however, in addition to gaining community trust, the response teams must also be able to interoperate at short notice and without previous preparation and negotiation - in effect, displaying interoperability as a unilateral property [21].

5 Conclusions and Further Research

The aware, perceptive, intelligent and extrovert Sensing Enterprise holds the promise to revolutionise all areas of the current market and society landscape.

Following a brief review of the SE research state of the art and the description of the typical SE capabilities, the paper has described the evolution of the VO concept from its origins up to the current, dynamically *created* VO. Next, the SE capabilities have been applied to the current VO concept in order to enhance its agility and evolve it into a next generation, genuinely real-time Dynamic Virtual Organisation (DVO).

Furthermore, it has been exemplified how the DVO concept could be employed in an area demanding extreme agility and dynamism, namely disaster management. A brief review of the current problems in disaster management and shortcomings of the previous models based on the legacy VO concept was performed. This was followed by the application of the new DVO paradigm to disaster management task forces and response teams in order to improve collaboration, safety, response time and efficiency.

The SE and VO areas are continuously evolving. Therefore, further research is necessary in order to update and refine the Next Generation DVOs SE-related attributes and to test them in various case studies.

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Tourism Destination Management: A Collaborative Approach

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Abstract. Collaboration is a key factor of sustainable growth across territories and industrial sectors. Tourism, one of the largest industries in the world, has been subject to strongest innovation in the last years. Main reasons of this reside both in the availability of new ICTs - Information and Communication Technologies - and organizational models, which directly connect tourists among them and with service providers, and in the always more personalized supply of tourism experience. Tourism destinations can benefit of such innovations if they are able to reorganize the territorial tourism offer around different pattern of collaboration in order to give *2.0 tourists* opportunities to live an *augmented tourism experience*. This paper deals with the possible forms of *collaborative networks* that can rise within a destination with a focus on relationships between services delivered by the Tourism Destination and the requests of services at the different phases of the *tourist 2.0 lifecycle.*

Keywords: Tourism breeding environment, Collaborative Networked Organization, Tourism Extended Enterprise, Tourism Virtual Organization, augmented tourism experience, tourist 2.0 lifecycle.

1 Introduction

Last decades were characterized by a growing interest toward tourism sector due to its increasing impact to the economic development of many countries [1].

Anyway, not all tourism destinations over the world are able to benefit of the tourism industry development. Nowadays, even the traditional tourism destinations are invested by the current financial and economic downturn experimenting the discharge from the tourists' preferred destinations at global level [2].

The traditional development model, based on an outdated tourism supply chain model, appears inadequate and unsustainable to support tourism destinations in the strong and globalized competition [3]

As argued in [4], in recent years the *tastes of tourists* have changed and the numbers of tourists in search of "something different" from mass tourism is growing. Culture and people thus become part of the tourism product; competition is always more based on offering tourists articulate packages composed by different services (hotel, restaurant, nature, visits to cultural heritage, sports, handicrafts, etc.) that, all together, enable tourists experience a territory as a whole [5] [6] [7].

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 217–226, 2014.

In this context, the accelerating and synergistic interaction between the ICTs and tourism brought extensive transformation of the industry itself, gradually generating a new paradigm-shift. The ICT is changing the tourism industry structure providing a whole range of opportunities for all stakeholders; it is widely recognized that ICT alter barriers to entry, revolutions distribution channels, as well empowers consumers to identify, customize and purchase tourism products [8] [9].

The depicted industry evolution shows new potentials for local service providers usually marginalized from main tourism flows, due to their small sizes, and unable to compete in the globalized market. In many regions characterized by niche tourism vocation (e.g.: historical, business, sport, cultural, rural, religious etc.), or localized in developing countries, or simply where some organizations decided to create "alternative" development paths, local tourism operators have started organizing themselves spontaneously in "Collaborative Networks", *CNs*. The main objective of such CNs is to create aggregate tourism offers able to compete with big tourism operators thus transforming regions with potential and vocation in real tourism destinations. At the same time, tourists have the opportunity to experiencing a good holyday respecting the local place and people.

The aim of this paper is to describe how the organizational paradigm of collaborative networks applied to the tourism sector, when correctly managed and supported by ICTs, can be the right means for the sustainable development of local areas. The paper is structured as follows. In section 2, a characterization of a tourism destination, highlighting the key factors for its development in contrast with the traditional supply chain, is proposed, reporting also main advantages for adopting a CN model for the tourism destination management. In section 3, the concept of the tourism 2.0 lifecycle is introduced, related to the tourist's needs for an augmented tourism experience, giving the motivations why the adoption of a CN model is an effective way to answer the tourist's needs. Section 4 reports the operationalization of the concept of CN in tourism. Conclusions of the study are reported in section 5.

2 Characterizing a Tourism Destination

The presence of attraction factors (both physical elements, like natural resources and monuments, and social factors, like the language spoken and friendliness of the local people), although a necessary condition, is not enough for turning a territory in a tourism destination [10], [11]. The key factor for the rise and continuous development of a tourism destination resides in the quality and efficacy of relations among service providers and between them and the destination's environment. Effective relations can give the tourism destination the basis for agility in dynamic and turbulent market conditions. Offering to an always more demanding tourist an integral, flexible and personal experience, as a result of the interactions among specialized service providers, can be a winning strategy for the tourism destination to gain sustainable development and emerge in the global competition.

In a tourism destination, live and operate different autonomous entities (people and organizations) whose business is related to the sector. While these entities can be heterogeneous in terms of their operating environment, culture, social capital and goals, they all aim to achieve the common goal of tourism destination development and to increase the general competitiveness respect to other geographical areas within the global competition. We define these entities as *tourism service providers* that can be grouped into the following categories [5]:

- *Hospitality Services Enterprises*: companies that offer overnight accommodation (e.g. hotels, B&B) and meal provision (e.g. restaurant).
- *Transportation Services providers*: public and private companies that provide services of people transportation (i.e. buses, taxies, airplanes, trains, etc).
- *Event Management Services*: public and private companies dealing with the organization of events (e.g.: conferences, conventions, concerts, sport events).
- *Tourism complementary goods and services providers*: companies that produce and offer complementary goods and services for travelers, like local shops, museums, excursion services, sport & leisure facilities, handicrafts.

Although the tourism service providers interact at different levels, from the commercial to the operational one, they all collaborate to develop the tourism destination in the forms of both partnership agreements and informal relations. Their aim is to deliver a competitive offer of tourism services. Interactions among service providers model the set of all services characterizing the tourism destination.

From the set of relations within a tourism destination results the tourism supply chain whose success depends from the way it is managed.

Actually, the real obstacle for the sustainable development of the tourism destinations is that the tourism supply chain control remains in the big companies charged to market the destination (generally, the international tour operators). Big tourism corporations control almost every services selling among disconnected operators and tourists through complex supply chains. A typical example is the tourist village model, where all the services are provided by the village owner, often a big not-local company whose aim is only the fast return on investment with all the consequences for the local socio-economic and natural environment. Consequences of the traditional tourism supply chain control's model, reside in territory saturation, environmental degradation, stress on infrastructures, in the loss of bargaining power for local service providers, and, with time, the deterioration of the services provided.

As tourism service providers become a part of the global economy, local collaborative actions that generate externalities for the companies increase in importance. Engaging in new forms of collaboration and promoting and maintaining relationships within business networks have become a natural way for organizations to meet increasing flexibility and performance requirements in competitive markets [12]. Reduced cost and investments, improved efficiency, scale and scope economies are further motivations for local players in engaging collaborative actions within the industry.

In the tourism sector, the supply chain management is moving from a centralized task of the majority chain shareholder to a collective responsibility among channel partners. Models of CNs in the tourism sector are characterized by a direct connection among local service providers and tourists with these explicit ethical and political goals: re-vitalisation of territory identity and local community relations to local natural, cultural and historical heritage, linking with sustainable agriculture and handicraft, economically viable and socially responsible practices [13]. In other words, the traditional and centralized supply chain model, based on the overexploitation of the destination's resources, is always more turning in a collaborative and sustainable one.

Scholars tried to deepen the understanding of the CN in tourism phenomenon proposing theories and identifying successful case studies of "alternative" tourism supply chain showing how collective intelligence of the members is appropriated to ensemble innovative information-based products for tourists, highlighting how a common vision among all stakeholders is mandatory to protect the resources and the importance of a collaborative approach in the marketing of the destination [14].

3 The *Tourist 2.0 Lifecycle* and the *Augmented Tourism Experience*

In the effort to deepen the tourism experience from the tourist point of view, scholars introduced the concept of the *tourism experience lifecycle* [15]. A diffused approach in defining it consists in adapting generic models to describe consumer behavior in purchasing products or services [16]. Other scholars, suggested that travel is a "linear" process, defined the touristic experience from a temporal perspective which involves three phases: the anticipatory phase; the experiential phase; and the reflective phase [17]. Unfortunately, according to Swarbrooke and Horner [16], there are several reasons why most of previous models are no longer adequate to describe the process of tourism today. The main problem seems to be that previous models are dated and do not fit to the present scenario in which the use of Internet has dramatically changed the ICT use and the consumer behavior.

The Internet technologies, by the providing of sharing, context aware and automation services radically changed the meaning of mediation in tourism context: not only tourists get connected in a anticipatory way with destinations through web media contents, but they become more and more autonomous in decision-making processes, disintermediating players of tourism market, such as travel agencies and tour operators, and exploiting the customer insights and reviews, provided by people through social media.

The availability of networking ICTs allowed the rise and diffusion of CN models all around the world by enabling operators to develop original ways to manage the tourism supply chains, the destination marketing and relations with customers.

From a tourist perspective, ICT provides services able to help the decision making process. The possibility to taste in advance a trip (thanks to videos, photos, opinions and storytelling of other users), the opportunity to compare thousands of offers through fare aggregators and meta search engines, the immediate delivery of a set of tourism services (e.g. reservation or booking, payment, etc…) are among the features that make the *Internet&tourism* an absolutely winning combination. The emergence of social networking platforms have further influenced the whole tourist experience lifecycle by the mean of the new ways tourist interact with peers. Moreover mobile technologies have challenged today's tourists expectations getting personalized access to tourism information at any time, from anywhere with any media, creating a paradigm shift in how information is accessed and digested, and transactions performed [18].

Demand and supply of ICTs have innovated considerably the sector in operational workflows, management and marketing of tourism packages and in new paradigms of tourism experiences

We can name this paradigm shift as *augmented tourism experience.* To be effective and competitive on the market, a tourism destination needs to deliver information services for matching necessities of each phase of the *tourist 2.0 life cycle* in the effort to offer tourists an *augmented tourism experience.*

In the effort to clarify how ICTs have reengineered the tourism experience, we need to analyze how ICT provides specific contents and automates the activities typically carried out by a tourist.

In what follows, we propose the *tourist 2.0 lifecycle* i.e. a model of tourism experience that fits the modern consumption paradigm of tourism products/services.

The model consists of the following phases:

Dreaming: The process begins with the emergence of a need, a desire to travel. In this phase, tourists look for inspiration for their vacation. While in the past, most of the ideas came from photos, stories and memories of friends' past experiences or brochures of Travel Agencies (TAs) or Tour Operators (TOs), today the internet greatly simplifies this step. The dream of holiday is fed by an overabundance of photos, videos, or maps on the web, allowing users to gain virtual previews of the holiday, explore places, identify the location, refer to opinions and recommendations published by travelers who already had an experience and then prospected tourists begin to "dream" their vacation. In this direction goes a category of ICT services that could be delivered by “inspiration portals”, like Tripfilms.com, Panoramio.com, Pinterest.com, Facebook.com etc., which provide the opportunity of sharing geotagged multimedia content among users by allowing them to get a preview of the territories, cultures and type of vacation.

Planning & Booking: Once the tourist identifies the potential destination and the type of holiday he intends to do, he proceeds with the detailed planning of the trip. After establishing the details of the whole holiday, all that remains before travel is to make reservations of transportation, accommodation and any additional services (car rental, excursions, events, etc.) that will complete the tourism package. Until a few years ago, planning and booking activities were generally carried out by TAs and TOs, who had to book transportation, accommodations, and activities or to create complete packages for the customer whose only concern was to pay the broker.

Nowadays the availability of web services based on comparison, recommendation systems, and booking services like booking.com, trivago.com, e-dreams.com, expedia.com, etc., leads consumers to make self-service reservations with increasing frequency, allowing them to enjoy lower costs related to the absence of intermediaries, to book at any time from everywhere.

Experiencing: This phase is mainly related with the in-place tourism activities: the tourist overnight stays in hotels, make excursions, enjoy meals, visit local attractions etc.. The main difference with the past at this stage is the availability of contextualized information and additional services (maps, location-based services, context-aware mobile tourism guides, augmented reality etc..) offered to the tourist 2.0 through mobile devices as well as the opportunity to share location-based multimedia contents through web-services like Foursquare.com, Facebook Places, Loopt.com, etc.. Examples of context-aware mobile tourism applications are mTrip guides, myTrip, Tripadvisor, that provide contextualized information and services to produce more focused and useful recommendations to the user. Based on location, user profile (preferences), time, and pre-stored trip information, a user get recommendations about points of interest, plan personalized tours, get informed on nearby restaurant opening times, be advised where to eat on the basis of his food preferences, get public transport information, etc. [18]

Recollecting: After experiencing the holiday, the tourist comes back home and remembers the experience through photo albums, souvenirs and storytelling. At this phase of the tourism 2.0 lifecycle, the main ICT tools are those based on sharing services, as in the dreaming phase. The meaning of using specialized portals to share photos, videos, stories and opinions on visited places is to collect some snapshot of the vacation in order to recall its memory and to give tips and advices on the experienced tourism destination.

4 CNs Model to Deliver a Competitive Augmented Tourism Experience in a Tourism Destination

An extensive literature recognizes benefits deriving from CN agreements both from partner organizations and customers. The satisfaction of customers' expectations, create wealth for CN members giving value for both parties, according to a win-win logic. Organizations operate in collaborative networked environments seeking for complementarities that allow them to offer integral and personal experiences around their products and services for a specific customer at any specific time, location and context [19]. Collaboration allows the leverage and rapid configuration of resources as well the possibility for organizations to continually disintegrate and reintegrate themselves in order to quickly respond to customers preferences, providing the basis for agility in dynamic markets [12].

For tourism destinations, increasing request of augmented tourism experience obligates tourism operators to create new and improved services, to adjust them to individual consumer needs and specific interests, to deliver up-to-date information and knowledge sharing systems supporting the self-configuration of tourism packages. Considering that an augmented tourism experience is based on a wide range of heterogeneous aspects (including transportation, accommodation, catering, entertainment, cultural heritage, information systems, knowledge sharing), service providers have to either integrate their resources and organizational systems with others to form networks able to exploit market opportunities. Motivations to establish a CN among operators of a tourism destination also reside in the business flexibility that such model guarantees to partners in the configuration of an augmented tourism experience. Concentration of each member on core competencies, charging the marketing and information services to a destination manager, strong orientation to tourists' needs, creation of value-adding tourism services are the main competitive advantages of CNs. Competitivity of a CN strictly depends on a correct exploitation of the ICTs which are the enabling factor for a modern CN rise and development. On the one side, ICTs are a means for coordination and control of CN activities, inter-organizational business process automation, and decisional support. On the other side, ICTs can create an efficient and immediate interface between the destination and the web tourists; they can utilize the information and booking services, made available by the destination manager, for their needs during the 2.0 lifecycle.

The set of information shared among each service provider and its customers, concerning the context in which information services are used, can be exploited to generate more detailed knowledge about visitors' mobility at the destination. Immediate feedbacks of marketing choices come both from data-mining of tourism experience choices and from social networking analysis activities; they could be used to support destination managers in their decision making processes [20]. Data obtained from all the networked operators can be used to analyze the spatial and temporal behavior of the entire body of subjects in aggregate. The destination manager can analyze and aggregate data coming from each service provider in the CN to understand the way in which space and time are consumed in order to formulate a more reasoned tourism planning policy aimed to manage the tourist flows in a more rational manner, to relieve the burden from the destination's more congested areas, to encourage tourists to explore other less visited sites or to buy less purchased services. The result would be a more coherent pattern of tourist temporal and spatial activity, which would benefit tourists and the destination as a whole [20].

5 Operationalizing the Concept of CNs in Tourism: Tourism Breeding Environment and Forms of Collaboration

From an operational point of view, when some of the tourism service providers decide to reinforce collaboration, they can set stable prescriptive agreements in the forms of Touristic Associations, Syndicates, Touristic Consortia or Touristic Districts, adhering to a base long term cooperation agreement, and adopting common operating principles and infrastructures which constitute the framework of the tourism supply chain. Each agreement characterizes the organizational form of the tourism supply chain in terms of structure of membership, activities, definition of roles of the participants, governance principles and rules. In this study, we name each of such agreements as a ***Tourism Breeding Environment*** (*TBE*) i.e. a *Breeding Environment* [21] in tourism sector whose members (i.e.: **the tourism service providers**) share values, culture and infrastructures and have the potential and the will to cooperate in order to pursue the general long-term objectives of territory development and competitiveness.

In a TBE the tourism supply chain control and ownership are distributed among members. They generally appoint the tasks of activities coordination and supply chain management to a ***Destination Management Organization, DMO***, which creates and manages an overall strategic plan for the tourism destination development. It can be a public institution or private organization that aims to promote incoming tourism (territorial marketing) selling composite packages of hotel accommodation, excursion tickets, and other services.. According to Fabricius et al. [22], focus of the DMO is to look inward and towards destination to ensure the quality of the visitors stay while its fundamental task is to create a sustainable breeding environment on which the marketing of the destination and the delivery of the experience are dependent. *A strong DMO will be necessary to provide the leadership and to drive and co-ordinate this process. Creating the right environment includes: planning and infrastructure, human resources development, product development, technology and systems development, related industries and procurement.* Besides its strategic planning and control tasks, the DMO is charged to manage the operational flows related to the service delivery on the ground. This means that the DMO ensures the quality of every aspect of the visitor's experience once they arrive at the destination.

Members of a TBE compete with the others and with players outside the TBE in searching for new business opportunities in the global market. When a business opportunity is identified, a subset of the TBE members can be rapidly selected to become part of a short term ***Collaborative Networked Organizations, CNOs,*** oriented to catch the opportunity [12]. Scholars analyzed several cases of such kinds of CNOs in the tourism sectors. Akoumianakis [23] uses the term *cross-organizational virtual alliances*, referring to the *affiliation of partners* in collaborative product development (dynamic packaging) in tourism sector [24], *strategic business network* in cruise-tourism sector [25] *virtual tourism business system* [26].

Although characterized by different contexts, development paths and, also, terminologies, we can cluster classify the different instantiations of CNOs in tourism in only two kinds of short term CNOs that are most evident in a TBE:

Tourism Extended Enterprise (TEE): it refers to a tourism operator that "extends" its business boundaries by involving all or some of its suppliers in the product packaging and delivery in order to offer customers possibilities to a more complete tourism experience. For example, a TEE can be formed by a hotel that stipulates commercial agreements with restaurants, lidos, amusement parks, cruise ship companies. Tourist perceives the overall TEE offer as a whole and, typically, purchase it directly at the hotel (web) site.

Tourism Virtual Organization (TVO)***:*** It represents a temporary alliance of private and public organizations that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose collaboration is supported by computer networks. A TVO is established in a short time to respond to a competitive market opportunity; it has a short life cycle dissolving when the short-term purpose of the TVO is accomplished [27]. New trends in tourism sector demonstrate a growing interest for customers towards the self-creation of personalized tourism packages. Availability of systems for tourism packaging enable tourist to (self) compose a personalized tourism product choosing a subset of services provided by TBE members (e.g.: 2 nights in the hotel A, 1 night in the hotel B, 2 meals in the restaurants C, 1 ticket for a football match, etc.). Members of the TVO collaborate in order to respond to a market opportunity provided by the tourist and they will work together until their short-term purpose is accomplished.

6 Conclusions

The importance of a distributed and efficient supply chain management for a tourism destination is related both to the possibility to give sustainable development to the destinations, in the effort to overcome limits of touristic organization's size and reach economy of scale and competitiveness in contrast to big players; and to the necessity to answer to the request of personalized tourism offer, in line with the new demand trends. Many case studied confirmed that a common planning of networked organizational models and ICT supporting solutions make possible the operationalization of the collaboration concept in the tourism sector and the setting up of CNs in a TBE. In this paper we further motivated the adoption of CN models for a tourism destination highlighting how globalization and ICT evolution made much more efficient and timely the way both of being a tourist (introducing the *tourist 2.0 life cycle* and the *augmented tourism experience* concepts) and to manage, coordinate and control activities of networked organizations.

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Collaborative Networked Organizations as System of Systems: A Model-Based Engineering Approach

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Abstract. It is admitted that there is parallel between a System of Systems (SoS) and Collaborative Networked Organizations (CNOs). SoS Engineering (SoSE) carefully focuses on choosing, assembling and interfacing existing systems to build the so-called SoS. In this context, and as demonstrated by the literature and the System Engineering domain, interoperability takes on its full meaning and has to be fully considered as a decisive factor when organizations set up a CNO. This paper proposes to 1) model the SoS through a meta-model that includes concepts which 2) enable interoperability modeling and the analysis of its impact on the SoS' characteristics, stability, integrity, performance and behavior. The proposed analysis is based on a verification approach mixing simulation and formal proof techniques.

Keywords: Collaborative Networked Organization (CNO), System of Systems (SoS), System of Systems Engineering (SoSE), Interoperability, Modeling, Verification.

1 Introduction

Today's organizations tend to set up their Collaborative Networked Organization (CNO) by integrating more complex and capable entities. This collaboration helps to overcome the limitations of each organization to achieve a common mission that an organization alone cannot achieve [1]. In this sense, a CNO can be considered as a System of Systems (SoS) in terms of the ARCON reference modeling framework [2]. Hence, System of Systems Engineering (SoSE) started to be a critical need to conduct such complex and large systems design in the context of sociotechnical environments. SoSE can be distinguished from the classical System Engineering (SE) [3]. Beyond the classical SE, SoSE carefully focuses on choosing first the entities (i.e., existing, pre-defined entities) that will form the SoS, then assembling and interfacing them to allow their interaction. In this context, the interoperability of each entity takes on its full meaning and has to be considered prior the assembling. Assembling the entities establishes some kind of interactions between them. This imposes to define and validate interfaces of various types (e.g. physical, procedural, etc.) to facilitate and permit these interactions. In other words, defining the interfaces allows entities to improve their capacities to work together, i.e. to enhance their interoperability,

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without huge efforts or reverse effects. The requested interactions between socio-technical entities are not been yet addressed by the literature. It is a new challenging area and there is a trend toward discovering it [4]. Therefore, it is required to enable to manage various kinds of interactions between the entities.

This paper focuses first on the similarity between SoS and CNO. Afterwards, it analyzes the relationship between the interoperability and other SoS' characteristics. It contributes then to the field of the SoSE by introducing a means to better understand the interoperability's impact on the SoS' analysis perspectives defined here as stability, integrity and performance as proposed in [5]. The first objective is to develop a Domain Specific Modeling Language (DSML) that allows having a working environment to model the SoS and analyze the SoS model in a coherent way. This DSML permits to consider the SoS dynamicity and to describe SoS' global architecture considering interoperability and analysis perspectives dimensions. The second objective is to assist managers, engineers and designers, involved in SoSE process in achieving verification tasks and particularly to check the relationships between interoperability and the other SOS' characteristics described below. This is based on a verification approach applied on the SoS model and on complementary formalisms (formal proof of properties and simulation techniques).

2 SoSE Principles

SoS vs. CNO - Giving a definition for the SoS and CNO is required to draw a parallel between these two concepts. The literature provides a large number of definitions given to the SoS. However, this paper will not delve into the current debate of choosing an appropriate definition. Thus, and in attempt to come to terms with these definitions, it is largely agreed that a SoS is seen as a group of, in most cases, existing entities assembled together to interact, during a timeframe, to produce some kind of capabilities, products or services and to **achieve a global mission** that a system alone cannot fulfill [6]. Moreover, there are seven crucial characteristics for the SoS [7][8], such as: **Operational Independence**, **Managerial Independence**, **Evolutionary Development**, **Emergent Behavior**, **Geographic distribution**, **Connectivity** and **Diversity**. SoS' size, its complexity and its characteristics, induce an additional effort over the SE [3] to respond to what it is expected from the designed SoS.

On the other hand, a collaborative network is "*a network consisting of a variety of entities (e.g. organizations and people) 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***, *thus jointly generating value, and whose* ***interactions*** *are supported by computer network*" [1]. Furthermore, most CNs require an organization over the activities of their entities, fixing roles for the participants, and some governance rules. Therefore, these CNs can be considered as manifestations of CNOs. The hereinbefore definitions highlight the first similarities between some SoS and CNOs fundamental characteristics. Furthermore, both SoS and CNO life cycles draw the second line of similarities. At macroscopic level, a CNO life cycle comprises at least four phases known as Creation, Operation, Evolution, Dissolution, or eventually Metamorphosis [1]. During the Creation phase (corresponding to the Assembling phase of the SoS), the entities that will form the CNO are selected depending on their capacity to participate in performing the global mission and their abilities to interoperate. In the Operation phase (Connectivity phase of the SoS), entities are supposed to be able to exchange, cooperate and interact together. In the Evolution and Metamorphosis phases (Evolution phase of the SoS), internal and external changes occur, e.g. adding, removing, updating entities, or even when major changes in objectives or principles take place. In Dissolution phase, CNO ceases to exist and each entity returns to its own mission.

***Interoperability vs. CNO Analysis Perspectives* -** Two entities are interoperable if they are capable of establishing a link that allows them to perform a mission and to destroy it once the mission is accomplished. We argue that there is a strong linkage between interoperability and the CNO's basic characteristics. This link concerns the CNO's life cycle and all CNO's entities for the following reasons. First, each CNO's entity can evolve separately from the other entities, therefore CNO's entities have to be capable of building links with each other among their interfaces and destroying them dynamically [8]. Furthermore, it becomes possible to easily remove, modify or add an entity. This **dynamic evolution** is consistent with the loosely coupling hypothesis offered by interoperability. Second, entities are of **heterogeneous** nature (notion of diversity) but have effectively to be able to exchange with each other without enormous effects. This is consistent with the 'without interfacing effort" (plug and play) offered by interoperability. Last, entities must stay **independent** in an operational sense (they continue to provide flows and services corresponding to their own mission) and managerial sense (they remain able to take decisions). Once more, this is consistent with the hypothesis of **autonomy** offered by interoperability [9].

A lack of interoperability of one or several CNO's entities can impact the CNO's analysis perspectives:

- **Stability** is the quality that reflects the CNO ability to maintain its viability and to adapt to any change in its environment [5] (e.g. adding a new entity) by returning to a previous known and controlled functioning mode. A CNO shows both homeostasis and adaptive behavior, as it can constructively respond to disturbances or novel environmental conditions. Therefore, improving the interoperability helps to ensure and to increase the CNO stability all over its lifetime even if none of the existing architectural styles of self-adaptation for SoS guarantee the SoS' stability [10].
- **Integrity** is the quality that reflects the CNO ability to maintain its viability and to adapt to any change in its environment when facing a local modification e.g. modifying or removing one of the existing entities. If an entity inside a CNO is interoperable then it is able to pursue the collaboration without huge impact on the global behavior. In the same way, if this entity has to be replaced, then the requested interoperability level of the new one guarantees a well-functioning of the whole CNO.
- **Performance** is the quality that reflects the CNO ability to reach its performance's objectives. The goal here is not to guarantee a maximum level of performance but to become able to meet more rapidly a sufficient level of performance. For this, the 'plug and play' vision, permitted by an interoperable entity, seems more interesting because it allows reducing time, costs and efforts requested in case any changes in the CNO's entities take place (adding, leaving, modifying).

SoSE Needs and Work's Contributions - Considering the similarities between CNO and SoS, it seems hazardous to build a CNO without engineering approach such as proposed for SoS and named SoSE. The subject of SoSE versus SE is debated in the literature. Some authors agreed that SE principles, processes and standards are enough to perform SoSE activities [11] and no additional processes are needed. However, SoS characteristics, assembling, interfacing and interactions between its entities, induce an additional effort over the SE [3]. SoSE is classically considered as a model-based approach. A model helps to address new requirements, presents a better understanding of the SoS' entities and their relationships, it helps to understand the SoS functionality and monitors and assesses changes all over SoS evolution. Therefore, as in any other scientific or engineering discipline, the first need is to propose relevant modeling languages to better understand the SoS area and to supervise and manage the operations of the SoS during its life cycle. Furthermore, a model should help to predict and simulate behaviors and offer a means for better decision-making. The existing modeling methods do no cover all the needs of CNOs and there is no single formal modeling approach to model all CNOs problems [12]. Therefore, this research addresses the first SoS need by proposing a 1) meta-model that groups all concepts and relations required to model various kinds of SoS (CNO). Moreover, decision-making in all SoS' lifecycle should be based on well verified models. Therefore, 2) verifying the SoS model is the second SoS' need.

3 SoS Modeling Languages

The modeling phase contains, on the one hand, a tailoring of existing and traditional SE modeling languages focusing on requirements, functional and physical modeling. On the other hand, this phase requires having a means and languages for describing behavioral aspects and particularly to describe interactions between the SoS' entities (see Fig. 1). Available DSMLs do not allow to model seamlessly and homogeneously the four views of the SoS. The here developed DSML offers a unique and homogenous environment that allows at the same time, (1) to model the SoS, and (2), to analyze the impact of the interoperability on the SoS analysis perspectives.

Requirements Modeling Language (ML): Requirement engineering activities for a SoSE are greatly expanded. To understand the SoS requirements, they should be modeled at different levels and from three viewpoints. The first viewpoint is the users' perspectives (stakeholders' requirements). The second viewpoint covers the entities' requirements. Finally, and at the highest level, the third viewpoint which is the SoS requirements / characteristics that have to be respected and maintained all over its life cycle. Moreover, during SoSE and further to the traditional "*-ilities*", new ones, such as adaptability, **interoperability**, flexibility etc. are imposed.

Physical ML: In SoS, it is important to understand the set of entities which enable the SoS capability and to understand how these entities are interfacing together to interact and contribute to the SoS objectives. Interfacing the entities appears in the creating phase of the CNO life cycle. One of the famous problems in CNO is the physical integration of multiple entities due to the diversity of interfaces [13]. Assembling the entities establishes some kind of interactions which make them able to work together. These interactions impose to have interfaces of various type:

technical (respecting general standard of physical interconnection of technical systems, software etc.), physical (hardware), informational (model, knowledge, information and data exchange protocols), organizational (communication rules, separation process public/private, protocols and rules of: organization, control, taking responsibility, delegation etc.) or HMI (human machine interface). These interfaces are necessary to ensure entities' interoperability. The challenge raised here is to design the interfaces which will improve the interoperability by managing the interactions without affecting the entities. This phase will facilitate the verification phase where a part of it has to be done on the interfaces between the SoS' entities.

Functional ML: CNO function is the collection of coherent processes, which perform in a continuous way within the CNO, to support the CNO's mission. SoS functional architecture is the premier key for the SoS' success. Its architecture should resemble the entities and SoS functions. CNO life cycle helps to draw some functions to consider in the functional architecture. The minimal life cycle of CNO comprises four phases and, during these phases, new functionalities and requirements are elicited. These functionalities are ensured by a set of core elements of the here-proposed SoS model. The functional concepts of the "Creation" phase cycle of the meta-model do not fully deal with the partner's selection. Multiple researches contributed to the partner's selection during the assembling phase of the SoS [14]. However, this SoS model facilitates this selection by analyzing their aptitude and capacity required to provide the services/products/resources which allow them to participate in the SoS's global mission. Moreover, this model offers a means to select the partners' with compatible interfaces adapted to allow interoperability.

Behavioral ML: The interactions between entities are important to fulfill the SoS' mission, or also to prevent and avoid any identified or even identifiable disturbing events or risky situation. However, these interactions can be at the origin of various emergent behaviors and properties that remain not predictable. Therefore, it is essential to model them to improve the local interoperability between entities and to allow controllability of their impact on the SoS. The interactions between the entities of the CNO appear mainly in the operational phase of the CNO life cycle. This phase includes some functionalities such as: Basic information exchange interactions, Events/exception handling, Advanced cooperation, Material/services related aspects and collaborative environments [15]. The partners/entities must ensure that the interactions between them are effective and, eventually, that their autonomy (operational and governance autonomy – managerial and operational independency) is preserved. An *interaction* is an emission of a source entity - *SoSEntity* (materialized by a *Flow* or *Field*), that impacts directly or indirectly the state of one or more destination entity - *SoSEntity* leaving a concurrent/non-concurrent *Effect* on each of these destinations. An *Effect* is the embodiment of an *Interaction*. It is the result manifested by the impact on the structure, mission and/or behavior of a *SoSEntity* in terms of analysis perspectives (Stability, Integrity and Performance). An *Interaction* is caused by a reaction, a feedback, *Event* or a chain of events. An *Event* announces a *Risk* which is produced only and only if there is a *Danger* and *Vulnerability*. A *Danger* is caused by an *Event* or a combination of events. Moreover, a *Risk* can have serious impacts on the mission of the SoS (functional aspect - performance) and/or its structure (organic aspect- *SoSEntity* - costs) and consequently on the system usage.

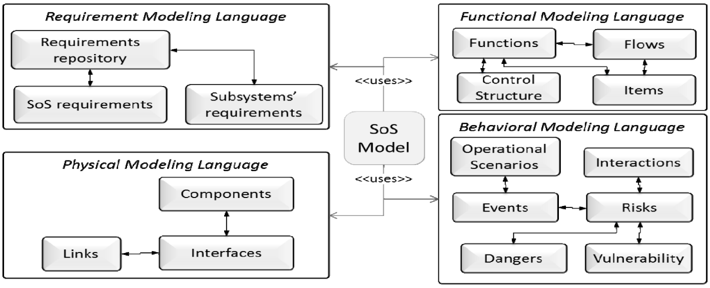

Fig. 1. Main concepts and relations modeling elements for building SoS model

4 Verifying the SoS Model

Verifying the SoS model, whatever may be its size and complexity, is not being yet fully discovered by the research. The goal here is to check that the SoS' requirements have been taken into account when building the SoS model. Some of these requirements focus on the interoperability. The proposed verification technique intends to mix execution and formal proof techniques. The execution allows simulating the SoS' model behavior and formal proof techniques allow proving properties. Indeed, requirements are being formalized under the form of provable properties. As described in Fig. 2, the execution consists first on launching one modeled operational scenario which describes how a SoS may evolve in a particular context. A set of *D*isturbances *D* is defined according to a repository that includes types of disturbances such as adding new entities, retrieving entities, modifying entities, etc. For a chosen scenario, a set of interoperability requirements to analyze is fixed (phase 1) *e.g.* an acknowledgement is requested after an exchange of flows between entities [16]. The simulation is then launched. With each instant *T* a disturbance D occurs (phase 2), the simulation is stopped and the SoS model state (*S*) is frozen (phase 3). The selected properties are then formally proven starting from the current state *S* (phase 4) and ending with the set of future reachable SoS model states (*S'*). S' are obtained by using an execution path finding algorithm starting from the initial S. Moreover, S' might be fully independent of the initial operational scenario. The formal proof is done by using a model checking technique [17]. The goal is to detect changes in terms of requirements that are not checked at a specific moment. Furthermore, these changes can be detected for all future states that become reachable due to the behavioral interactions between the SoS' entities. Any modification in the interoperability requirements induces a variation on the SoS' analysis perspectives. As presented in Section 2, if the interoperability is improved, the SoS integrity and stability are improved due to the notion of "plug-and-play" of the interoperability. However, the SoS performance might increase or decrease. For example, if the frequency of the information exchange rate between the SoS' entities increases, theoretically this induces an improvement in the SoS performance, however, if any entity cannot/not ready to absorb the increased frequency, this will induce a decrease in the performance. In other words, if an enterprise A is sending products to another enterprise B in the same CNO at a frequency F, if F increases, the SoS performance increases since the production/sending frequency is now higher, however, if B does not have the enough capacity to receive/stock the products at this frequency, this induces some kind of system overload and the SoS performance will then decrease. Therefore, this kind of variation has to be interpreted on the model by an expert after fixing him a set of rules which allows him to make the correct interpretation. The simulation will resume until every possible disturbance is injected (phase 5).

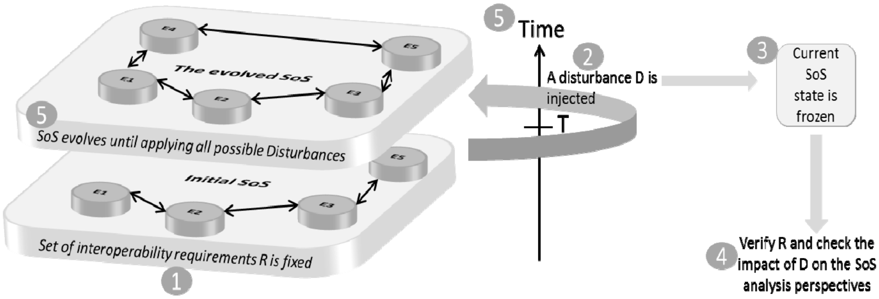

Fig. 2. Verification methodology mixing simulation and formal proof techniques

Aspect Waving Model approach based on a meta-programming environment e.g. Kermeta [18] is used for simulation. The advantage of using the Aspect Waving Model approach is to avoid the data loss and time consuming resulted from transforming the modeling language into other language (e.g. Multi-Agent language). It is possible, by using this approach, to recover the developed model without any transformation, to add properties on the fly (attributes and methods) and to describe the behavior of each method (by giving it an operational semantic). However, the use of the Model Checking requires having a deterministic SoS behavioral model. Therefore, a step-by-step simulation has been used here where it is possible to have a deterministic SoS behavioral model at a definite instant of the simulation.

5 Conclusion and Perspectives

CNO and SoS share the same crucial characteristics. Therefore, SoSE is used to guide the CNO. Interactions between subsystems are required to achieve SoS' global mission. However, these interactions impose to have interoperable systems. This paper has shown how interoperability shares common characteristics with the SoS and how it impacts the SoS' analysis perspectives. A SoS model has been presented. It describes the SoS behavior and the interaction between its entities. A verification approach based on formal proves and simulation has been proposed. It helps to understand the interoperability's impact on the SoS' analysis perspectives.

We aim to propose an interoperability requirements repository and to define an operational semantic for the proposed DSML to make a model provable and interpretable i.e. to permit the simulation of the SoS behavior taking into account its environment. We are willing to verify the consistency of the developed meta-model, refine it with the new interoperability requirements, verify that all the interaction have been considered and finally check that the SoS' analysis perspectives remain relevant.

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Cyber-Physical Systems

A Framework for Energy-Efficiency in Smart Home Environments

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Abstract. A resource-efficient Europe is a pillar of the EU 2020 program which aims at smart, sustainable, inclusive growth. The diffusion of smart networked environments, wherein humans, intelligent agents and devices collaborate, is fundamental for achieving energy-efficiency in buildings. In this context, this paper deals with the topic of Smart Home Environments (SHEs), where users can exploit multimedia services to interact with heterogeneous and interconnected smart appliances in order to save energy, reduce costs and improve users' comfort and safety. In particular, we propose an interoperable architectural framework and a related knowledge-based management model, associated with a specific forecasting model, for monitoring and managing energy consumption in SHEs.

Keywords: Energy Efficiency, Smart Home Environment (SHE), Interoperable Home Energy Management Systems (HEMS), Information Management Model, Energy Consumption Forecasting.

1 Introduction

Recent years have been characterized by a growing awareness towards sustainability and energy-efficiency issues, which have taken a central role in the debate on energy policies. In this scenario, it has been clearly shown that energy efficiency in the buildings sector is one of the keys for reducing overall energy consumption and greenhouse emissions [1]. Nowadays, commercial and residential buildings represents nearly 40% of yearly total energy consumption in most developed countries and are responsible for a similar level of global CO_2 emissions [2]. In particular, residential buildings are becoming one of the major contributors to the countries energy balances, due to growth in population, increasing demand for home services and comfort levels, and rise in time spent in them.

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A large number of options can be implemented to reduce the end-use energy consumption and greenhouse gas (GHG) emissions in the residential sector. These also include optimizing the home energy efficiency through improving the building envelope characteristics, replacing existing heating equipment and household appliances, using higher efficient lighting sources and switching to less carbon-intensive fuels for space and domestic hot water heating. Among the various approaches for optimizing energy efficiency in buildings, collaborative and interactive Home Energy Management Systems (HEMSs) offer an interesting alternative to save energy, reduce costs and, at the same time, improve users' comfort and safety in home environments [3].

Until a few years ago, the lack of really interoperable and collaborative HEMSs has represented a matter for monitoring and managing in real time energy consumption in a home environment [4]. Recent advances in Information and Communication Technologies (ICT) tools and Internet of Things (IoT) approaches have led to the development of various solutions of HEMSs for "Smart Home Environments" (SHEs), featuring heterogeneous and interconnected smart home devices with local intelligence and connectivity services and, therefore, able to acquire, manage and apply knowledge about the environment, to interact with other smart objects and to adapt their behaviour according to the needs of the home inhabitants [5]. A deep review of such systems and technologies is presented in [6]. Nevertheless, the interoperability between typical home sub-systems and appliances still remains an open issue, also due to the different system architectures, device characteristics, communication protocols and syntactic rules of the different proposed solutions [6].

In this context, we propose a general architectural framework and a knowledge-based management model for monitoring and managing in real time energy consumption in typical real home environments, where most of the existing heterogeneous sub-systems and appliances are lacking of intelligence and connectivity services. In particular, in order to achieve energy and cost saving, as well as users' comfort and safety, the proposed architecture features smart peripheral devices and a central management system, which provide the network interoperability and the implementation of some energy-control services, also performed on the basis of energy consumption predictions by exploiting a specific forecasting model.

2 Smart Home Environment Architectural Framework

The traditional concept of collaborative networks as aggregation of companies and their supply chains is evolving toward a wider concept [7] known as "collaborative ecosystems", i.e. smart networked environments wherein humans, organizations, intelligent agents and devices collaborate. In fact, notions such as sensing enterprises, collective awareness systems, smart cities, and ambient intelligence, that are emerging in recent years, are expressions of new collaborative ecosystem paradigm, being applicable in many fields, such as security, transportation, construction, education and manufacturing.

This concept can be also applied for energy-efficiency in SHEs, where heterogeneous devices need to perform joint execution of tasks in an efficient and collaborative manner to be really interoperable [6], also according to the users' needs and habits, and to the particular state conditions of the considered environment. Indeed, being distributed architectures, SHEs need a certain degree of interoperability to manage sub-systems and appliances which are typically developed in isolation and, consequently, feature different operating systems and connectivity services [4].

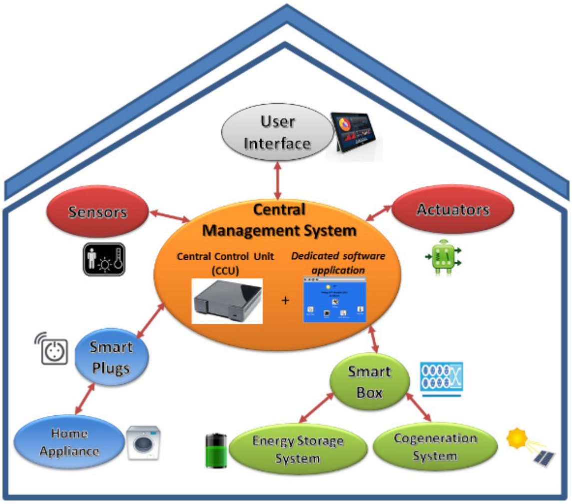

Fig. 1. Proposed architectural framework for SHE

In order to achieve the interoperability in existing home environments, the proposed architectural framework, shown in Fig. 1, is based on a centralized model. In particular, the central smart management system, consisting of a Central Control Unit (CCU) with a dedicated software application, “talks” to all involved actors within the home environment (such as users, sensors, actuators, home sub-systems and appliances, energy service providers, etc.) through different technologies (e.g., powerline, Ethernet, wireless, web-based). Therefore, the CCU represent the data-aggregation gateway and the decision-making core of the system: it interacts with all involved actors, collects and processes in real time all information about machine-to-machine and machine-to-human interactions, and, consequently, makes decisions, also on the basis of energy consumption predictions, by taking into account a defined set of decision algorithms and interoperability rules.

In Tab. 1, all the elements of the architectural framework and their related services are described. It is worth noting that, in the proposed model, the communication between the central management system and an existing home appliance (e.g., refrigerator, washer, TV, etc.) is provided by the use of a specific smart peripheral device, shown as “smart plug” in Fig.1, thus adding intelligence and connectivity services to the related appliance. In particular, as reported in Tab. 2, this smart object allows the implementation of some energy-control services on the connected appliance, such as the monitoring of device energy consumption and status (on/off), and the activation/deactivation of the appliance in response to CCU and/or user requests. Another fundamental element in the proposed framework is the “smart box” (see Fig. 1 and Tab. 1). This peripheral device provides some significant energy-control services to the system. Firstly, it allows the monitoring of overall energy consumption in the considered home environment. Moreover, through the use of such device, the system is able, in response to CCU and/or user requests, to integrate the energy supplied by the power grid with the energy provided by a local cogeneration system and/or a local energy storage system, and to manage the recharge of the latter.

Table 1. Architectural elements of the proposed SHE model

Element	Services
Central Control Unit (CCU)	- Communication with all involved actors of the system (smart peripheral devices, sensors, actuators, users, energy service providers, etc.) through powerline, Ethernet, wireless and/or web-based technologies. - Collection, interpretation and elaboration in real time of all data concerning machine-to-machine and machine-to-human interactions (e.g., energy consumption of home appliances, environmental data, user request, etc.) for statistical and training purposes. - Prediction of home energy consumption and environmental conditions. - Sending of control signals to peripheral devices for energy-control services based on a defined set of decision algorithms and interoperability rules, also in response to the performed predictions, as well as to specific user requests. - Detection of abnormal situations and failures, and subsequent generation of alarm signals on user interface devices through an appropriate notification system.
Sensors	- Detection of environmental data (e.g., user presence, temperature, lighting, etc.) - Sending of environmental data to the CCU.
Actuators	- Execution of operational actions on home sub-systems or appliances in response to CCU and/or user requests.
Smart Plugs (SPs)	- Energy consumption monitoring of the connected appliance. - Detection of the operating status (on/off) of the connected appliance. - Sending of energy consumption and status information to the CCU. - Activation or deactivation of the connected appliance in response to CCU and/or user requests.
Smart Box (SB)	- Monitoring of overall energy consumption in the considered home environment. - Integration of the energy supplied by the power grid with the energy provided by a local energy storage system and/or a local cogeneration system in response to CCU and/or user requests. - Managing of the recharge of the local energy storage system in response to CCU and/or user requests.
User Interface (UI)	- Interaction with users through dedicated web-based or mobile Apps.

3 Information Management Model for Energy-Control Services

The proposed architectural framework features a set of peripheral devices, such as sensors, smart plugs and smart box, which make available a large quantity of data within the considered home environment. In order to fully exploit such amount of information and the device interoperability, it is needed to define a fruitful knowledge-based management model whereby all data can be collected, interpreted and handled to support real-time decisions for energy- and cost-control services, as well as for comfort and safety purposes, also on the basis of users' needs.

Fig. 2 shows the proposed information management model, according to the previously described architectural framework. As already stated, the central smart management system operates as data-aggregation gateway. Indeed, the CCU interacts with all involved actors within the SHE through different technologies: for example, it can communicate with all the peripheral devices (smart plugs, smart box, sensors and actuators) through powerline and/or wireless technologies, and with the users and the energy service provider through dedicated web-based interface Apps. Therefore, all information about machine-to-machine and machine-to-human interactions is collected through the Middleware Gateway, and stored in real-time in the Knowledge Repository, as described in Fig. 2. Then, the central management system interprets and processes all data in order to make real-time decisions and, consequently, to perform automatic actions for intelligence-based energy-control services (such as the smart scheduling of events and scenarios, the energy overload management, and the smart scheduling of the recharge of the local energy storage system), also on the basis of energy consumption predictions.

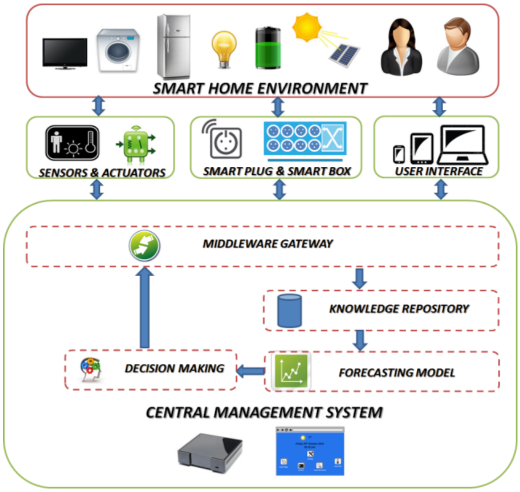

Fig. 2. Proposed information management model for SHE

4 Energy Consumption Forecasting Model

As highlighted in Fig. 2, in most cases, the implementation of management services requires a foregoing prediction of energy consumptions and environmental state conditions in the considered SHE, through the application of quantitative forecasting methodologies for analysis of historical data, in order to provide the adaptability of the system to the user's habits and needs [8]. For example, accurate forecasting allows scheduling energy- and cost-saving actions, such as suggesting which are the best time slots for using some home appliances or else when it is most convenient to recharge and use the energy storage system managed through the smart box, or else which energy source to be used for charging the energy storage system among those available (i.e., the cogeneration plant or the traditional power grid).

In order to define an appropriate model for home energy consumption forecasting, firstly, it is necessary to identify the characteristics of time series related to the historical energy consumption data. To this purpose, several authors have been observed that, even if the exact shape of the energy load curve depends on the region, the climatic conditions and the users' behaviour, long-term series present a specific seasonality component and, consequently, a certain degree of regularity [9-10]. In particular, it is possible to observe two seasonal cycles in yearly home energy consumption: an intra-daily cycle (i.e. the daily load profile) and a weekly cycle [10]. By taking into account these considerations about the characteristics of time series related to home energy consumption and basing on the results shown in [11], in this work we propose an extension of the Holt–Winters exponential smoothing formulation for the energy consumption forecasting model in SHE, in order to catch the two seasonal cycles (i.e., intra-daily and weekly) observed in the electricity demand time series. This leads to the introduction of an additional seasonal index in the original formulation, as well as an additional equation for the introduced index.

Let us consider $y_t, t = 1, \ldots T$ as the historical time series of hourly energy load in a SHE. We indicate with D and W, respectively, the intra-daily and the weekly seasonality components. Assuming that $y_t, t = 1, \ldots T$ is a continuous and regular time series, we indicate a and b as the smoothed level and the linear trend in the long run, respectively. Moreover, indicating with C_D the duration of the daily cycle and with C_W the duration of the weekly cycle, we assume, without loss of generality, that the available historical data are sufficient to cover an integer number $k_D = \frac{T}{C_D}$ of daily cycles and an integer number $k_W = \frac{T}{C_D}$ of weekly cycles.

Therefore, the formulation of the proposed forecasting model, based on the multiplicative seasonality, is given by

$$a_t = \alpha\left(\frac{y_t}{D_t * W_t}\right) + (1-\alpha)(a_{t-1} + b_{t-1}) \qquad t = 1, \ldots., T \tag{1}$$

$$b_t = \beta(a_t - a_{t-1}) + (1-\beta)b_{t-1} \qquad t = 1, \ldots, T \tag{2}$$

$$D_t = \delta\left(\frac{y_{t-C_D}}{a_{t-C_D} * W_{t-C_W}}\right) + (1-\delta)D_{t-C_D} \qquad t = C_D + 1, \ldots., T \tag{3}$$

$$W_t = \gamma\left(\frac{y_{t-C_W}}{a_{t-C_W} * D_{t-C_D}}\right) + (1-\gamma)W_{t-C_W} \qquad t = C_W + 1, \ldots., T \tag{4}$$

$$p_T(\tau) = (a_T + \tau\, b_T)D_{T+\tau} * W_{T+\tau} + \omega^\tau(y_T - ((a_{T-1} + b_{T-1})\, D_T * W_T)) \tag{5}$$

$with\ \tau = 1, \ldots, C_D$

Assuming that the forecast origin is T, in equation (5), $p_T(\tau)$ represents the τ-step-ahead forecast, while the term involving ω^τ represents an adjustment for first-order autocorrelation. It is worth noting that the prediction is carried out for a day-ahead time horizon. In our implementation of the method, the duration of the daily and weekly cycles, i.e. C_D and C_W, have been set as follows: C_D *=24,* C_W *=168.* The smoothing parameters $\alpha, \beta, \delta, \gamma \in [0, 1]$ and ω are estimated in a single procedure by minimizing the sum of squared one step-ahead forecast errors, while the initial values for the level, trend and seasonal components are estimated by averaging the time series.

For testing purposes, we have applied the proposed forecasting model to a real home energy consumption time series (see Fig. 3), taken from the website of the Italian grid operator for electricity transmission [12]. In particular, the considered energy consumption time series refers to a 28-days time horizon, from 17th of March to 13th of April 2014. Fig. 3 also reports the comparison of the results obtained through the implementation of our forecasting model with the real data measured in 14th of April 2014, showing a good fit between the forecasted values and the real ones. The smoothing parameters α=0.05; β=0.3; δ=0.7; γ=0.5 have been obtained by minimizing the Mean Absolute Percentage Error (MAPE). The calculated overall value of MAPE is 4,17%.

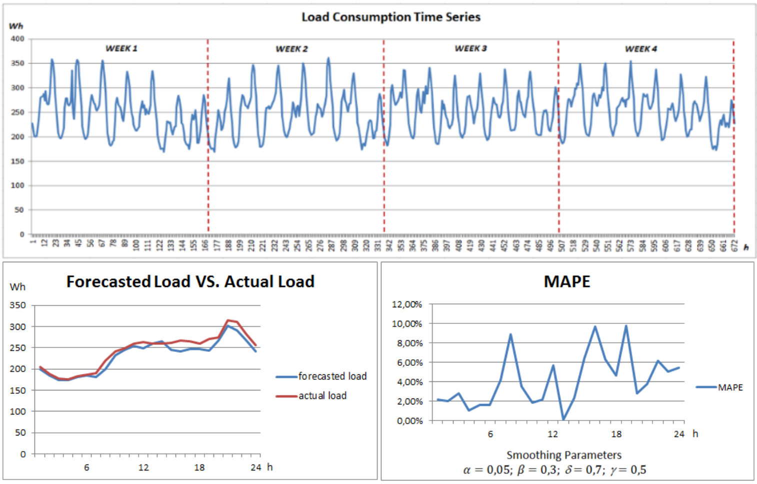

Fig. 3. The considered energy consumption time series in our test (on the top) and the comparison between forecasted and measured values (on the bottom)

5 Conclusions and Future Works

An energy resource-efficient Europe is a pillar of the EU 2020 strategy which aims at sustainable development. Over recent years, it has been widely shown that the diffusion of smart networked environments, wherein humans, intelligent agents and devices collaborate, is fundamental for achieving energy-efficiency in buildings. In this context, this paper proposes a general architectural framework and a related knowledge-based information management model, associated with a specific energy consumption forecasting model, for monitoring and managing SHEs, where heterogeneous and interconnected smart devices interact with the goal of saving energy, reducing costs, and as well as improving users' comfort and safety. Moreover, the proposed SHE framework, featuring a centralized model and a set of smart peripheral devices, is characterized by a low architectural impact, also due to the use of wireless and/or powerline technologies, thus making it well suited to existing home environments. The development of the hardware components (such as smart plugs, smart box and Central Control Unit), as well as of the knowledge-based management software of the system prototype is still ongoing, according to what presented in this paper. Once completed the development of the HW and SW components, future works will concern the testing of the system prototype in laboratory and in real home environments in order to validate our SHE architectural framework and the proposed information management model in terms of cost and energy saving.

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Towards a Generic Enterprise Systems Architecture Based on Cyber-Physical Systems Principles

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Abstract. Systems that can tightly integrate physical with virtual components have represented a priority for the research in the area of ICT. Research efforts have been concentrated in domains such as: Internet of Things, Internet of Services and recently in the domain of Cyber Physical Systems. An important driver for the area of research is represented by the large-scale integration of the physical and cyber worlds. The authors propose a Generic Information System Architecture for Cyber Intelligent Enterprise by taking into account the paradigms of Cyber-Physical Systems

Keywords: Cyber Physical Systems, Cyber Intelligent Enterprise, Future Internet.

1 Introduction

In order to benefit from novel business opportunities and increase their agility, enterprises should adopt a new generation of IT systems capable of (tight interaction) with the physical environment. These context-aware systems come in part as a realization of the pervasive and ubiquitous computing visions. In order to fulfill these novel computing paradigms, the next generation of enterprise information processing systems will have to be able to scale(execute on a spatially distributed array of computing nodes / devices) and to seamlessly integrate a multitude of heterogeneous data streams generated by a large number of connected devices. [9]

Lately, the research effort undertaken toward the achievement of this objective has received a major boost from the research into Cyber-Physical systems and Internet of Things. These two emerging areas of research have slightly different perspectives:

- The Internet of Things (referred as IoT) research is primarily aimed at developing technologies and system architectures, similar to those on which large-scale, loosely coupled systems are being built upon, such as the today’s Internet, in order to accommodate uniquely addressable virtual representations of physical devices. [10]
- Cyber-Physical systems on the other hand are focused more on the development of control theory – the study of systems with complex interactions between components unfolding over a wide range of temporal

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 245–252, 2014.

> and spatial scales. Cyber Physical Systems (referred as CPS) are defined by the National Science Foundation as engineered systems that are built and depend upon the synergy of computational and physical components and unlike the IoT vision, research into CPS doesn't explicitly aim at developing Internet scale systems. [8]

These research directions have covered the problem of system integration from slightly different perspectives, but their ultimate goal can be considered similar taking into consideration the proposed solutions.

In both directions, the research has been mainly driven by the possible future applications that a large-scale integration of the physical and cyber world will enable. Various overview papers in both Internet of Things [4][5] and Cyber Physical Systems [2][3] fields highlighted the benefits and impact that the developed systems might have.

2 Related Work

Research in the area of Future Internet with the main components: Internet of Things (IoT) and Internet of Services has been a priority for FP7 Research Program and is continuing and now integrating with research in the area of Cyber-Physical Systems in the emerging Horizon 2020 Research Programs.

The motivation of developing a Generic Enterprise System Architecture for Future Enterprise [8] is related to the following aspects:

- Enterprise Systems need the means to automatically acquire raw, partially processed or structured data through the help of sensing devices in order to generate information related to the real world.
- The dynamic character of the current economy is determining major changes in the enterprise strategy and organization, triggering new business methods, models and practices which requires agility from Enterprise System.
- Enterprise Systems need to process a rapidly increasing number of new heterogenic parameters and indicators.

Cyber-Physical Systems (CPS) concept integrates:

- Cyber, which refers to computation, communication, and control that is discrete, logical and switched,
- Physical which relates to natural and human-made systems governed by the laws of physics and operating in continuous time.

A generic CPS is composed of: physical objects, sensors, actuators, computing devices (e.g. controllers) and communication networks. [8], [9]

A paradigm shift form Information Society towards Knowledge Society is triggering a technology shift from Intelligent Systems based Enterprise towards Future Internet based Enterprise and Cyber – Physical Systems based Enterprise.

A generic model of the next generation of Enterprise Systems will be introduced, based on the paradigm of Intelligent Cyber-Enterprise. [9]

Intelligent Cyber-Enterprise combines the principles of Cyber Physical Systems and Intelligent Systems in order to facilitate human interaction with both physical and virtual environment, data acquisition and information processing, semantic interoperability and enterprise adaptability.

3 Generic System Architecture for Cyber – Intelligent Enterprise

In order to develop a capable (/viable/feasible) Cyber Intelligent System [8], [9], we consider the following major aspects:

- Physical device abstraction
- Information processing
- Domain representation

The system will need to employ powerful abstractions in order to be able to create accurate virtual representations of the devices that interact with the environment – sensors and actuators and their capabilities. Depending on the system's objectives, various abstractions can be used for these devices, but mainly the service computing paradigm is employed.

Domain representation is an important aspect of any system that integrates physical and virtual resources. It is essential for dealing with the heterogeneity of the system's components and the complexity of the environment. Following the large-scale adoption of Semantic Web technologies, the system's domain is usually represented through a set of ontologies – both generic and system specific. An under-explored aspect of domain representation is its dynamic nature. The domain representations evolve with the system as it gains concepts which increase its expressive power, allowing the system to deal with new situations. The evolution of the system's domain can be enabled by the information processing capabilities of the system such as determining new relationships between concepts, creation of new concepts and rules, importing schemas from legacy data processing systems such as relational or XML databases.

Taking into account these three functional aspects, we propose a generic architecture for a Cyber Intelligent Enterprise [9] system. The proposed architecture will have a layered structure:

- The lower level of the system contains the system's interface with the physical world / physical phenomena represented by the enabled devices – sensors and actuators – and the communication infrastructure required to connect them to the upper level
- The intermediate middleware layer that implements common operation related to the roles of a Cyber-Physical System
- The upper layer contains the systems applications that implement the domain specific logic(system specific objectives)

A generic architecture of a Cyber Intelligent Enterprise is presented in Fig1.

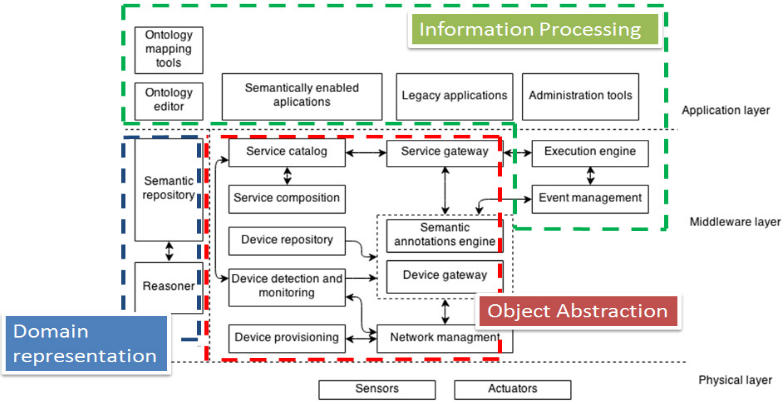

Fig. 1. The three main roles of each IoT / Cyber-Physical system

The middleware layer contains the following components:

- Network management components that manage all low level aspects of the communication with the enabled devices, such as network formation, device discovery and data transfer

- Device detection and monitoring component facilitates the implementation of self-configuration and adaptive behaviors. Using existing protocols such as Universal Plug and Play (UPnP), WS-Discovery, the component will detect when devices join or leave the network and publish the corresponding events to relevant system components or applications thus enabling the deployment of fallback strategies.

- The device gateway is an important component for realizing the physical device abstraction aspect of the system as it manages the instances of the device wrapping components. Based on device joining events generated by the device detection and monitoring" component, the device gateway will fetch and instantiate the corresponding device wrapping components from the device repository. These instances will be removed when the system detects that the devices are no longer present in the managed network. The device gateway contains a rule-based semantic annotator that updates the messages relayed to the upstream components with annotations referring to the system's ontology

- The device provisioning component allows the system to alter the pre-defined capabilities of the physical devices through firmware, a method already proved feasible [7][8]

- The device repository component manages the library to wrapper component for the devices supported by the system. Each of these specialized components must hide the device's proprietary interfaces and expose instead a uniform, semantically-enabled interface.

- Service gateway – manages the endpoints of the services defined in the system and represents the main access point for the top level applications to the available resources. In order to lower the requirements for the top level applications / to ease the process of integrating existing applications into the proposed system, the service gateway component should be able to handle various types of semantically enhanced web services such as OWL-S, WSMO, or semantically enabled REST – SA-REST

- Service composition – allows the creation of new services based on the existing resources / services available in the system with the aim of fulfilling a user specified objective. In order to simplify the underlying planning task, a user defined abstract composition template may be used. Early research into the problem of composing physical services, such as [6], has delivered encouraging results.

- Service catalog – represents the central repository of services for a node of the system. Novel service query and selection methods are required in order to deal with services referring to physical objects. [7].

- Event management – facilitates the usage of asynchronous, event-driven interactions between the system's components (and/or applications) by implementing the role of an event broker. Thus, it will accept events published by system components and route them to interested components that have previously registered matching subscriptions.

- Rule based execution engine – executes and manages a repository of simple, event-driven programs. It simplifies the deployment of new system behaviors by removing the execution responsibility from other components. These event-driven programs will be able to consume event, publish new ones and call any service registered in the system's service catalog. For describing these simple programs, a simple and portable language can be used, such as the SCXML (State Machine Notation for Control Abstraction), a new W3C submission.

- Semantic repository – stores and manages the system's ontology that includes not only the concepts required to describe the physical and virtual processes with which the system interacts, but also instances that represent system objects such as services, enabled devices, system components, etc. The semantic repository uses an external semantic reasoner for the deduction of implicit relationships between ontological concepts and to insure the validity of the representation.

In order for an Enterprise to be able to adapt to the changing environment, data collected from sensors must generate events leading to changes to the Enterprise Business Process.

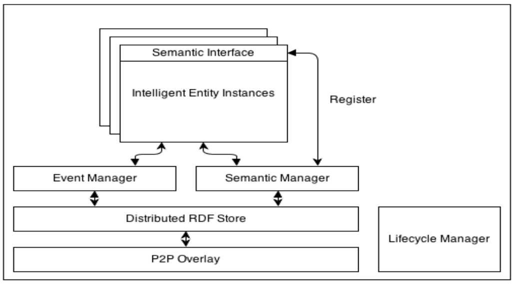

Fig. 2. Semantic interfaces representation [9]

With the vertical evolution of control system, up to the concept of Cyber-Physical Systems, the systems gained more autonomy by modeling more complex behaviors.

4 Enterprise System Based on Generic System Architecture

In this section the authors propose a fully-distributed ontology based implementation based on the Generic System Architecture presented in the previous section.

An important aspect of the system is represented by the ontology. The system's ontology is used to store not only the concept that describe the processes, virtual or physical, that the system interacts which, but also its structure, state and the available interaction mechanisms. As such, several classes in the ontology will be used to describe the structural aspects of the system such as Device, Component, Application and the interactions between components: Service, EventSink, EventSource. This approach will enable rapid development of flexible systems.

A distributed deployment of the system will require that a distributed RDF store is used as "Semantic Repository", allowing the storage of RDF triples in a structured P2P overlay and the execution of SPARQL queries with RDFS reasoning. A Distributed RDF Store component is created for each node.

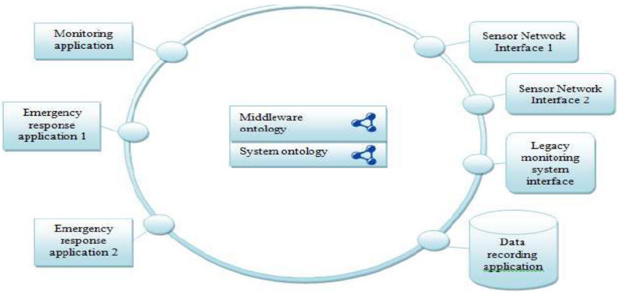

Fig. 3. Node block diagram

This component can also be used to build an implementation of the "Event Subscription Management" and "Event Routing" components, by applying the Triplespace computing paradigm. This will require the implementation of a continuous query processing algorithm, applications can register SPARQL queries and be notified when the selected information changes. The subscriptions will be queries selecting "EventSource" semantic instances. The Event Manager will transmit the event generation rule from event sinks to the event sources and will ensure the correct registration in the Distributed RDF Store of the semantic instances representing current event sources, event sinks and events. The Intelligent Entity Repository is a separate component in this implementation.

The "Semantic Manager" component: provides an interface to the Distributed RDF Store with OWL reasoning, allows the registration of the elements of the Semantic Interface exposed by each Intelligent Entity.

As mentioned in the previous, section, the system will allow the rapid deployment of simple, event-driven programs that will be stored and executed in the "Execution Engine" component. A snippet form one such program written in an extended version of the SCXML notation is described in "Listing 1". The program registers and event sink (event subscription) for the events generated by temperature sensors from the location with code "123" and an event source referencing the same location. The event source defines the channel through which the deployed behavior will generate its own events. The “Behavior Execution Engine” analyzes the content of the SCXML document on deployment and adds the semantic definitions contained by the “sinks” and “sources” elements in the system’s ontology. The events will be routed to the “Behavior Execution Engine” with the assistance of the “Event Manager” that processes the event sink definitions and transforms them into event subscriptions.

```
<state id="idle">
            <transition event="EventSink1"
cond="#{event.hasEventData.hasTemperature &gt; 25}"
target="alert" />
          </state>
          <state id="alert">
            <onentry>
              <send event="VirtualSensorSource1">
                <sys:EventData>
                  <sys:hasAlert>
                    <sys:Alert>
                      <sys:alertLevel>WARNING</sys:alertLevel>
<sys:message>Elevated temperature at location
&quot;123&quot;</sys:message>
                    </sys:Alert>
                  </sys:hasAlert>
                </sys:EventData>
              </send>
            </onentry>
                   …..
          </state>
```

Fig. 4. Listing 1

In the current example, the temperature events routed to the behavior’s event sink can be used to transition from an “idle” to an “alert” state, as shown in Listing 1. The transition will happen when an event received through the previously defined “EventSink1” validates the condition “temperature above 25”. When the state of the defined behavior becomes “alert”, the “Behavior Execution Engine” will generate an alert event associated with event source “VirtualSensorSource1”. The event will convey the information contained by the “EventData” OWL Individual defined inside the “send” element.

5 Conclusions

A Generic System Architecture for Cyber Intelligent Enterprise must include and not restrict to capabilities such as: semantic concepts for the description of system components, support for both asynchronous and synchronous communication and a distributed storage of the system’s semantic concepts.

An application based on Generic System Architecture for Cyber Intelligent Enterprise has been implemented and tested using a predefined scenario. Comparing the system's behavior to similar systems based on currently available technologies, we proved the feasibility of the middleware's architecture and its advantages. Further research related to system performance is being conducted in order to prepare for "real-life" enterprise conditions.

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Usability Requirements for Complex Cyber-Physical Systems in a Totally Networked World

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Abstract. "The Internet has made the world "flat" by transcending space. […] The Internet has transformed how we conduct research, studies, business, services, and entertainment." [1] Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components. Advances in CPS will enable capability, adaptability, scalability, resiliency, safety, security, and usability that will far exceed the embedded systems of today. CPS technology will transform the way people interact with engineered systems. "CPS have a highly disruptive effect on market structures. They will fundamentally change business models and the competitive field of today […]" [2] Usability is a driving force for the rapid take-up and acceptance of these Cyber-physical systems. [2] In this paper we define CPS and highlight the importance of usability for CPS. Then we describe two different cases and provide different methods how to improve the usability of CPS.

Keywords: Cyber-physical systems, Usability, a best practice process model.

1 Cyber-Physical Systems

Baheti and Gill define CPS as Systems that integrate the cyber world with the physical world. The computational and physical components of such systems are highly interconnected and coordinated to work effectively together, sometimes with humans in the loop.[3]*"Cyber Physical Systems (CPS) are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa."* [4]

CPS will also contribute to safety, efficiency, comfort and human health. Therefore, it helps to solve some key challenges of our society such as the ageing population, limited resources, mobility, or the shift towards renewable energies, which were caused by the demographic transitions and globalized world. [5]

"*The promise of CPS is pushed by several recent trends: the proliferation of low-cost and increased-capability sensors of increasingly smaller form factor. The*

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availability of low-cost, low-power but with high-capacity [...] and the wireless communication revolution […] continuing improvements in energy capacity, alternative energy sources and energy harvesting. The need for CPS technologies is also being pulled by CPS vendors in sectors like aerospace, environmental control, […] factory automation and healthcare who are increasingly finding that the technology […] is seriously lacking." [6]

About 98 percent of the microprocessors nowadays are working embedded, connected via sensors with the outside world. They are increasingly networked with each other in the Internet. The physical world merges with the virtual world, the cyberspace. [7]"A large variety of collaborative networks have emerged during the last years as a result of the challenges faced by both the business and scientific worlds. Advanced and highly integrated supply chains, virtual enterprises, virtual organizations, professional virtual communities, value constellations, and collaborative virtual laboratories, represent only the tip of a major trend in which enterprises and professionals seek complementarities and joint activities to allow them participate in competitive business opportunities." [8] CPS extend the notion of these collaborative networks by the integration of physical nodes and their virtual representation as specific entities within collaborative networks.

The trends push CPS to perform well and be useful in the mentioned areas. People and the industry want to have user-friendly devices which are not only handy but also have great appearances with high performance as well as capacity and of course with lower prices. The demand of using CPS is pulled by several industries and that is why CPS is always being developed in the application areas such as industry 4.0, automotive and avionic industries, logistics structures and other engineering fields where CPS has a valuable contribution. [6]

Another essential argument about achieving the goals is to link human intelligence with computer power, set by Lanz and Torvinen as follows: "*The real operating environment is not stable or predictably behaving. Systems in all fields have become parts of bigger systems via cooperation and communication within each other […] In order to operate in such dynamic and complex environment best of the both worlds; human intelligence and computers' computing power needs to be utilized in right places.*" [9] "*Cyber physical systems research aims to integrate knowledge and engineering principles across the computational and engineering disciplines (networking, control, software, human interaction, learning theory, as well as electrical, mechanical, chemical, biomedical, material science, and other engineering disciplines) to develop new CPS science and supporting technology*." [3]

The rapid research and technological advances in Internet of Things and increasing availability of sensors, actuators, and mobile devices have created an exciting new ubiquitous computing paradigm as an emerging paradigm is changing the way we live and work today. Via a ubiquitous infrastructure consisting of a variety of global and localized networks, users, sensors, devices, systems and applications may seamlessly interact with each other and even the physical world in unprecedented ways. To realize this usable and trustworthy computing that delivers secure, private, and reliable support for interconnected systems (i.e. organizations, services, objects) usability plays a pivotal role. [10]

2 Usability of Complex Technical Systems

"*Usability is the ease of use and learnability of a human-made object. The object of use can be a software application, website, book, tool, machine, process, or anything a human interacts with.*" [11]

Nonetheless not only usability is a crucial point of interaction of humans with technical and cyber-physical systems in the virtual world but trust and reliability is also a major issue to be considered. "[…] designing predictable and reliable components makes it easier to assemble these components into predictable and reliable systems. But no component is perfectly reliable, and the physical environment will manage to foil predictability by presenting unexpected conditions." Especially in quite complex and critical environments like cyber-physical systems sometimes are trust and reliability becomes very important.

Technical complexity refers to either the fundamental interaction characteristics (input and output) of the technology being complex, or where the underlying system architecture is complex, linking a variety of different systems, architectures, agents, databases, or devices. [12] At some point a decision must be made regarding the system interaction approach that is made towards the user. While issues of technical complexity have been discussed for many years, the rapid pace of change in disruptive technology domains means we are now required to design for a whole new range of cyber-physical systems that are emerging into common use and demand the development of new interaction styles and new guidelines.

Contextual complexity includes the broader tasks, roles, or jobs the technology is proposed to support, especially when tasks are open-ended or unstructured. A well-designed system will consider this more contextually complex type of scenario when developing a system, to ensure that the appropriate information required to support these contextual goals is incorporated into the system.

One implication of the need to reflect both technical and contextual complexity in design is an emphasis on multiple methods. While laboratory and quantitative work still has an important part to play, most often addressing the issues of technical complexity, qualitative methods such as ethnography, interviews and content analysis, and detailed observation are also vital for capturing the factors that contribute to contextual complexity. In practice, we find that methods need to be used in combination so that all aspects of usability can be addressed.

3 Case Studies

Based on this, we present examples from our work in two specific domains that encompass both technical and, in particular, contextual complexity. We concentrate on considering the applicability of methods in complex situations.

The first example is a case, where security tokens connected to machines guarantee that only official products are produced, where the challenge of design and evaluation is being able to effectively create intercultural systems, and capture the contextual characteristics of real and virtual working environments.

The second domain is energy efficiency management in large connected environments, where the variety of inputs and outputs, the challenge of working with traditionally disconnected domains, and the lack of design guidelines or standards pose challenges for the usability experts.

Table 1. Case Studies

Domain	**Production**	**Energy**
Case description	Security tokens connected to machines guarantee that only official products are produced	Energy efficiency management in large connected environments with variable inputs and outputs
Technical complexity	e. g. managing of different security tokens	e. g. balancing of energy; connection of different environments; managing the variable inputs and outputs
Contextual complexity	e. g. producing customer individual productions using different (customer) context	e. g. management of priorities of inputs and outputs, if there might be a higher need of energy
Usability	Using different methods to improve the usability: • Using cost-efficient and field-tested concepts • Repetitive and detailed model (also for customer specific projects) • Clearly specified process using an accepted framework and process model based on standards • Testing of products and processes using defined criteria • Considering always both sides: vendor and users • Etc.	

The cases demonstrate two points: They illustrate the importance of both technical and contextual complexity in different technology contexts and they provide example methods that can be applied to examine the human factor issues associated with complex usability. Because of the inherent complexity, it is often necessary to use multiple methods in combination.

Complexity takes on both a technical and contextual dimension. A number of methods are considered, and across both case domains there is an importance on using multiple methods to address usability, there is no one single method that can be used to ensure usability and this is particularly apparent in cases of usability of cyber-physical systems. Because complexity may exist from a number of different sources, it is necessary to sometimes use different approaches to unravel all the various issues that might lie within (see also table 1).

The various methods have its own strengths and weaknesses. Qualitative interviews are open to subjectivity on the part of the usability specialist, whereas more quantitative work is only as valuable as the reliability and validity of the data being collected. Using a number of methods can improve accuracy and enables us to build a fuller understanding of the critical issues.

4 Summary and Conclusions

CPS connect the cyber world with the physical world. The cyber and physical components of these systems are strongly coordinated to work effectively with humans in the loop. [3] The rapid deployment of CPS leads to more and more interactions between human and the networked world. Usability, reliability, trust and security are the important key issues for the CPS success. The ability to interact with, and expand the capabilities of the physical world through computation, communication, and control is a key enabler for future technology developments. [3]

In this domain complex usability has two dimensions, a technical and a contextual dimension. The two are interdependent, and both are of high importance to usability specialists and the successful implementation of systems that are relevant to complex usability. It is unlikely that a single method will be sufficient to capture all aspects of technical and contextual usability. If methods are used in combination across the different aspects of complexity, then there is a possibility to identify critical issues to address them. There is a need to ensure that new methods are generalizable across applications or domains and new methods must acknowledge both the technical and contextual complexity of systems. This makes it necessary to have a toolbox from which users can select tools appropriate to the complex usability issues that they encounter.

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Business Strategies Alignment

Achieving Coherence between Strategies and Value Systems in Collaborative Networks

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Abstract. Collaborative networks that emerge as consortia to deal with new market opportunities consist of different autonomous entities. Each one holds a set values and defines its own strategies in order to deal with its defined objectives. The enterprises heterogeneity leads sometimes to contradictory objectives, and misalignment of value systems and strategies. Enterprises willing to participate in a collaborative network, as thus willing to avoid these misalignments, have to achieve coherence between the strategies they activate and the values they hold. To facilitate achieving such coherence, this paper contributes with an approach to identify the strategies that should be activated in order to be coherent with the values held by each enterprise. It specifically considers the scenario in which consortia are temporarily formed and values and strategies are set out in the short term. A potential application is exemplified through a numerical example.

Keywords: value systems alignment, strategies alignment, collaborative networks, consortium, emergent core value.

1 Introduction

Collaborative networks have been widely studied over the last years due to their decisive contribution to small and medium enterprises (SMEs) performance in a context of market turbulence. According to [1], collaborative networks are composed of autonomous and heterogeneous entities which collaborate in order to better achieve common or compatible goals that would be never achieved by isolate entities. In spite of the benefits derived from collaboration [2], SMEs can face a number of challenges when participating in collaborative networks, such as sharing goals, aligning strategies, achieving suitable levels of trust, reaching agreements in practices, and aligning values [3] [4] [5].

This paper particularly focuses on the value systems alignment and the strategies alignment issues. The main aim is to provide an approach to deal with the coherence between the strategies activated or operationalised by collaborative partners and the

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value systems held by the enterprises belonging to the network. The *value system* is more permanent in time while the *strategies* have a specific duration throughout the collaborative consortium. In other words, a strategy is activated at a defined time period and finishes after having been performed, when the objective has been achieved.

In order to address the paper's purpose, the concepts and models to deal with the strategies alignment and the value systems alignment are presented (section 2). After that, the research motivation is formulated in section 3. The research approach, in section 4 develops the solution proposal to cope with the raised research motivation. In order to provide an intuitive insight on the developed approach, a numerical example is presented in section 5. Finally, conclusions and future research lines are presented in section 6.

2 Background

This section provides a brief overview of the concepts of strategies alignment and value systems alignment. The adopted modelling approaches are given in both cases.

The *alignment* concept is considered as the compatibility of the value system or the strategies defined by one enterprise with regards to the value systems or strategies belonging to other networked enterprises. Misalignments appear when incompatibilities and negative influences arise among network partners.

2.1 Strategies Alignment

The business objectives are statements that establish what is to be achieved within the enterprise, but without specifying how to achieve them. Hence, enterprises define strategies as a set of actions to be performed in order to achieve the defined objectives. The strategies of members in a collaborative network are considered to be aligned when each activated strategy not only promotes the achievement of the objectives defined by the enterprise that raises such strategy but also boosts the accomplishment of the objectives defined by the rest of the networked partners [5].

In order to model the process of strategies alignment, a set of five objects have been defined: (i) the network ($n_n \in N$), (ii) the set of enterprises forming the network ($e_i \in E$, $e_{ni}=(e_i, n_n) \mid e_i \in E \wedge n_n \in N$), (iii) the objectives defined by each enterprise ($o_{ix}=(o_x,e_i) \mid o_x \in O \wedge e_i \in E$), (iv) the key performance indicators (*KPIs*) to measure the level of objectives' achievement ($kpi_k \in KPI$, $kpi_{ixk}=(kpi_k,o_x,e_i) \mid kpi_k \in KPI \wedge o_x \in O \wedge e_i \in E$), and (v) the strategies adopted by each enterprise in order to reach the objectives ($s_s \in S$, $s_{is}=(s_s, e_i) \mid s_s \in S \wedge e_i \in E$). A strategy can be active (s_{is}^1), when it is carried out or non-active (s_{is}^0) when it is not put into practice.

Collaborative networks success is influenced, inter alia, by the alignment of strategies. Modelling the network allows to identify the set of strategies that if activated achieve the maximum optimum of the enterprises' KPIs and the global network KPI (considering the global KPI as the sum of all the enterprises' KPIs). Accordingly, when there is alignment, the set of activated strategies are characterised by promoting positive influences onto all the objectives defined by the networked enterprises, enhancing the establishment of collaboration.

2.2 Value Systems Alignment

A Value System defines the set of values and priorities that guide the behaviour of an organisation; as such, it determines or at least constrains the decision-making processes of that organisation. Therefore, the identification and characterisation of the Value Systems of a network and its members is fundamental when attempting to improve collaboration. The Value Systems are aligned when the core values of one member are compatible with the core values of another, and therefore, the potential for emergence of conflicts is lower.

The set of characteristics that each enterprise ($e_i \in E$) (or network ($n_n \in N$)) considers as the most important for itself and that motivate or regulate its behaviour are called core-values ($cv_i \in CV$). According to the conceptual model proposed in [6] the set of core-values, of an entity ($ent_i \in (E \cup N)$) and respective preferences (priority $w_i \in$ (fair,high,very high)) are represented by the core-evaluation perspective ($cep_x = (dv_x, wv_x) \mid dv_x = < cv_1, cv_2,.. cv_n > \wedge wv_x = < w_1, w_2,.. w_n >$), which is part of the core value system.

Aiming to provide methods to systematically analyse core value systems in collaborative environments, an analysis framework based on qualitative causal maps and graphs, was proposed in [7]. This framework defines two types of elementary maps:

(i) Core-values influence map (CVIM), which is a cognitive fuzzy map where each directional edge ($icv_{ij} = (cv_i, cv_j, p, s)$) represents the influence between core-values. The positive or negative influence is specified by the signal (s) of the edge and its intensity (p) is defined by a qualitative label (low, moderate, high);

(ii) Organisation's core-values maps and CN's core-values maps (CVM) are uni-directional graphs, where each edge ($ewi_{j} = (ent_i, cv_j, w_{ij})$) has a qualitative label that represents the core-value priority (w_i) to a specific organisational entity (ent_i).

Starting with these elementary maps, it is possible to aggregate them in order to build maps that evidence the impact of one core value system into another, facilitating the value systems alignment, and thus allowing an easy identification of the synergies and potential conflicts among network members [7].

3 Research Motivation

When a new specific business opportunity appears, a new temporary collaborative consortium, i.e. a virtual organisation (VO), is formed [1]. A set of heterogeneous enterprises take part in the consortium, each of them with different expectations and different value systems, which are sometimes incompatible. Accordingly, the strategies activated by one enterprise could be contradictory to achieve the objectives of other enterprises. The perception of outcomes is also likely to be different for each of the collaborative partners belonging to a new consortium. These different perceptions are related to the values of each enterprise [8]. Besides this, each consortium has a specific duration, ending once the business opportunity has been fulfilled. In this context, for each specific enterprise, the core values held could change when a new collaborative consortium is created. In the light of this, two scenarios can be considered:

(i) **New values** may appear, induced by the newly created consortium. Once the consortium is created, new values can be adopted by the entities forming it, to specifically carry out a collaborative opportunity. To exemplify this case, let us consider two SMEs (SME_1, SME_2). The core values held by SME_1 are *knowledge* and *reputation,* while the core values held by SME_2 are *standardisation* and *social awareness*. Both SMEs take part in a new collaborative consortium, i.e. a consortium created to participate in a joint research project. In this concrete example a new core value might emerge in both enterprises, that is *innovation*. Probably, the *new values,* such as the *innovation* in this example, will remain even after the dismantling of the consortium, namely if the outcomes of that initiative were considered positive to both SMEs.

(ii) The **priority of core values change**, increasing or decreasing their importance according to the context of the collaborative consortium. Unlike the previous case, this scenario considers that not always new values emerge when a consortium is created. However, the priority of some core values held by the enterprises can be temporarily modified within the context of the consortium. Considering the example stated before, let us assume that the priorities are initially defined as follows: SME_1 *knowledge (fair)* and *reputation (very high)* and SME_2 *standardisation (high)* and *social awareness (high)*. However, once a consortium is created, the priorities of these core values might change according to the consortium's nature. In our example, the consortium is created to participate in a joint research project and therefore the priorities might temporarily change for this context as follows: SME_1 *knowledge (very high)* and *reputation (very high),* and SME_2 *standardisation (fair)* and *social awareness (high)*. The priorities change during the consortium life cycle, and when it finishes, the priorities likely return to the qualitative values initially defined.

Just like the core values temporarily change, appearing new ones or changing their priorities, the objectives also change in each new consortium and consequently, the strategies raised to achieve these objectives.

During the consortium formation, the VO planner evaluates the candidate organisational entities in terms of their value systems in order to select the partners presenting the lowest risk of conflicts, and the highest level of synergies. However, partners' selection based only on the value systems alignment criteria does not assure the sustainability of the collaboration, since there is no guarantee that strategies activated by each member are coherent with the values defined by the rest of members forming the network.

In order to achieve coherence between the activated strategies and the value systems of each collaborative enterprise, the motivation for this work is to identify proper strategies to be activated in order to achieve positive influences between these strategies and the values defined in each consortium.

Figure 1 schematically represents the approach followed in order to deal with the raised research motivation. The attainment of coherence between the *activated strategies* and the *value systems* of the enterprises forming the collaborative consortium is pursued through the *Objectives definition.* In other words, the *objectives* establish the link between strategies and value systems. Firstly, the objectives are defined based on the values held in the enterprise. For instance, taking into account the aforementioned example, the emerged value (*innovation*) in both enterprises

(*SME_1* and SME_2) leads to define the following objective: *Increase the innovation by15%*. Secondly, the objectives are achieved through the strategies definition, e.g. *Participate in a PF7 research project*. Thus, this approach allows linking both concepts: strategies and value systems. Since the strategies are directly related with the objectives and those are based on the core values, the alignment of strategies will allow to get coherence between strategies defined and the value systems held. That is a situation in which the strategies fit the core values held by the enterprises belonging to the collaborative consortium.

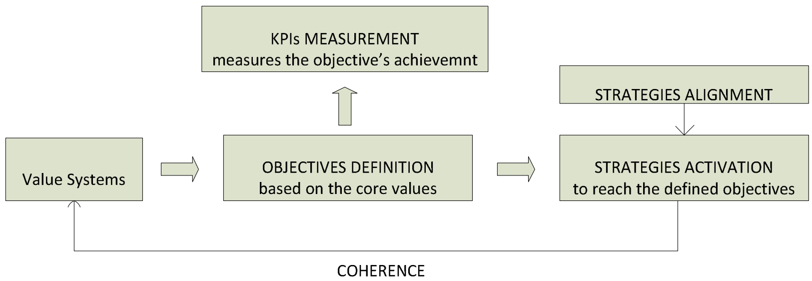

Fig. 1. Coherence between the Value Systems and the activated Strategies

4 Research Approach

4.1 Adopted Research Methodology

The lack of coherence between the adopted strategies and core values may lead to partnership failure [9] [10]. Mechanisms to promote coherence between the activated strategies and the value system of each enterprise of the collaborative consortium are needed. In order to deal with this relevant problem, this paper is based on a theoretical body of knowledge regarding Collaborative Networks, Industrial Management, and System Dynamics. Collaborative Networks discipline contributes with the theoretical base concepts about virtual organisations, consortium formation [11], value system analysis in collaborative contexts [7] and strategies alignment in collaborative networks [5], while Industrial Management contributes with the main concepts about Performance Indicators Management. The Systems Dynamic body of knowledge contributes with optimisation methods applied to identify the set of strategies that are coherent with the Value Systems. Furthermore, the approach is grounded in the *Constructive Research* method (Figure 2) [12] based on building models and methods to provide a solution domain in the defined problem, in order to create knowledge on how the problem can be solved. Finally, the practical relevance will be shown through an application example.

In the current phase of this research, the main aim is to provide models and methods to achieve coherence between the activated strategies and the value systems held by the enterprises of the collaborative network, in order to promote sustainable collaboration. This purpose is carried out through the approach provided in Figure 1, in which the objectives are defined in relation to the core values. This definition of objectives allows linking the core values with the strategies. Having connected both concepts, identifying the aligned strategies that are associated with these objectives will achieve the main purpose of guaranteeing coherence between strategies and value systems.

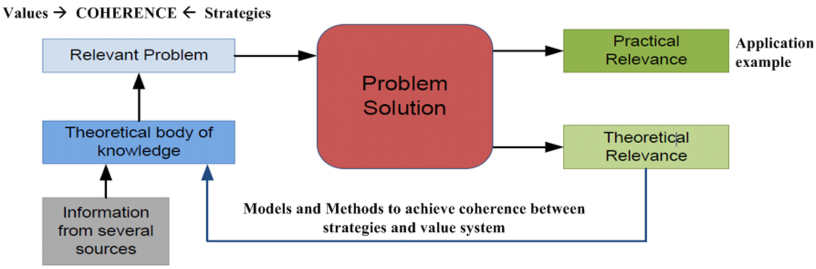

Fig. 2. Constructive Research method

4.2 Solution Proposal

When a new consortium appears, participating enterprises deal with two possible situations, as stated before: (i) the "appearance" of new values, or (ii) the change of priorities of the core values. Considering these two situations, whenever a new collaborative consortium is created, an *Emergent Value System* appears within the enterprises that are prone to take part. The concept of "emergent" in this work means that new values are adopted or values priority change when the new collaborative consortium is formed.

The conceptual model of the *Emergent Value System* is represented through a UML class diagram, in which the relations between elements are depicted (Figure 3). For better understanding of the relations among the modelled elements in the UML diagram a brief explanation follows.

The *Emergent Value System* is characterised by the *Emergent Evaluation Perspective* that gives to each value of the emergent system different priorities (*Value Priority*). The *Emergent Evaluation Perspective* has a set of *Emergent Core Values*. The approach provided by [6] identifies the *Core Value* and the *Core Evaluation Perspective* in order to build the enterprises' *Value System*. Based on this work, the approach here provided adds the *New Value* concept, corresponding to the new values appearing when a new collaborative consortium is created in order to respond to a new market opportunity. Therefore the *Emergent Core Values* consist of the New Values and *Core Values* with changed priorities.

This new approach introduces the definition of *Objectives* based on the *Emergent Core Values*. The formulation of *Strategies* and *KPIs* are considered in order to deal with the defined *Objectives* [5]. Furthermore, a new contribution is provided in this work, the *Objective Priority* in which the objectives are defined with a certain priority as well as the core values (*Value Priority*). As such, a new *Set of Prioritised Objectives* is defined. Nevertheless, it must be taken into account that the *Value Priority* is not to be necessarily the same as the *Objective Priority,* although in some occasions they may coincide. Once the *Objectives* are defined based on the *Emergent*

Core Values, the *Strategies* are formulated and the *KPIs* are designed in order to measure how the *Strategies* influence the accomplishment of each defined *Objective*. As the *Emergent Core Values* are linked with the *Objectives*, and these in turn are linked with the *Strategies*, it can be considered that the *Emergent Core Values* and the *Strategies* are also linked. Therefore, the identification of the aligned strategies will allow achieving the desired coherence between the *Strategies* activated and the *Emergent Core Values*. The set of strategies that are suitable to be activated will positively influence the *Emergent Core Values* within the networked partners belonging to the new consortium.

The set of aligned strategies are identified through the model provided by [5], in which the strategies are considered aligned if and only if there is a positive increase on the KPIs defined in each networked enterprise. Thus, the optimum performance at both enterprises and network level is obtained.

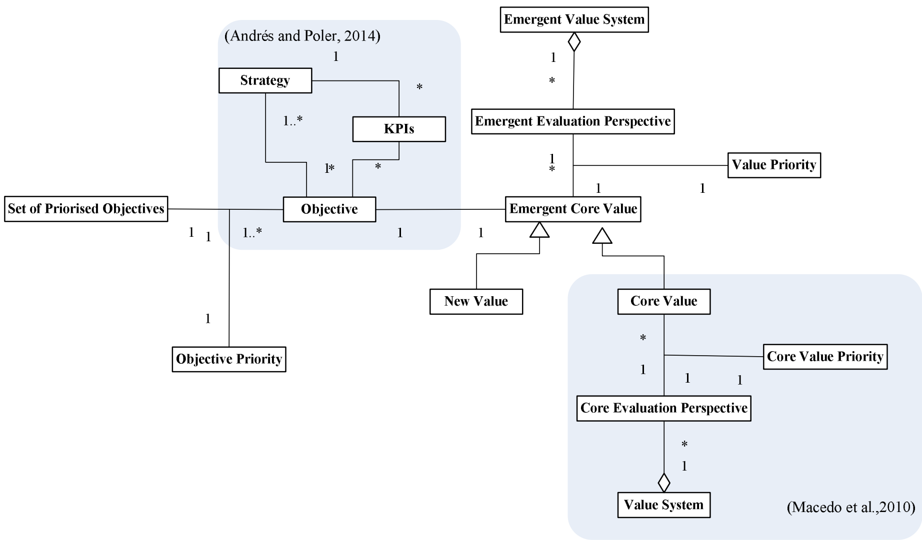

Fig. 3. UML class diagram of the conceptual model of Emergent Value System

5 Application Example

The main purpose of this example is to show how to identify the strategies that are aligned in order to be activated. These strategies will be characterised as being coherent with the values defined by the enterprises.

In order to model the strategies alignment process, *AnyLogic* simulation software is used [13]. This simulation software is founded on the dynamic systems methodology providing an optimisation tool that allows to identify the strategies that have positive influences in the objectives defined, both in the same enterprise an in the other networked enterprises. The optimiser maximises the network performance through identifying which strategies activate (s_{is}^{1}) in each enterprise in order to achieve the scenario in which the activated strategies are aligned.

The output of the proposed model is the *strategy units* (s_{is}) to be activated in order to achieve the maximum increase on the performance (KPIs) [5]. *Strategy units* (s_{is}) are considered as the number of units of strategy to be activated in e_i (Table 1).

Table 1. Definition of strategy units (Andrés and Poler, 2014)

Variable	Definition
s_{is}	Number of units of strategy s_{is} to be activated in enterprise e_i
expenseRatio_ s_{is}	Cost of one unit of strategy s_{is} activated in enterprise e_i
s_{is}***_mu***	Total monetary units invested in strategy s_{is} activated in enterprise e_i $s_{is}\_mu = s_{is}\ x\ expenseRatio\_s_{is}$

Thus, the optimisation tool in *Anylogic* software identifies the number of *strategy units* that should be activated in order to obtain the set of aligned strategies within the network partners. Furthermore, the activated aligned strategies will be characterised by being coherent with the value systems of the enterprises forming the collaborative consortium.

According to the aforementioned, a numerical example is developed hereafter. The example considers modelling two enterprises (e_1, e_2) that take part in a new collaborative consortium. Each enterprise initially holds one core value ($e_1 = cv_1$ and $e_2 = cv_2$) with its specific degree of priority ($e_1 = w_1$ and $e_2 = w_2$). When these enterprises take part in the new consortium, new values appear and the priorities of the initial core values change (Table 2).

Table 2. Core Values

Enterprises (e_i)	Initially defined Core values set (cv_i) with *value priorities* (w_i)	New Consortium Core values set (cv_i) with *value priorities* (w_i)
e_1	Standardisation (*high*)	Standardisation (*fair*), **Knowledge** (***very high***)
e_2	Uniqueness (*very high*)	**Innovation** (***high***), Uniqueness (*fair*)

In the developed example the two aforementioned scenarios are considered:

(i) **New values** may appear. In the new collaboration consortium the new core value of e_1 is *knowledge* with a *very high* priority, and in e_2 the *innovation* core value appears with a *high* priority.

(ii) The **priority of core values change.** In the new collaboration consortium the core values initially defined temporarily change the priority. In e_1 the *standardisation* core value has a *high* initial priority, but when the consortium is build the initial priority changes to *fair*. In e_2 the *uniqueness* core value has a *very high* initial priority and once the new consortium appears the priority momentarily changes to *fair*. The changes of priority are due to the context of the consortium temporarily changes.

The impact analysis (once the new consortium arises), in terms of core values, of the e_1 and the e_2, shows that:

- Innovation (e_2) positively influences Knowledge (e_1)
- Innovation (e_2) negatively influences Standardisation (e_1)
- Uniqueness (e_2) negatively influences Standardisation (e_1)

The variables of the new consortium are, then, mathematically characterised and exemplified in Table 3:

- *Core Values*: core values held by each enterprise ($e_1 = cv_1, cv_2$ and $e_2 = cv_3, cv_4$) with its priorities ($e_1 = w_1, w_2$ and $e_2 = w_3, w_4$)
- *Objectives*: for each core value (cv_i) an objective is defined ($e_1 = o_{11}, o_{12}$ and $e_2 = o_{21}, o_{22}$). The objectives definition is based on the core values.
- *Strategies*: the strategies are set out to achieve the defined objectives ($e_1 = s_{11}, s_{12}$ and $e_2 = s_{21}, s_{22}$)
- *KPIs*: the objectives are measured through the KPIs ($e_1 = kpi_{111}, kpi_{121}$ and $e_2 = kpi_{211}, kpi_{221}$).
- *KPIs increase*: (∇kpi_{ixk}) shows how one objective (o_{ix}) is influenced by the activation of a particular strategy (s_{is}) (∇kpi_{ixk}^{is})
- *KPIs priority*: the priority of the KPI is directly related to the priority to achieve the objectives in each enterprise (*priority_kpi*$_{ixk}$)
- *Expense Ratio*: each strategy (s_{is}) has an associated cost that is defined through the *expenseRatio_s*$_{is}$ (measured in monetary units – *m.u.*).
- *Budget*: each enterprise has its own budget to activate the strategies ($e_1 = b_1$, $e_2 = b_2$).

The set of core values, objectives, strategies and KPIs are defined in Table 3. The data regarding the KPIs increase, KPIs priority, expense ratio and budget is exemplified in Table 4. Table 4 summarises the data to be introduced in *Anylogic* simulation software in order to build and solve the numerical example. The optimisation experiment is compiled and the results are depicted in Figure 4. The optimisation tool maximises the KPIs increase (∇kpi_{ixk}) through modifying the parameters represented by the strategies s_{is} (in this example: e_1: s_{11}, s_{12} and e_2: s_{21}, s_{22}). On the right side of Figure 4 it is depicted the graph that shows the iterations compiled in the model in order to find the parameters that maximise the solution. Each dot in the graph corresponds to a single simulation run.

The results derived from the example using the optimisation tool (Figure 4), show the *strategy units* the enterprises have to activate. Thus:

- e_1 activates 16 units of strategy s_{12}, considering that the *expense ratio* of one unit of s_{12} is *5 m.u.*, the monetary units invested s_{12}*_mu* are 80 m.u. (s_{12}*_mu = 16*5*) out of the *budged* of e_1 to ($b_1 = 100$), and
- e_2 activates 15 units of strategy s_{21}, considering that the *expense ratio* of one unit of s_{21} is *10 m.u.*, the monetary units invested s_{21}*_mu* are 150 m.u. (s_{21}*_mu = 15*10*), e_2 spends the total budged ($b_1 = 150$).
- Furthermore, it is seen that in order to achieve the maximum performance, strategies s_{11} (e_1) and s_2 (e_2) will not be activated by the networked enterprises.

This solution shows how the strategies s_{12} and s_{21}, besides being aligned, are also coherent with the emergent value system in which the *knowledge* (e_1) and *innovation* (e_2) are the *new values*, defined with very high and high priorities, respectively.

Table 3. Objectives, Strategies and KPIs defined in order to achieve the values defined in each networked enterprise

Enterprise	Objectives	Strategies	Key Performance Indicators
e_1	o_{11}: Increase **Standardisation** by 5%	s_{11}: Application, arrangement and enhancement of standards established in all the enterprise production processes. Implement Processes Standardisation through processes definition, identification, documentation, formalisation and audit.	**kpi_{111}**: Standardisation_level = $\frac{\text{Standardisation}_t}{\text{Standardisation}_{(t-1)}}$
	o_{12}: Increase by 25% the exchange of **Knowledge** among the partners	s_{12}: Implement a platform to share tacit knowledge and support discussion forums	**kpi_{121}**: Knowledge_Increase = $\frac{\text{Knowledge exchange}_t}{\text{Knowledge exchange}_{(t-1)}}$
e_2	o_{21}: Increase **Innovation** by 15%	s_{21}: Participate in research European Projects in *H2020*	**kpi_{211}**: Degree_Innovation = $\frac{\text{Innovation}_t}{\text{Innovation}_{(t-1)}}$
	o_{22}: Increase the **Uniqueness** by 20%	s_{22}: Implement the Engineering to Order Strategy (ETO) for products that require engineering and every customer order results in a unique set of material elements, procedures and processes. Unique product that offers original design and therefore its manufacturing process also has unique features and options including customisation	**kpi_{221}**: Degree _Uniqueness = $\frac{\text{Uniqueness}_t}{\text{Uniqueness}_{(t-1)}}$

Table 4. Numerical Example: Data

Strategies (expenseRatio_s_{is})	**Enterprise 1 (e_1) → Budget (b_1) = 100**		**Enterprise 2 (e_2) → Budget (b_2) = 150**	
	kpi_{111} (priority_kpi_{111} = 0,3)	**kpi_{121} (priority_kpi_{121} = 0,7)**	**kpi_{211}(priority_kpi_{211} = 0,6)**	**kpi_{221}(priority_ kpi_{221} = 0,4)**
s_{11}^1 (5 m.u.)	∇kpi_{111}^{11} = 1	∇kpi_{121}^{11} = 0	∇kpi_{211}^{11} = - 0,3	∇kpi_{221}^{11} = - 1
s_{12}^1 (6 m.u.)	∇kpi_{111}^{12} = 0	∇kpi_{121}^{12} = 1	∇kpi_{211}^{12} = 1	∇kpi_{221}^{12} = 0,5
s_{21}^1 (10 m.u.)	∇kpi_{111}^{21} = - 0,7	∇kpi_{121}^{21} = 1	∇kpi_{211}^{21} = 1	∇kpi_{221}^{21} = 0,6
s_{22}^1 (4 m.u.)	∇kpi_{111}^{22} = - 1	∇kpi_{121}^{22} = 0	∇kpi_{211}^{22} = 0,6	∇kpi_{221}^{22} = 1

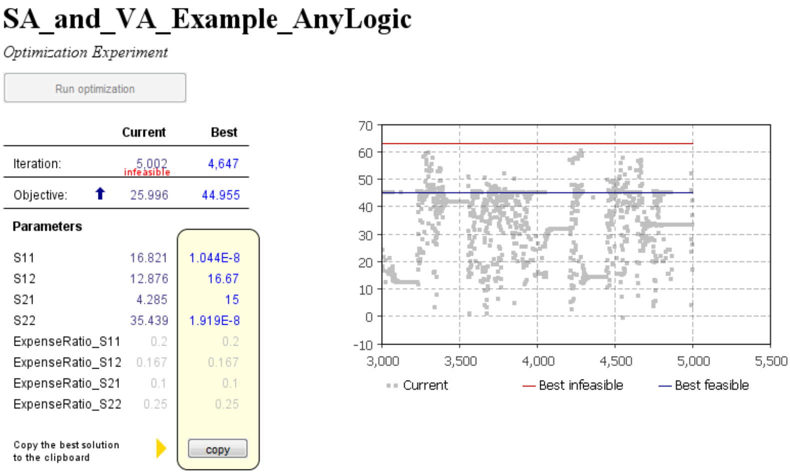

Fig. 4. Optimisation Results

The results obtained from the example seem to be logical. However, in a consortium consisting of more entities the solution is not as trivial; being, the developed model, useful to handle higher amounts of data. Nevertheless, gathering these data is seen as a drawback to implement the model. Taking into account that a collaborative network is characterised by uncertainty and incomplete information, the provided model should deeply contemplate these restrictions and consider the possibility of providing a more realistic approach in terms information collection and also deal with the dynamism characterising the network. Despite these limitations, the approach developed implies an original scientific contribution in terms of collaborative strategic planning, partners' selection, and assessing and enhancing the enterprises readiness for collaboration.

6 Conclusions

This paper provides an approach, based on dynamic systems, to tackle the possible incoherencies among the activated strategies and the values held in each enterprise, guaranteeing the strategies alignment. This paper is contextualised on the creation of new collaborative consortia to deal with new market opportunities. The novel concept of *emergent core value* is considered consisting on: (i) new values and (ii) values that temporarily change the priority when a new consortium is formed. The proposed approach deals with the coherence between the strategies and the *emergent value system*. The approach is applied through defining objectives based on the core values that belong to the *emergent value system* and setting up the strategies that allow reaching these objectives. With the provided method, the aligned strategies that are to be activated are identified, enabling the coherence between these strategies and the *emergent value system*. An example is developed showing the solution approach applicability.

Future research lines are led to apply the proposed solution in a real collaborative network consortium. Furthermore, an improved approach could be reached through considering a new variable to compute the degree of coherence between the activated strategies and the value systems; in order to have a more accurate solution approach. As the adopted approach focuses on collaborative consortia with a limited length, future work could extend the approach to long term associations; in order to define how the strategies activated in a determined periods of time affect the values held by the enterprises in the long term context.

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Business-IT Alignment in PSS Value Networks: A Capability-Based Framework

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Abstract. Advanced information technology (IT) is regarded as a foundation for the operation of product-service system (PSS) value networks. This requires alignment between IT and PSS business strategy. Business-IT alignment (BIA) in a value network can raise the ability of partners to collaborate effectively and improve network performance. However, the theory of traditional firm-level BIA is not tailored to the specific situations of PSS value networks. In this paper we investigate the applicability of BIA concepts and definitions at a PSS value network level. Alignment in firm-level literature looked at fit between business and IT capabilities. To substantiate this at a PSS value network level, we identified and classified generic value network business capabilities on the one hand and IT capabilities on the other hand. By exploring and discussing the interrelations between the two types of capability, a conceptual framework for understanding BIA in a PSS value network is derived.

Keywords: Product-service system, value network, business-IT alignment, business capabilities, IT capabilities, capability-based framework.

1 Introduction

In the era of servitization, offering a product-service system (PSS) becomes a prominent business strategy in the pursuit of value co-creation with customers and other partners in a PSS value network, for any firm that struggles to differentiate itself from competitors. The service content must not be seen as 'only' a support service, or stand-alone after-sales offering, but as an integrated part of the total offering [1]. Such integrated solutions imply a shift in focus from product functionality to the actual outcomes of products and services for customers' operations and processes [1]. In line with current literature on PSS, this study refers the PSS as an ongoing relational process, in which a provider aims to jointly solve the customer problem by reciprocal interaction and long-term collaboration with customers and other value network partners to deliver a bundle of goods and services to fulfill customer demands. We use terms PSS and an integrated solution interchangeably.

Increased emphasis on integrated solutions among scholars and practitioners highlights the role of IT as the essential technological foundation for operation of the PSS value networks. IT makes joint activities, integration and communication among

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partners possible; therefor it needs to be aligned with a business strategy. Business-IT alignment (BIA), in a context of PSS value networks, enhances the ability of all actors to collaborate more effectively. In this paper we take the position that the status of BIA at a strategic level can be determined on the basis of alignment between business and IT capabilities. In the case of PSS, that requires firms to go beyond their organizational boundaries and to utilize the resources and capabilities of all PSS value network partners to co-create value, implies looking at business capabilities and IT capabilities that are specific for the PSS and studying the fit required between them. Both business and IT capabilities are identified through a literature review. This is followed by a classification of the findings. As a result, seven Business capabilities and six IT capabilities (ITCs) have been identified. Subsequently we developed hypotheses to examine the possible relationship between ITCs and business capabilities and to propose the research framework.

Summarizing, this study aims to answer the following research questions:

1. What are the key business and IT capabilities in a PSS value network?
2. What are the possible relationships between such business and IT capabilities?

Our study contributes to the emerging literature on BIA research in a context of PSS value network in twofold. Firstly, we identify and classify the key PSS business and IT capabilities. Secondly, we operationalize the notion of BIA in this context by investigating the link between IT and business capabilities in a conceptual framework.

The outline of the paper is as follows. Section 2 gives some definitions of BIA and an overview of current works. Then the research approach is described. The research results regarding business and IT capabilities are given in section 4. In section 5 the research framework is proposed. Finally, conclusions and future work are presented.

2 Current Works

After the seminal work on alignment between business and IT strategy by Henderson & Venkatraman [2], a vast body of literature on this topic has emerged over the past three decades. BIA discusses the best possible use of IT resources to meet enterprise objectives [3]. It refers the extent to which the IT strategy supports, and is supported by, the business strategy [4]. So far, the focus in literature has been on the notion of BIA with an internal perspective on a single firm, fall short with respect to the dynamic collaborative business network environments [5, 6]. The question is: how can this notion are extended to PSS value networks? Santana Tapia et al. [6] developed a maturity model to assess BIA in collaborative networks. They proposed four domains need to be addressed by collaborative networks in BIA process. Derzsi and Gordijn [7] studied the issue of inter-firm alignment in networks and tried to operationalize the value-based alignment process. The research of Pijpers et al. [8], based on multiple views on interactions between firms in a network addressed a process of creating inter-organizational BIA which is concerned with the coherence between the actors. Grefen and Lüftenegger [9]developed the framework in a PSS business network that can be seen as a service-oriented operationalization of BIA model. It consists of three pyramids; business, applications, and IT platforms. Each business layer (i.e. business strategy, business model, service composition, business service) is supported by corresponding layers in the applications pyramid, then, mapped to the IT infrastructure pyramid.

The variety of BIA approaches and definitions indicates that there is no consensus on a comprehensive definition of the concept of BIA in the context of a PSS. In fact, BIA is a multidimensional concept encompassing strategic, structural, operational, and social dimensions [5, 10]. In this study we will focus on the strategic dimension. We define strategic business-IT alignment in a context of a PSS value network as the degree to which the IT strategy enables the PSS business strategy. But even with this focus we see that research on strategic BIA typically focuses on notions such as a fit between IT planning and business strategic planning [4, 10, 11]. These concepts are highly abstract, and become even more complex at a network level due to issues such that relationships, a delivery of an integrated offering, information representation, user customized interfaces, dynamically adjusted to assist different actors, and services provision supported on cloud computing [12, 13]. To elaborate the notion of BIA, an operationalization is required. Addressing BIA using a capability lens can be an appropriate approach, due to the fact that creating strategic value as the ultimate goal of BIA lies in the usage and alignment of business and IT capabilities. A discussion on capabilities is rooted in a resource-based view (RBV) a well-known theory within the strategic management literature. Under RBV the term capability is defined as special resources that are unique and valuable, encompassing a firm's capacity to coordinate and deploy resources to affect a desired end [14, 15]. Within IT research, the notion of IT capability is also grounded in RBV theory. ITCs are those capabilities necessary to ensure that organizations can exploit changing technology to achieve business value through IT over time [16]. IT capability is a firm's ability to mobilize and deploy IT-based resources in combination with other resources and capabilities [17]. It is not a specific set of sophisticated technological functionality but rather than the organizational capabilities to leverage technology to differentiate firms from competitors [2]. In previous works BIA has already been studied from a capability point of view. Peppard and Ward [18] addressed ITCs in a BIA model and argued how well ITCs in relation to different aspects of the BIA model can improve a firm performance. McLaren et al. [19] developed a multilevel strategic fit measurement model to measure alignment between a firm's competitive strategies and its IT capabilities. Similar work in a PSS context has not been found. We feel that in a case of an integrated solution, which is inherently based on resources and capabilities of autonomous and geographically distributed network partners, increases the need of alignment between IT and business capabilities to facilitate the interaction and collaboration among partners in fulfilling common business values. Here, alignment represents the extent to which the ITCs meet the requirements of key business capabilities and enable them to achieve desired goal of PSS value networks. The 'key' refers to the fact that we will focus only on those capabilities that enable the PSS as a whole and are in particular required to function in a value network. Similarly, our investigation of key IT capabilities focusses at those that are specific for a PSS environment. In response to the gap in literature, this study aims to define the key business and IT capabilities and to identify potential relationships between such capabilities resulting in the conceptual framework.

3 Research Approach

To support the elaboration of BIA in a PSS value network from a capability perspective we need to identify and define business and IT capabilities that are relevant in such a context. In the first step of the study a structured literature search has been executed to identify these key capabilities. Several search strategies were used. First a generic search was used to identify a number of well-known and well referenced authors of papers on BIA, business capability, and IT capabilities. Based on these, a number of keywords including a number of synonyms were identified and used in the search. Finally, relevant papers were used in a backward (i.e. looking at papers cited) and forward (i.e. looking at papers citing the paper) snowball process. The search processes resulted in collecting 10 and 12 relevant papers on PSS business and IT capabilities respectively. Since the results are mixed and there is no consensus on specific sets of key capabilities, we executed a structured classification process to obtain well-founded sets of key business and of key IT capabilities. For this the Metaplan approach was selected. The Metaplan method is a card sorting technique based on a group discussion [20]. The researchers of this paper felt they had sufficient knowledge to carry out the classification, especially since the group discussion aspect of the approach tends to cancel out individual bias. Each classification was carried out in an iterative process whereby classes were identified in one iteration and then refined in two following meetings. Finally the resulting groups of capabilities received group-named and definitions, closely following information from the literature used. The process leads to the construction of seven PSS value network business capabilities (table 1) and six ITCs (table 2) which are described in the following section. Based on these two sets of capabilities, again in a group discussion, in three iterations a number of research hypotheses were formulated that can be used to investigate the extent to which IT capabilities enable PSS value network business capabilities. The results are shown in a research framework (fig.1). The hypotheses which are theoretically supported by literature show relationships between IT and business capabilities. Further validation of them will be done in the future empirical works.

4 Research Result Regarding Business and IT Capabilities

4.1 Business Capabilities

In the following the key business capabilities of PSS value networks that resulted from the literature search and the classification process are presented.

Customer understanding capability: The ability of a value network to understand customer requirements to offer high-value customized solutions that address individual customer's operational process and business needs [21–23]. It assists to get customers' ideas and identifying customers' value to enhance the PSS offerings.

Partnership capability: The ability of a value network to develop collaboration and partnership among actors including customers in order to access complementary capabilities [14, 22, 24, 25]. In value networks a focus of value creation moves from the internal firm processes to interaction processes among partners. Active dialogue and social interaction instead of one-way communication, are therefore prominent and of critical importance in value co-creation [24, 25].

Trust-Based Interaction Capability: The ability of a value network to have a non-opportunistic behavior and establish long-lasting relationship among actors [21, 22, 25]. Offering PSS is actually an ongoing interaction that is built on mutual trust and commitment. Trust is one of the factors that differentiates collaborative relationships from transaction and includes both economical (i.e. risk-based trust) and social (i.e. goodwill trust) perspective of trust [26].

Engagement Capability: The ability of a value network to involve all partners to contribute in integrated solutions [22, 27, 28]. In this context, firms inextricably depend on other parties to provide a PSS due to specialization, knowledge intensiveness and technological complexity of such integrated solutions [24]. The ability to engage partners in the value co-creation lead to deliver a PSS that can differentiate network from competitors.

PSS Design and Delivery Capability: The ability of a value network to design and deliver combinations of products and services to individual customers by using the capabilities of all partners [15, 21, 23]. In this sense, the service elements of a PSS range from traditional product-related services to services supporting customer operational processes [21].

Process Management Capability: The ability of a value network to coordinate and integrate collaborative processes within a network, to maintain efficiency of PSS design and delivery[15, 22, 23, 29].

Knowledge Management (KM) Capability: The ability of a value network to capture, transfer, share, and utilize knowledge resources across the network to deliver integrated solutions [23, 29]. In line with the well-defined framework of [30] we consider the KM capability as a multidimensional construct encompassing infrastructure (technical, cultural, structural) and process (acquisition, conversion, application and protection) capabilities. KM capability implies the focus on symmetric knowledge sharing among actors and learning from each other. Firms share their own expertise and knowledge resources for the enhancement of their co-creation partners' skills [22].

Table 1. Key business capabilities of a PSS value network

Business Capability	References
Customer Understanding	[21–23]
Partnership	[14, 22, 24, 25]
Trust-based interaction	[21, 22, 25]
Engagement	[22, 27, 28]
PSS design & delivery	[15, 21, 23]
Process management	[15, 22, 23, 29]
Knowledge Management	[23, 29]

4.2 IT Capabilities

In the following the key IT capabilities resulting from the literature search and the classification process are discussed.

IT Architecture Capability: The ability of a value network to create a coherent blueprint of technology, data, application, and their relationships, that meet PSS business requirements[11, 16, 31, 32]. Recently the service-oriented architecture (SOA) has become a prominent IT paradigm. SOA is an IT architectural style in which discrete bundles of software functionality are componentized and delivered to other systems as "services," enabling different applications to use common parts [33].

IT Development Capability: The ability of a value network to recognize technology trends and developments within the IT sector and to make appropriate recommendations for adopting emerging technologies, or altering or adapting current ones to leverage technology to achieve desired ends [16, 18, 32].

Flexible IT Infrastructure Capability: The ability of a value network's IT infrastructure to develop, diffuse, and support various system components quickly to cope with constantly changing business requirement [29, 34, 35]. It depends on the degree to which the IT infrastructure is connective, compatible, modular, and can handle multiple business applications [34].

IT Integration Capability: The ability of a value network to interlink different applications distributed in a network, in order to communicate with each other and timely and idiosyncratic exchange data. It involves both application integration and data consistency[29, 36, 37].An inter-organizational information system (IOIS) is a combination of technologies, people and processes that a value network uses to manage information across a network. Part of IOIS would be a shared system among partners and part of it would be an individual organizational system that needs to link. In this sense, the ability to link and maintain this linkage and keep logical and ontological data interchange among divers applications is called IT integration.

IT Management Capability: The ability of a value network to manage IT functions such as IT planning, investment and monitoring, coordination, control, IT project management, and negotiations with vendors[31, 32, 34, 36]. A PSS value network with greater IT management capability is expected to achieve more efficient and cost-effective IT operations to deliver business value.

IT Personnel Capability: The ability of the IT staff in the value network. It encompasses technical (hardware and software system), behavioral (interpersonal) and managerial skills of IT personnel [17, 31, 32, 34, 38]. These ranges of skills and knowledge are essential for IT personnel to be able to design, develop and deploy reliable IT solutions in order to meet both technical and business requirements of PSS and also to be able to communicate well with partners in a value network.

Besides the aforementioned ITCs, IT-business integration and partnership are also mentioned in the current literature as ITCs [32, 38, 39]. The former refers to the management ability to envision how IT supports business strategy while the latter refers to relationship, communication and coordination between IT and business for active engagement in related issues. We omit these capabilities in our discussion because both business and IT communities are responsible to share their experiences and knowledge, to understand each other, to integrate their functionalities, and to facilitate dialogue and interaction to work together. These capabilities are more relevant to the social and perhaps cultural dimensions of BIA, while we in this paper focus on its strategic dimension.

Table 2. Key IT capabilities of a PSS value network

IT capability	References
IT Architecture	[11, 16, 31, 32]
IT Development	[16, 18, 32]
Flexible IT infrastructure	[29, 34, 35]
IT Integration	[29, 36, 37]
IT management	[31, 32, 34, 36]
IT Personnel	[17, 31, 32, 34, 38]

5 Framework Development

In this section a framework for capability based BIA in a PSS value network context is developed. First, the internal relationships between IT capabilities are discussed. Since these relationships are supported well in literature, this part of the framework can be used as a basis for the further discussion. Then, a number of hypotheses are developed to show the relationship between IT and business capabilities as potential areas of capability alignment. The research framework is presented in figure1.

IT management and IT personnel capabilities can serve as the supportive capabilities which feed into the other IT capabilities to leverage them and enhance their performance. Previous studies show that firms with competent IT management and IT personnel skills are better at transforming IT resource into business value than their competitors [31, 34, 36].

Relationship a) *IT management and IT personnel capabilities enable other IT capabilities.*

As technology develops, the IT architecture is changed. IT architecture is a blueprint to place a new enabling IT technology in a context of value network. Evolution of internet-based technology like cloud-computing that enables convenient on-demand network access to a shared pool of computing resources requires a new architectural style for realizing cloud-computing in a PSS value network environment. Here cloud-based architectures need to be designed for network access [40, 41].

Relationship b) *IT development capability enables IT architecture capability.*

A flexible IT infrastructure is supported by network-wide architecture. SOA as a new architectural approach aims at increasing the flexibility of the IT infrastructure [33, 42]. It facilitates the realization of the modularity and connectivity by applying services as loose coupling of software functionalities. Also SOA promises to simplify the application integration by providing universal connectivity to existing systems and a consistent view of the data in terms of both semantic and syntactic integration [29]. Instead of point-to-point individual applications connections, SOA contributes to the many-to-many integration [33, 43].

Relationships c,d) *IT architecture capability enables flexible IT infrastructure and IT integration capability.*

A flexible IT infrastructure able to support the design, rapid development, reconfiguration, and implementation of heterogeneity of applications [34, 44, 45].Within a service-oriented environment, the integration and implementation of service-based applications rely on the flexible IT infrastructure. These services are reusable components that represent repeatable business activities and should be accessible through a shared IT infrastructure that enables intra- and inter organizational value networks [46, 47].

Relationship e) *Flexible IT infrastructure capability enables IT integration capability.*

According to fig.1, by following the proposed relationships between the IT capabilities, this points to the IT integration capability as a final resulting IT capability. In the following section we will discuss possible relationships between this IT capability and the previously identified business capabilities.

The ability to quickly gather and transfer information through integrated applications allows a better response to customer requests [48, 49]. In this respect, new types of IOIS have been developed based on social media technology called as a social customer relationship management to facilitate real-time, interactive two-way communication, and dialogue with customers to understand customer values [50]. IT integration aids a PSS value network to get a coherent picture and real time monitoring of customer requirements.

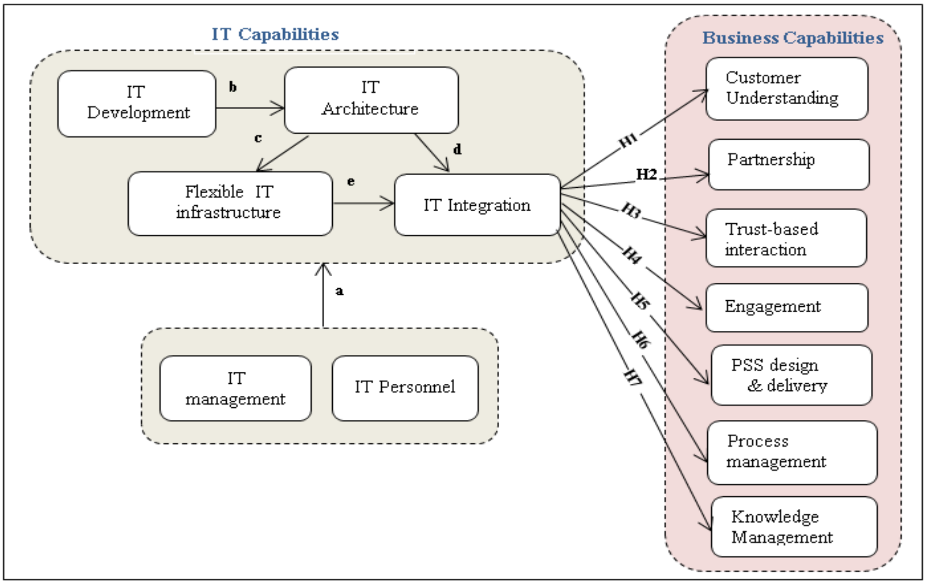

Fig. 1. Research framework, business- IT capabilities alignment in PSS value networks

Hypothesis 1: *IT integration capability supports customer understanding capability.* The ability to couple various applications and data sources within a PSS value network enhances information flow and therefore enables interactive relationship among partners, while they are encouraged to co-create value. Web-based IOIS have been identified in prior studies as a key component to support the inter-organizational efforts and to strengthen partnerships [48, 49, 51].

Hypothesis 2: *IT integration capability supports partnership capability.*

IT integration based on web technology facilitates interaction and two-way communication with partners which are necessary in building trust. Commitment and trust can be enhanced and solidified by allowing partners access to real-time data and providing information transparency which is enabled by IT integration [51, 52].

Hypothesis 3: *IT integration capability supports trust-based interaction capability.*
Partners' engagement in collaborative activities can be realized via applications and data sources integration as means to share their resources and capabilities. It helps firms to access to complementary capabilities of their partners to discover opportunities and to respond to the market with customer-driven offerings [35]. A geographical scattering of partners implies any involvement in the co-creation value has to occur via an IOIS that aims to improve involvement in a service provision [53].

Hypothesis 4: *IT integration capability supports engagement capability.*

IT integration facilitates gathering and processing more reliable information from partners which in turn enables value networks to check the availability of resources, to select the best options, and to combine products and services in more rapid and cost-effective ways to enhance and widen offerings. Design and delivery of PSS with more extensive services to meet divers customer demands could not have been possible without a well-functioning IT integration [35, 54].

Hypothesis 5: *IT integration capability supports PSS design and delivery capability.*

Integrated solutions rely on interconnected and interdependent activities undertaken by partners. With advanced IOIS a value network ability to integrate inter-firm business processes at lower costs has become more feasible. IT integration aids a successful operation and coordination of collaborative processes and increases the effectiveness and efficiency of inter-firm processes [29, 48, 49].

Hypothesis 6: *IT integration capability supports process management capability.*

In value networks different firms involve in a co-creation value, they share not only explicit knowledge but also tacit knowledge, information is a key factor to create value and promote integrated solutions especially in complex offerings. IT integration helps a value network to timely acquire information of market spaces and customer requirements. It also enhances knowledge sharing among partners through common standards and protocols [29, 48, 49, 53].

Hypothesis 7: *IT integration capability supports knowledge management capability.*

6 Conclusion

This study presents a further step towards elaboration of the business-IT alignment at a network level. A PSS value network with more emphasis on establishing closer relationships with partners, operational linkages, enhanced information sharing, and cooperation among partners, requires additional insights of BIA. We examine the notion of BIA in a more operationalized way in the light of a capability approach. We identify two sets of business and IT capabilities from literature on a PSS value network and subsequently redefine and classify under new labels. We define seven business and six IT capabilities. In the next step, by developing hypotheses comprising a conceptual framework we investigate the relationship between IT and business capabilities defined as the business-IT capability alignment. The proposed framework suggests that the IT integration capability is the core essential ITCs that supports business capabilities. IT integration is a solid foundation of a PSS value network; it promotes information flow, collaboration and partnership, trust-based relationship, and coordination among partners. In future work we aim to validate these hypotheses by doing case studies and survey research. The framework can aid PSS value networks to leverage their both IT and business capabilities to gain competitive advantage over time. We will investigate whether this notion of business-IT capability alignment does indeed improve the performance of a PSS value network.

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A Phylogenetic Classification of the Video-Game Industry's Business Model Ecosystem

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Abstract. Since 1990, Business Models emerged as a new unit of interest among both academics and practitioners. An emerging theme in the growing academic literature is focused on developing a system that employs business models as a focal point of enterprise classification. In this paper we attempt a historical analysis of the video game industry business model evolution and examine the process through the prism of two-sided market economics. Based on the biological school of phylogenetic classification, we develop a cladogram that captures the evolution process and classifies the industry's business models. The classification system is regarded as a first attempt to provide an exploratory and descriptive research of the video game industry, before attempting an explanatory and predictive analysis, and introduces a system that is not governed by the industry's specific characteristics and can be universally applied, providing a map for researchers and practitioners to test organisational differences and contribute further to the business model knowledge.

Keywords: Business Models, Video-game Industry, Cladistics Classification, Evolution.

1 Introduction

The term "Business Model" continues to attract significant attention on behalf of both academics and practitioners since 1995. However, contrary to how often the term is used, current literature is far from converging in providing a unanimously accepted definition of what a business model actually is [1]. The lack of consensus among scholars over what exactly a business model is has not prevented them from employing the notion at the centre of management theory and strategic management, opening new paths of research [2]. In this Section we aim first and foremost, based on the literature that governs business models, to establish the theoretical foundations of business model evolution through the three evolutionary principles, namely selection, variation, and replication.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 285–294, 2014.

Business models are regarded as something more than a simple recipe or blueprint for organizational change. According to [3], the business model is an opportunity-centric concept while strategic management is an environmental-centric one, rendering business model an integral part of the firm's strategic decisions regarding value creation and capturing. Compared to strategic management, it emphasises on cooperation, partnership and value creation. Consequently strategic management and business models are conceptually complementary [4]. Based on the above, the business model is regarded as a source of innovation and competitive advantage, providing support to the argument that places it at the core of strategic management ([5] and [6]). In other words, business models are viewed as a unified approach, on behalf of the enterprise, to meet different sets of success criteria both financial and non-financial ones ([7] and [8]), circumventing the narrow boundaries of enterprises, and in some cases industries, and has attracted much academic interest focusing on industrial and organisational change. Based on the above, it can be safely argued that business models are selected based on survivability maximization terms ([5] and [9]).

We have already discussed that business models can be a source, or facilitate the creation, of sustainable competitive advantage on behalf of the enterprise. Both intrinsic and extrinsic factors force enterprises to change their corresponding business models to realise both short and long-term strategic goals [10]. The mechanisms that govern this change, usually termed as business model innovation, have also been central to the growing literature. In [11], the authors examined the two sources of change, internal and external, and described these mechanisms in terms of their feasibility and effectiveness. Further work regarding the dynamics of business model innovation includes [12], the authors of which developed a theoretical framework that distinguishes between two interdepended processes, namely design and reconfiguration. The success of the process is governed by experimentation or imitation of other successful examples, usually derived from a given industry. Alternatively, the authors of [13] examined the evolution of electric vehicles business models through the prism of path dependencies. Several studies, including [14], provide evidence that the innovation process is strongly correlated with superior enterprise performance. Consequently, business models can be regarded as a focal point of replication ([1]; [4]; [11]; [12]; and [13]) and variation as the result of business model innovation ([1]; [2]; [10]; [14] and [17]).

In this paper we aim to contribute to the literature by employing business models as a conceptual tool and the focal point of enterprise classification. To achieve that, we shift our viewpoint to the biological school of classification, namely cladistics taxonomy, in order to organize an industry's business models into homogenous groups. We employ the dynamic, and relatively young, industry of video games as a typology to apply this new classification approach and examine its effectiveness. The short lifespan of the video-game industry allow us to perform a more detailed and thorough historical analysis of the industry which is essential for the classification process. As we will describe in Section 3, cladistics classification presents a series of scientific advantages and it is a well-developed and philosophically robust taxonomy approach. The output of our analysis, the cladogram, could be regarded as a map of the evolution process of the industry's business models and could be used to identify the factors that affected this process through time. Our results are interpreted via the prism of a two-sided market networking providing empirical evidence that aims to explain the evolution of the industry's business models in order to meet the strategic goals imposed by the two-sided morphology of the industry's market [41].

2 Related Work

An emerging theme of the literature revolves around business model classification ([15] and [16]) providing an initial step towards industry analysis and profiling [17]. Business model classification is mainly focused on fast growing and technologically driven industries, similar to the video game industry, because they provide a fertile grown for business models' evolutionary dynamics exploration. Most of the classification attempts were directed to biotechnology and pharmaceuticals ([16]; 24] and [15]), telecommunication and information industry ([19]; [20]) and e-business models ([21];[22]). Regarding, the development of a formal classification framework, in [23] the revenue streams are employed as a criterion, while in [24], the authors developed a two-dimensional classification framework based on the strategic perspectives and economic and operational factors of the enterprise. On the other hand, in [6], a first analogy is attempted between the biological objects of classification, namely species, and enterprises. Finally, [25] introduced a multi-dimensional e-business model classification system, arguing that the two-dimensional ones are far too limiting.

According to [2], most business model classification approaches are driven by the researcher's knowledge and is followed by a case-study based validation ([26] and [27]) or via the contingency theory ([28] and [15]). Consequently, the taxonomy approaches vary significantly among researchers based on their conceptualization and knowledge. In other words, compared to the biological school of classification, these phenetic approaches, which are based on similarities among the objects of classification are highly subjective [9]. One of the first works that aimed to implement cladistics classification in industrial evolution of manufacturing systems was [9] who argued that cladistics taxonomy provides a classification system that is scientifically more appropriate because of its objectivity.

3 Methodology

In this paper we employ the classification methodology as described in [9]. To facilitate discussion we provide a brief, yet solid description of cladistics classification. Cladistics taxonomy in biology classifies organisms based on identifying their most recent common ancestor. Similarities (dictated by *characters* and their corresponding *character states*) among organisms are examined in order to track the evolutionary process. However, the major difference between phenetic classification and phylogenetic classification is that, in the latter, entities are classified based on their most recent common ancestor and characters are used to identify that ancestor.

Initially the industry has to be selected which formulates a form of classification as well [9]. In our case it is the video-game industry that interests us, albeit the business models that aim to create and capture value through the development, publication and distribution of video games no matter the content of the game (entertainment, fun, engagement, education etc.). In this analysis, we employed an elemental definition of what constitutes a business model based on the works of [30], [31] and [32]. Adopting a more general definition would result in analogies that would erode the descriptive power of our classification. Analogies, in the biological school of classification, are created by grouping entities together using characters inherited from two different ancestors.

3.1 Character Development and Selection

In order to determine the characters, a historical analysis is performed to track the milestones of the industry (technological advances, monetisation strategies, customer segments etc.) through the evolution process and identify the appropriate business model characteristics. This process is called *Character Search* and *Selection*. The historical analysis was based on published academic papers or reports that describe the operations of various enterprises through history and how they adapted to various environmental and internal factors. We elaborate further on this matter in Section 4.

The selection of a character is validated through a test of homology [33] and character conflict resolution. The process of character conflict resolution is a dynamic one that requires the construction of several conceptual cladograms followed by direct test of homologies. Character conflicts are the main source of creating analogies. Character conflict resolution takes place continually from the point of character determination, selection and conceptual cladogram creation.

The choice among the various conceptual cladograms is governed by the test of parsimony, which means that the clade with the least possible character changes is chosen, based on the parsimony rule which dictates that evolution follows the shortest path. Based on the outgroup comparison, characters are grouped into derived through evolutionary process (variation) and inherited from the most recent common ancestor (outgroup). This process is called “establishing character polarity”. Finally, after solving the character conflicts that may occur, the nomenclature is established. In this paper we aimed to define archetypes based on informative and commonly used terms by both academics and practitioners [42].

4 Data

Performing a historical analysis presents a significant challenge in order to avoid subjectivity during the process [29]. In our work, historical data are used for two purposes. Firstly, we aim to identify the video-game industry business model archetypes, and secondly the characters that are used for classification purposes. We based our approach on the *Business model Canvas* developed in [34] followed by a video-game industry historical analysis ([29]; [35], [36]; [37]; [38]; [39] and [40]). The Canvas was also used to facilitate comparison among the different archetypes and as a reference point. Through the historical analysis, we created a time series of case studies and proceeded with a comparative examination focused on *Mining for Species* and character search and selection. We constructed several conceptual cladograms, followed by a series of parsimony tests. Character conflicts were resolved via a test of homology and the most parsimonious cladogram was chosen. The process of archetypes identification is dynamic, and as more data become available new business model archetypes could be identified. However, as new species become known, they enrich the already existent cladogram along with the newly acquired characters without having to undergo a whole character and species rearrangement. The business model archetypes (or species) we have identified through our analysis are 11: i) *Outgroup: Electronics Manufacturing*, ii) *Arcade Games Manufacturing* iii) *Console Manufacturing*, iv) *Console Manufacturing-sales-at-a-loss*, v) *Publishing*, vi) *Freemium-game publishing*, vii) *Independent game-developing*, viii) *Third-party game-developing*, ix) *In-house game-developing*, x) *Second-party game-developing*, and xi) *Crowd-funded game-developing*.

Table 1. List of classification characters and character coding

Code	Character	Code	Character
1	Platform manufacturing	19	Outsourcing publishing
2	Console manufacturing	20	Price discrimination
3	Selling-at-a-loss revenue stream	21	In-game advertisement
4	Own distribution channels	22	Digital distribution
5	Third-party distribution channels	23	Outsourcing digital distribution channels
6	Own development studios	24	Multidisciplinary development team
7	Outsourcing game development	25	Exclusive publishing agreements
8	Localisation services	26	Development Independence
9	Video games development	27	Revenue stream via royalties
10	Layout design and printing	28	More than one publishing contracts
11	Intellectual Property (IP) acquisition	29	Small, close-knitted teams
12	IP creation	30	Use of middleware
13	Universal development support	31	Exit strategy
14	Production risk minimisation strategy	32	Cost minimisation strategy
15	High marketing costs	33	Engine released as open-source
16	Hit driven strategy	34	Crowd-funding
17	Royalty payments	35	Self-funding
18	Hardcopy sales	36	No platform-manufacturing
		37	Owned by publisher

The character that were chosen for the classification purposes, based on [34], for systematic reasons are shown in Table 1. For space considerations we will not include a table that contains the character states for each business model archetype of the video-game industry. However, the character evolution (and polarity) can be seen in Figure 1 in the next Section.

5 Results and Discussion

In this Section we include, and discuss, the factual cladogram that tracks the evolutionary process of the video-game industry's business model archetypes shown in Figure 1.

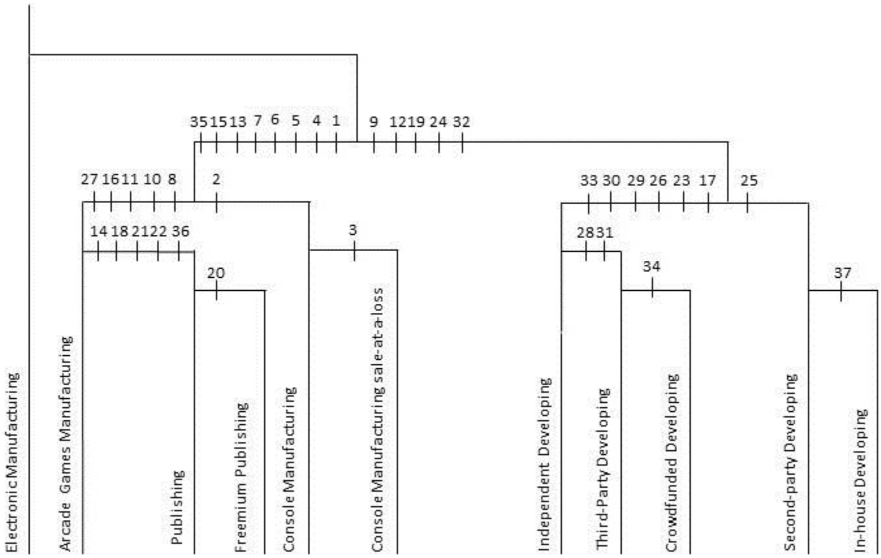

Fig. 1. The Video-games Industry Cladogram: Business model archetypes are grouped together based on their most recent ancestor. Numbers represent the characters that have been inherited or developed through the evolutionary process.

Figure 1 shows the evolution of the video-game industry's business model ecosystem based on their most recent common ancestor. The figure also depicts the evolution of characters through time. Business models are grouped together into two broad categories or families: 1) the *Platform Manufacturing* and *Publishing*, and 2) *Video-game Developing*. We examine the relations among these archetypes and focus our analysis through the prism of two-sided market economics, as part of the networking literature that focuses on the intermediaries of the market [41].

Arcade Games Manufacturing: This business model is focused on manufacturing platforms dedicated to a single game. The enterprises characterized by this business model were combining characteristics of both publishing and manufacturing in an all-in-one approach. The key partners were entertainment hubs and public houses which was the main target group of coin-operated machines similar to pinballs. Due to the increased manufacturing costs and the technological limitation vertical disintegration was impossible during the early days of the industry [42]. The vertical disintegration of this family of business models placed the foundations of the video-game market transformation into a two-sided one.

Console manufacturing: with the advent of new technological advances that allowed lower manufacturing costs new platforms, no longer dedicated to a single game, were produced. Console manufacturing business model is focused on maximizing the console sales which are supported by games developed specifically for a given platform preventing cross-platform compatibility. This interdependence between publishing hit-driven titles and player-base maximization was responsible for another business model (*sale-at-a-loss*), also known as *razor-blade*, which effectively entails that console manufacturing business model focuses on market infiltration maximization instead of profits [43];[44]. To achieve that, the business model needs to establish networks [42] with another business model, namely *publishing*, operating in a form of two-sided market [41]. It is safe to argue at this point that multi-sided markets determined the emergence of a symbiotic relationship between more than one business models [18]. This business model archetype acts as the intermediary between publishing/developing business models on one hand and customers on the other.

Publishing: the publishing business model is focused on revenue and profit maximization through video-game sales (physically or digitally) following a risk-averse strategy [42] that skews the publishing decision making heavily towards hit-driven titles. The apomorphic event took place when the business model discarded the manufacturing character and focused instead on monetisation strategies of physical and digital copies of video games [45]. This business model acts as the major revenue source and financially supports the console manufacturing business models in a symbiotic relationship, as discussed earlier, and the major source of funding for the *Video-game Developing* business models. Consequently, Intellectual Property (IP) acquisition and creation, internally via in-house development, is very important for the sustainability of this business model [42]. A specific aspect of two-sided market, publishers currently operate in, led many publishers to follow a price-discrimination strategy, usually called *Freemium Business Model* [41].

Video-game Developing: this family of business models focuses on the development of original or licensed titles creating new video games for all platforms. The group consists of *Independent developing, Crowdfunded Developing*, *Third-party developing*, *Second-party developing* and *In-house developing* business models. Their evolutionary trajectory is heavily affected by the relationship they develop against publishing business models which act as their major partners for financing and revenue streams. The major goal is survivability maximisation through production costs minimisation. To overcome these challenges, developing business models focus on the production process and key resources when it comes to business model innovation. *Independent developing* operates usually under the radar [38]. They employ digital distribution channels to directly sell the products to consumers, or via online markets (GoG, Steam, etc.). *Third-party developing* business models are focused on creating original titles or entering a contract with a publisher. The challenges that developing-studios face during project financing lead to the emergence of a new business model, namely *Crowdfunded-developing*, which aims to attract funding directly from customers. This initiated a series of domino effects on the production and monetization process of the games and is heavily based on the loyalty of the customer base, which is placed at the centre of production process for feedback and word-of-mouth marketing strategy. Economies of scale usually lead Publishing and developing business models to merge or acquire competitors [42]. *Second-party developing* business models are focused on engaging in dedicated contracts with a single publisher who acts as the financier of the project and the final customer. The studios operating under this business model rarely enjoy production independence and are focused on a hit-driven development strategy. Finally, *in-house development* studios are effectively owned by publishers in a strategically driven strategy to fuel IP creation but usually they operate in a relatively more autonomous way.

6 Concluding Remarks

This paper presents a new classification approach, namely cladistics classification. Assuming that business model change is governed by the three principles of evolution: 1) selection, 2) variation and 3) replication, we employ cladistics classification to group business models based on their most recent common ancestor. Other kinds of classification are based on a two-dimensional, phenetic approach, which in one hand informative, but on the other hand lacks the objectivity and overall applicability, cladistics classification offers an objective and philosophically robust alternative when it comes to business model classification.

We perform a historical analysis of the video games industry, which is used as a typology to examine the applicability of the cladistics classification when it comes to business models. The result of the classification process, namely the cladogram, is validated through the lenses of two-sided market economics and networking and we provide some initial evidence about the dynamics of the video-games-industry business model evolution.

As part of the creative industries, video-game industry business model analysis and classification could potentially be of value for cross-industry fertilization of new and innovative business models that could benefit music and film industry alike. Price discrimination and servitization, along with the dynamics of the business model networking, could provide valuable lessons, highly applicable to other creative industries or industries that share similar attributes as the video-games one.

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Financial Statement Analysis for Enterprise Network Design

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Abstract. Cooperation and collaboration is something already widely discussed in literature and several different types of Enterprise Network Management (ENM) models have been proposed, highlighting a certain degree of maturity of the literature on this topic. Nevertheless, the increasing demand for collaborative forms to face up to the actual market imposes the development of a systematic methodology. The aim of this methodology is to select the most appropriate ENM model for the pool of potential partners, following an engineered process of network design and implementation. In literature, studies on the appropriateness of different analytical frameworks for designing the most suitable ENM model for specific collaborative businesses have been formulated exclusively based on the analysis of non-financial dimensions of the companies; for example the investigated non-financial aspects are related to the purpose or the function of the collaboration, to the companies' degree of organization, to the market type or business model, to the pros and cons of the different legal forms, to the soft issues management and to many others. This paper extends the current research and introduces a decisional framework that integrates some of the previous listed endeavors with a quantitative Financial Statement Analysis (FSA) approach in order to guarantee a repeatable, reliable and reproducible selection of the most appropriate ENM model. Finally, the framework is tested in a case study with the aim of validating the methodology.

Keywords: Collaborative Network, Financial Statement Analysis, Network Design, Virtual Breeding Environment, Virtual Development Office, T-Holding.

1 Introduction

Cooperation among companies, especially Small and Medium Enterprises (SMEs), is something already discussed in several works [1]. The benefits coming from the strategic alliances have been studied under different dimensions of analysis, such as economical, financial, strategic, operative; for the opportunities resulting from the collaborations and as a result of the rapidly evolving challenges faced by business entities and society in general, a large variety of business networks have emerged in recent years [2]. Several studies have developed theories and guidelines for the management of the networks in their various stages of life, i.e. the phases of the network creation, the operations, the network evolution/metamorphosis, the network

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dissolution [3, 4]; thus, these works assume that a certain type of collaboration has already been established [7]. Contrarily, few works have developed tools or frameworks for the selection of the most appropriate ENM model for a pool of companies that want to start a collaboration [7] and no papers are available for the selection of the ENM model through a Financial Statement Analysis (FSA) conducted on the potential partners before and during the network creation. Different alliance forms represent different approaches that partner firms adopt to control their dependences on the alliance and on the other partners: the incorrect choice of the collaborative model could lead to the failure of the network. The authors believe that the choice of the most suitable ENM model is determined also by the financial positions of the potential partners of a nascent network. To minimize the risk of the choice of the incorrect ENM model, a FSA of the companies of the future network should be the first activity to be conducted to eliminate incompatible ENM models and to restrict the choice to a few well-matched collaborative forms. This is the objective of the paper, i.e. to present a framework aimed at restricting the choice to one, or two at maximum, ENM models, after an FSA of the companies that want to start a collaboration. The FSA is thus a tool for evaluating the overall financial situation of the potential partners and allows the managers of the nascent network to identify the correct ENM model, according to specific criteria described in the paper. The proposed methodology is, of course, a first attempt to formalize the preliminary phase of the network creation, i.e. the choice of the most suitable management model, and it is one of the criteria for choosing network members, to be used in synergy with other approaches. The paper does not assume that the collaboration has already been established but instead provides a methodology to suggest if an appropriate ENM model exists, or not, and if the companies can somehow collaborate based only on their financial situations. Even if the methodology can be generalized and extended to include other forms of collaborative networks, the authors' analysis considers only three types of collaborative networks and combinations, that are characterized by different degree of business and process integration, taken as representative of long term collaboration forms with different integration degree [12]: the Virtual Development Office (VDO) [5], the Virtual Breeding Environment (VBE) [6] and the Holding and T-Holding organizations [7] (where the T- stands for 'protection', thus a typology of holding suitable for those companies in crisis). The framework has finally been implemented and tested in an industrial case of 4 companies and the most appropriate ENM model is identified and proposed.

2 Financial Statement Analysis for Enterprise Networks: A Literature Analysis

Today a wide range of literature is available on the FSA, particularly on its use for forecasting and for taking strategic decisions, for increasing firms' competitiveness or for implementing actions to save companies in crisis, in general for understanding the health of the companies. Nevertheless, the adoption of the FSA for collaborative environments is few documented. This section presents some cases in literature where the FSA has been implemented in environments with growing degrees of collaboration and used as management or forecasting tool. Looking at the FSA for multi-company cases, a first implementation of FSA is presented by [8], that compared the financial performance of two manufacturing companies. The data were gathered from the annual reports of companies during the last three years and analyzed by FSA tools, which were financial ratio analysis and comparative financial statement analysis. The findings of the study could help companies to judge their present condition and take decisions about their future steps while taking into consideration financial issues. A broader approach is presented by the study [9] that explored the relationships of supply chain partnership, financial management and enterprise performance. The study used the FSA for assessing that partnership has significantly and positively influenced financial management; financial management has also significant and positive influence on enterprise performance; from the FSA the authors derived that the supply chain partnership can not only influence enterprise performance directly, but also influence it indirectly through financial management. Very few articles are dedicated to the FSA implemented in collaborative environments. For example, [10] proposes a framework for the FSA of a network of SMEs, employing it as financial measurement of the network. The FSA has been pursued focusing on eight measurement objects that were causally related to form a strategic map. The FSA is illustrated by a case of a leader-driven network of SMEs. Still less papers use FSA for collaborative environment design. [11] introduces a mathematical model that integrates financial considerations with supply chain network design and operation decisions under demand uncertainty. The model is formulated as a Mixed-Integer Linear Programming problem which incorporates financial statements analysis through financial ratios and, demand uncertainty through scenario analysis and is solved to global optimality using standard branch-and-bound techniques. The applicability of the model is illustrated by using a case study along with a comparison with a non-financially constrained model which supports the superiority of the proposed model and highlights the tradeoffs between these models. There are no papers discussing the use of FSA for designing long-term strategy enterprise networks or using the FSA as a tool for choosing the most appropriate business model for a pool of companies that want to start a reciprocal collaboration. The following paragraphs describe the framework used for this purpose and its implementation in a real industrial case.

3 The Framework: FSA for Enterprise Network Design

The framework for Enterprise Network Design (END) through FSA is depicted in Figure 1. It extends the methodology proposed by [7], and it covers the gap consisting in the missing analysis of financial dimensions of the potential partners that want to start a collaboration. The FSA is thus used to measure the economic performance and appraise the financial position of the company. On the basis of the FSA results, the framework suggests, if they exist, one or two more appropriate Enterprise Network Management (ENM) models for the pool of potential partners, and considers three ENM models, taken as representative of long term collaboration forms with different integration degrees [7]: the Virtual Development Office (VDO), the Virtual Breeding Environment (VBE) and the (T-)Holding organizations (including both the Holding and the T-Holding). However, the methodology can be generalized and extended to include other forms of collaborative networks. The procedure represented by the framework is divided in 3 different stages of analysis: 1 quantitative (the first stage) and 2 qualitative (second and third stages). The qualitative analysis of the second stage could be implemented as suggested by [12] and [13], or using different approaches aimed at investigating the heterogeneity or homogeneity of the business models of the companies that would start the collaboration (stage 2 of the framework) and to explore the Strategic Objectives (SOs) of the potential partners. The innovative section of the framework lies in the first and third stages, since the framework in Figure 1 extends the researches of [12] and [13] introducing the concept that some ENM models are included or excluded from the analysis according to the reference values of some financial statements related to the involved firms. In particular, the first stage is an FSA for the evaluation of the financial situation of the potential partners. The financial indicators identified by the authors as suitable for the analysis are: the “financial leverage”, the “repayment capacity” and the “incidence of financial expenses”. These indicators are a part of a bigger set of financial measurements, nevertheless they represent some of the most important measures adopted by “Standard & Poors” in its rating system. Based on the reference values of these indicators, it is possible to classify the firms depending on a good or bad financial situation. The reference values are derived from the standard parameters that the Italian (but not only) banking systems adopt to assess the attitude of the company to reimbursing its financial debt. Given the complexity of such kind of assessment, the three indicators have to be read in an integrated manner, concluding that the company is in a good or bad situation in regard to at least two of them. Table 1 summarizes the indicators used for the FSA and illustrates the reference values that allow the author to follow the branches of the framework. For example, if the average value of the financial leverage is smaller than the reference value 3, then the rationale is “firms in a good financial situation”. The second phase of the first stage is the calculation of the firms’ performance values. The indicators for the analysis are the “total turnover”, the “invested capital”, the “ROI” and the “ROE”. The aim of the second stage is to evaluate the nature of the companies’ business models in their quantitative features, i.e. the degree of homogeneity on how organizations create, deliver and capture value. This also implies the degree of homogeneity of the business strategy, that is something that somehow influences the global network strategy. For the second stage and as mentioned above, the authors propose the qualitative approach proposed in [12], through a questionnaire and a software tool. Another methodology can be implemented that could achieve the same results, and this could be the subject of a future research. In the third and last stage of the framework of Figure 1 the indicators of “strategy planning” and of “aggregation” are monitored. With reference to “strategy planning”, “Turnover breakdown by segment”, “Cost of core processes” and “Cost of support processes” are simulated through a managerial accounting approach. For “aggregation”, the statements to be calculated are “Total turnover”, “Value added”, “Equity”, “Net financial position” and “N. of employees” as aggregated values of the network. The conclusions from the framework can be summarized as follows. The VDO management model can be excluded for those firms with a financial situation evaluated as insufficient based on the reference values and it is more appropriate for those companies that have an heterogeneous business model. The VBE management model can be suitable for every combination of the financial statements, since the nature of the strategic objectives of the model are more oriented to Supporting Process Opportunities. The VBE model thus is not excluded a priori before conducting the last stage of the framework.

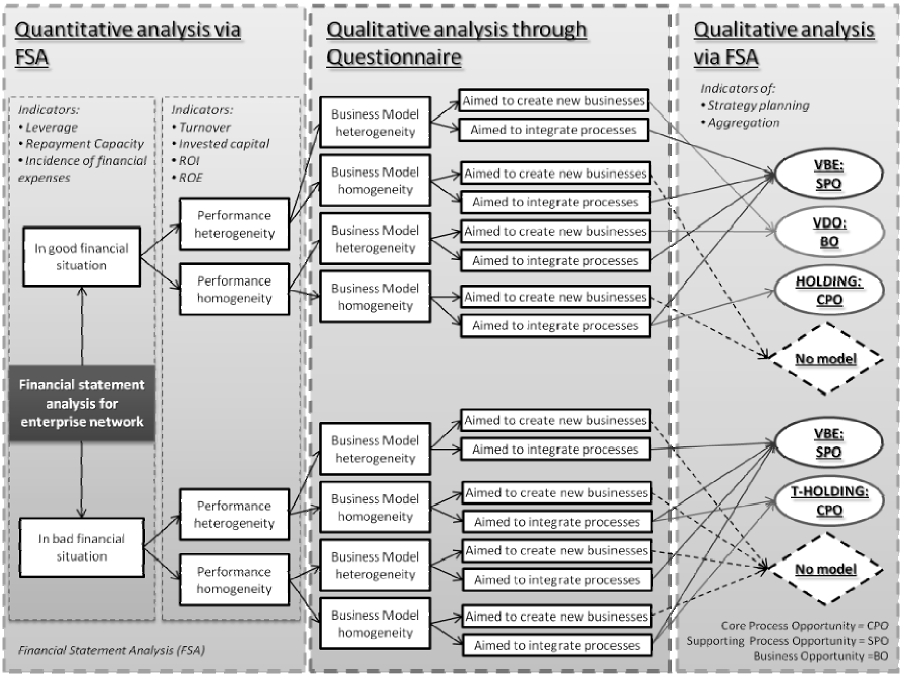

Fig. 1. Framework of analysis

Table 1. Financial Statements Indicators for the analysis and reference values for the rationale

Class of the indicator	Name of the indicator	Calculation	Ref. Value	Statement/Rationale
Financial situation	Leverage	Net financial position/Equity	3	If value < 3 of ref. value: good financial situation
	Repayment Capacity	Net financial position/EBITDA	5	If value < 5 of ref. value: good financial situation
	Incidence of financial expenses	Interest expenses/EBITDA	25%	If value <25% of ref. value: good financial situation
Performance heterogeneity or homogeneity	Total Turnover	Income Statement item	50%	If the difference between the average values of the 25% the companies' highest turnovers and 25% the companies' lowest turnovers is > 50% of ref. value: heterogeneity
	Invested capital (IC)	Reclassified Balance Sheet	50%	If the difference between the average values of the 25% the companies' highest IC and 25% of the companies' lowest IC is > 50% of ref. value: heterogeneity
	ROI	EBIT/Invested capital	5%	If value > 5% good operating profitability
	ROE	Net Income /Equity	8%	If value > 8% good return on equity
Strategy planning	Turnover breakdown by segment	Management accounting	n/a	Simulate turnover increase of new business development
	Cost of core processes	Management accounting	n/a	Simulate cost reduction through core process integration
	Cost of support processes	Management accounting	n/a	Simulate cost reduction through support process integration
Aggregation	Total turnover	Income statement item	n/a	Calculate total turnover of the network
	Value added	Reclassified Income Statement	n/a	Calculate total value added of the network
	Equity	Balance Sheet item	n/a	Calculate total value Equity of the network
	Net financial position	Reclassified Balance Sheet	n/a	Calculate total Net financial position of the network
	N. of employees	Management accounting	n/a	Calculate total employees of the network

The Holding is suitable for firms in a good financial situation and with high homogeneity in the performance and in the business model. Contrarily the T-Holding is appropriate for companies in bad financial situations and with an homogeneous business model: in fact the main mission of the T-Holding is to avoid the collapse and the disappearance of the companies in crisis [7].The "No model" solution could, instead, be proposed for all the bad financial situations and in general for the cases of strong homogeneity in the business model, i.e. where there is a high level of competition among companies or overlapped processes and operations. The aim of this last stage of the framework is to deepen the nature of the network strategy (new businesses or new processes), and to allow the researchers to choose the more suitable ENM model, if it exists and if there is only one. The last stage, whose methodology is presented in [13], has the goal of investigating the nature of the SOs of each considered ENM model, i.e. the reasons why firms aim to start an alliance for a long period, of different sizes and with different integration degrees (Business Opportunities – BOs, Core Process Opportunities – CPOs, Supporting Process Opportunities - SPOs) [12]. The next paragraph presents the implementation of the methodology in an industrial case of 4 companies that wanted to start a collaboration and thus facing the issue of the selection of the most appropriate ENM model

4 The Case Study

The Italian company, Elettromil srl, identified the opportunity to collaborate with 3 other companies in a more stable form (in the paper the 4 companies, including Elettromil, are named Company A, B, C and D in a random order for privacy reasons). The companies were already cooperating in some way with Elettromil, but in the classical supplier-customer paradigm in a classic supply chain form. The idea of the collaboration had been identified by Elettromil. With a lot of experience in the production of high-voltage transformers, the company perceived an opportunity to proceed to a synergy for the production of specific medium-voltage transformers, enhancing the productive excellence of companies in the territory who were operating in the same sector. The decision to start manufacturing this class of products was made as they are produced, at national level, by a few manufacturers that operate under an oligopolistic market with high margins on raw materials and highly specialized processes. The opportunity was characterized by a growing demand and interest, represented by the renewable energy sector, but also by all the applications on the medium voltage distribution and industrial applications on average voltage. The FSA analysis started from the financial statements summarized in Table 2. Given the overall results of financial indicators, the financial situation has been classified as substantially good and the level of performance heterogeneity as quite strong. From the questionnaire there emerged a moderate heterogeneity of the business model and a strong orientation to create new business opportunities and core process synergies. The final part of the analysis, i.e. the simulation of the turnover increase for new business development, the cost reduction through core process integration and the cost reduction through supporting process integration, suggested that the network strategy was more oriented towards Business Process Opportunities (BPOs). Thus, the VDO can be evaluated as the ENM model. Finally the measurement of the aggregated network values, i.e. total turnover, total value added, total value equity, total net financial position and total employees of the network, suggested that the new integrated entity set-up through a VDO model can be a good solution for facing potential increasing demand. This presents a valuable proposition that benefits from a total turnover of 30.148 K€, a valued added incidence on turnover of 18.8%, a total number of employees of 101 and a net financial position of 3.567 K€. The non-collaboration form could imply a weaker strategic position for all the involved companies. Instead, a VDO solution can be an opportunity for improving by taking advantage of the other companies' competences, skills, technologies, etc.: the objective is potentially achievable, and the VDO is the best type of collaborative form to achieve this objective.

Table 2. Financial statements from the case study (values in .000 €)

Class of the indicator	Name of the indicator	Company A	Company B	Company C	Company D	Average values	Statement
	Year	2012	2012	2012	2012	2012	
Financial situation	Leverage	1,23	16,40	62,36	0,47	19,88	good financial situation
	Repayment Capacity	2,33	13,29	5,16	4,07	4,18	
	Incidence of financial expenses	8,21%	39,77%	26,52%	1,83%	18,17%	
Performance heterogeneity	Total Turnover	23.913,64	2.596,69	2.222,63	1.415,21	difference >50%	heterogeneity in performances
	Invested capital	3.714,79	1.124,93	1.528,57	2.354,68	difference >50%	
	ROI	17,31%	4,12%	6,13%	3,60%	7,68%	
	ROE	20,58%	0,56%	26,31%	20,13%	16,90%	
Network aggregated values	Total turnover	Total value added		Total Value equity		Total net financial position	Total employees
	30.148	5.669		3.567		6.099	101

5 Conclusions and Further Research

Collaboration within a stable long-term strategy enterprise network is nowadays one of the most successful solutions for facing the financial and market crisis; several collaborative networked organization management models are currently formalized in literature and tested successfully in industrial cases studies. Nonetheless, the selection of the Enterprise Network Management model is still something not completely analyzed and it is too much often a casual process, sometimes left to the entrepreneurs' ability to involve partners. Instead, the choice of the most appropriate model should be made not only for achieving the goals of the network strategies, but also on the basis of the financial statements of the companies, in order to guarantee the sustainability of the collaborative environment. Thus, the paper presents a framework for assessing the financial statements of the potential partners, before they start the collaboration, in order to identify, if it exists, the most suitable Enterprise Network Management model among the three referenced models: the Virtual Development Office (VDO), the Virtual Breeding Environment (VBE) and the (T-)Holding. The framework has then been implemented in an industrial context where the VDO has been selected as the most apt management model. The proposed methodology is an initial attempt to formalize the first phase of the network creation, i.e. the choice of the most suitable management model, and it is one of the criteria for choosing network members. Simply having financial compatibility does not mean the potential members have the competencies required. In fact, it is important to highlight that the approach proposed by the authors is first a decisional support and it should be used in synergy with other methodologies: it could be limiting to evaluate the network's potential based on the network's average financial situation. This could contain the risk that the very good financial situation of one partner whitewashes the bad financial condition of another partner, which can result in a critical business situation. For this reason, the approach suggested by the authors could be extended considering different financial statements as well as including more alternative scenarios in the framework for covering other possible financial statements of the companies. Finally, for validating purposes, it should also be implemented in other case studies and in different sectors.

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Innovation Networks

An Agile Innovation Framework Supported through Business Incubators

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Abstract. Entrepreneurs and SMEs that develop new ideas are the main sources of innovation in products and services in the society. However, due to the lack of required resources and know-how innovation ideas may not develop into full-fledged results. Business incubators can play an important role here. They can provide innovators with the required enabling environment, guidelines, and tools supporting the innovation process. This paper proposes an enabling agile innovation framework, which is based on using VBE and VO paradigms. The paper first defines the innovation process, and then addresses a set of tools and mechanisms that need to be utilized to facilitate the innovation process. An example case in intelligent buildings is also provided.

Keywords: Business incubators supported innovation, innovation framework, innovation process, innovation in VBEs and VOs.

1 Introduction

Small and medium enterprises (SMEs) increasingly feel the pressure of global competition. To survive through the current market conditions, they need to respond to customers' demands much more efficiently and effectively than ever before. One approach to achieve this goal is through continuous improvement, and another through innovation in products and services. As defined in [1], "*An innovation is something original, new, and important - in whatever field - that breaks in to (or obtains a foothold in) a market or society*".

In spite of the large amounts of effort and interest presented in the literature related to this area, it is reported that most innovation projects fail. The main reasons, a number of which are also expressed in [2, 3] include the following:

- Innovating organization's goals are ineffectively deployed into actions.
- Organization does not have an enabling innovation management framework.
- Financial resources are not sufficient for developing the prototype of the idea.
- Planning, design, and development of the innovations are poor.
- Access to the required information and knowledge is poor.
- ICT support is not efficiently and/or sufficiently used.
- Inter- and intra-organizational collaboration is not sufficiently exploited.

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- The processes of finishing the innovation project and introducing its results to customers are slow.
- There is no mechanism to monitor and assess the whole innovation process.

A number of research efforts have focused on overcoming some of the listed problems, although with some limitations, as discussed in Section 2. But the biggest and the most common problem for innovation as reported by entrepreneurs and SMEs alike is the lack of necessary resources and know-how to properly develop their ideas. Business incubators possess the required expertise and therefore can support in this process. However, an innovation enabling framework which can be provided through the incubators to the entrepreneurs and SMEs is still missing.

Taking into consideration the common problems and challenges in innovation efforts, and focusing on aspects not yet addressed by the literature on related research, this paper proposes an *enabling agile innovation framework*. This framework is based on the concepts introduced in Virtual Organization Breeding Environment (VBE) [4, 5] and in Virtual Organizations (VOs) [6] paradigms, and introduces an innovation process as well as a set of assisting tools and methodologies to be used during the execution of this process. The business incubators domain is considered as the main domain for applying our innovation framework.

The remaining of this paper is structured as follows. Section 2 provides information about related work. Section 3 describes our framework and its main components. Section 4 provides an example, to show how an innovative idea gets processed by the steps of our proposed framework and the main outputs of the innovation process. Finally, Section 5 concludes the paper.

2 Related Work and Open Issues

This section provides the main examples of related research in this area. They are grouped here into four categories, based on the main focus area addressed by them, including: 1) open innovation, 2) collaborative innovation and innovation networks, 3) the role of VO/VBE, and 4) the role of ICT.

The first group of related work focuses on **open innovation**. For example, [8] and [9] focus on open innovation in SMEs. Open innovation is primarily introduced by Henry Chesbrough [7], who defines it as follows:

“Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology.”

The second group of related work focuses on **collaborative innovation**. The idea of innovation networks and collaborative innovation networks has become popular during the recent years and thus become the focus of research efforts, such as [11] and [12]. A Collaborative Innovation Network (CoIN) is defined by its original proposer, Peter Gloor [10], as follows:

“A cyberteam of self-motivated people with a collective vision, enabled by the Web to collaborate in achieving a common goal by sharing ideas, information, and work.”

The third group of related work focuses on the **role of VBE and VO paradigms in innovation**. The VBE and VO are two main types of Collaborative Networks (CNs) that have drawn considerable amount of attention. A VBE [4, 5] represents a long term alliance established among large number of organizations. VBE provides the necessary conditions and mechanisms to its members to support them with their need to potentially configure goal-oriented Virtual Organizations (VOs) [6]. A VO is established among a number of VBE members, when an emerged opportunity can be supported through their collaboration and joining their forces and resources.

VBE and VO have been considered by only a few efforts in the context of innovation. In [13], VO paradigm is used in the formation of virtual teams. In [14], the authors address the need for a methodological support on how to structure and conduct innovation processes in VOs. They propose VBE as the facilitator for an agile strategic innovation management for VOs.

The fourth group of related work comprises the efforts focusing on **the role of ICT in innovation**. In addition to emphasizing the importance of ICT, proposing ICT-based innovation support infrastructures has been the focus of a number related research efforts, such as [15] and [2].

Although there are large numbers of innovation related research efforts, most of them focus only on a single aspect related to innovation, such as: open innovation, or collaborative innovation network. Furthermore, although there are a few efforts addressing VO/VBE paradigms as key enablers for agile innovation process, the details of how these paradigms can be used for innovation is not yet investigated. A comprehensive approach for innovation is needed that encompasses a framework, based on innovation related paradigms, and providing both well-defined innovation process and guidelines on which tools and mechanisms to use at each step.

3 Proposed Agile Innovation Framework

Considering the reasons for the failure of most innovation projects and the limitations of other innovation related efforts in the literature, we propose a framework that combines technologies and conceptual paradigms to provide a comprehensive solution. This framework consists of two main building blocks: 1) innovation process definition, and 2) a set of tools/mechanisms to facilitate the execution of the process. More details are provided in Sections 3.1 and 3.2. The main underlying paradigms of this framework are the VBE and VO, which support the collaborative and open innovation paradigms. The main advantages of VBEs/VOs for the success of the innovation efforts are as follow:

- As [12] states, VBE can support the *exploitation of local competencies and resources* by an agile and *fast configuration of the most adequate set of partners* for each innovation project. This also enables producing economically viable solutions for innovative ideas.
- Trust management mechanisms are provided in VBEs, which enhances the cooperation/collaboration among member organizations, once within the VOs.
- VBE supports well defined roles and policies. Furthermore, mechanisms and guidelines for VO creation and collaboration are well defined; these act as agility enablers, and can be applied to convince organizations to collaborate.
- Continuous monitoring of VBE members' qualifications helps with both upholding competency level and gap identification to take corrective actions.

- Issues such as sharing only the necessary resources with other appropriate partners and IPR are well established in VBEs and support member autonomy.
- VBEs provide an effective common ICT infrastructure, which is indispensable for successful innovation projects, supporting needed agility in VO formation.

Considering these advantages, the framework proposed in this paper is based on the VBEs and VOs as key enablers. Furthermore, we have selected business-incubator-supported innovation as the main application domain. There are many entrepreneurs and SMEs that have innovative ideas, but do not have the necessary experience and resources to develop them. Business incubators provide the necessary means to support successful development of ideas into products. As part of this support, it is also necessary to provide innovators with a framework that consists of a guideline and a set of suggested tools/mechanisms to be used during the innovation process, which makes business incubator supported innovation a good-fit application domain for our framework.

Since the framework is based on the VBE, it is assumed that the incubators are also members of the VBE. Furthermore, when signing a contract with business incubators, the innovators (being entrepreneurs or SMEs) also become a member of this VBE. Many other production and delivery companies and financial organizations constitute the other members of the VBE. Innovation VOs interact with customers throughout the innovation process in order to involve them at all phases.

3.1 Innovation Process

To improve understandability of innovation process, first a number of terms used in this process are defined. A *Goal* is defined by an innovator to represent the main aim of an innovative idea. The innovator may divide/decompose a goal into *Subgoals,* in order to make it easier to achieve the goal. A *Subproduct* is a smaller unit of a product. A *Competen*cy for an organization corresponds to one capability or capacity.

The **innovation process** proposed and described below is rooted in and represents an enhancement of the results reported in multiple resources, such as the Stage-Gate Model [16]. This process specifies the actions to be taken throughout the innovation process, and is therefore of great value to be provided by business incubators to inexperienced entrepreneurs and SMEs. As we assume that ideas are already defined, some steps of the pre-development activities of New Product Development process (e.g. opportunity identification, opportunity analysis, idea genesis, and idea selection [17]), are not included in this process. Innovation process, provided by business incubators to innovators as an explanation of what to do at each step, as depicted in Figure 1, includes the following sixteen steps:

1. *Subgoals definition:* Innovators decompose the goal into subgoals.
2. *Market research:* Based on the subgoals, market research is carried out in order to identify the needs and constraints.
3. *Requirements definition:* Requirements for each subgoal are defined.
4. *Draft solutions design:* Draft(s) of possible solution(s), which meet the defined requirements, are generated at this step e.g. by means of brainstorming. Draft list of required subproducts might be identified at this step.

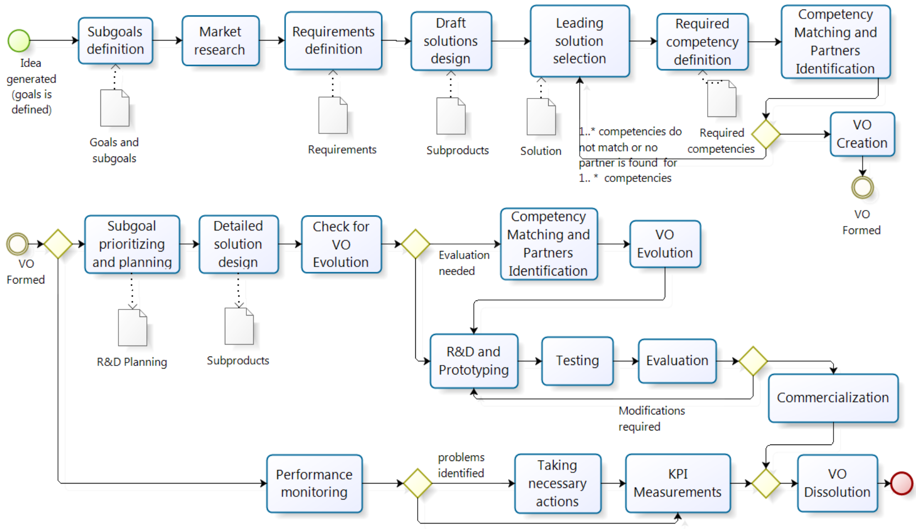

Fig. 1. Innovation Process

5. *Leading solution selection:* Considering the market needs and resource requirements (e.g. finances, time, people, materials, etc.), a number of metrics is defined for selecting the most suitable solution. Then, solutions are ranked and the first ranked solution is selected.
6. *Required competencies definition:* For each subgoal, competencies required for accomplishing the selected solution are identified. The terminology used by innovators might be syntactically and/or semantically different from the competencies specified in the VBE.
7. *Competency matching & potential partners identification*: Required competencies are automatically matched against the competencies of the VBE members in order to identify the potential partners in the innovation VO.
8. *Innovation VO creation*: The trustworthiness of the potential partners is evaluated to shortlist them. Then, a negotiation round takes place to identify the most suitable partners. The VO plan is detailed out and a contract is signed by each of the selected partners, which essentially marks the official launch of the VO.
9. *Subgoal prioritizing and planning*: It is identified by the VO members (including innovators) in which order the subgoals shall be achieved. Then, a detailed plan for the whole development process is made.
10. *Detailed solution design:* For each subgoal, a detailed solution is designed and subproduct(s) to be utilized or developed are identified.
11. *Checking if VO's evolution is necessary*: If new competencies are required according to the detailed solution and none of the VO partners possess this competency, than VO enters into an evolution phase.
12. *R&D and Prototyping*: The needed research and development activities are carried out and a prototype (e.g. physical) is produced at this step.
13. *Testing*: The developed prototype is tested to make sure that it works properly.
14. *Evaluation*: Prototype is evaluated by VBE members, through discussion forums.

15. *Commercialization*: Production is launched and final product is distributed to the market. Advertisements are also placed at this step.
16. *VO Dissolution*: Since the goal of the VO is reached, it is dissolved.

When a VO is created at Step 8, then the VO Operation phase starts, which needs to be continuously monitored. Therefore, a Monitoring activity runs in parallel to steps 9-15.

After the dissolution of the innovation VO, a number of activities need to be continuously carried out by the innovators initiating the process, such as evaluating the product, monitoring the market, and analyzing internal/external value and cost. Furthermore, although the VO is dissolved after the initial production of the idea, other types of VOs might need to be created later on, for example for mass production.

In addition to the main innovation process explained above, there are also some auxiliary processes (e.g. managing trust related data, managing member data, and managing competence data [18]) of which their details are outside the scope of this paper.

3.2 Supporting Tools/Mechanisms

In order to facilitate the execution of the innovation process, automated tools and mechanisms are needed. For innovation purposes, two main types of systems can be considered as part of the innovation framework.

One type of assisting system can address the *management of novel ideas*. Such a system may consist of tools that can for instance be used for idea mining and/or determining the idea uniqueness. Since we assume that innovators already have unique novel ideas, the idea management falls outside the current scope of our work.

Another type of system can address *Creation/operation of innovation VOs inside the VBEs*. As shown in Figure 2, our designed VO Creation/Operation System consists of:

1) **Competence Matching**: At Step-6 of the innovation process, innovators identify the competencies that are required to successfully achieve the subgoals. Since these competencies are specified in the terminology (or keywords) of innovators, at Step-7 they need to be matched against the competencies defined in the VBE, to find most suitable partners. P erforming this match manually by human is time consuming and error prone. The Competence Matching component can achieve this automatically by exploiting a number of syntactic and semantic matching algorithms and thus facilitates rapid formation of the innovation VO. Due to potential syntactic/semantic conflicts between these two specifications of competencies, user intervention might be required after the matching process has produced its results.
2) **Trustworthiness Evaluation:** Competence matching results in a list of potential VO members, which then gets refined based on their trustworthiness. The component for evaluation of organization trustworthiness can be built on top of the TrustMan system [19], developed previously.
3) **Negotiation Support:** After the potential most-fit members of the innovation VO have been identified, a negotiation round takes place. First, the negotiation objects, which require agreements, are defined. Then potential members discuss

about these objects through collaboration tools such as chat and forum. The results are reflected in the VO contracts. This component utilizes the Negotiation Wizard developed within the ECOLEAD project [20].

4) **Performance Evaluation:** During the operation phase of the life cycle of the innovation VO, performance of its members needs to be continuously monitored and measured. This is important for the success of the innovation VO. For this purpose, a set of Key Performance Indicators (KPIs) need to be defined and the performance of each member needs to be measured against these indicators, which would be addressed in future work.

The innovation *VO Creation/Operation System* is further extended with a number of VBE-related subsystems. The subsystems (indicated as related subsystems in Figure 2), are developed in two EU-funded projects, namely ECOLEAD [20] and GloNet [4]. Since these subsystems are auxiliary and considering space limitations, no details are provided on them, but the related information can be found in [18].

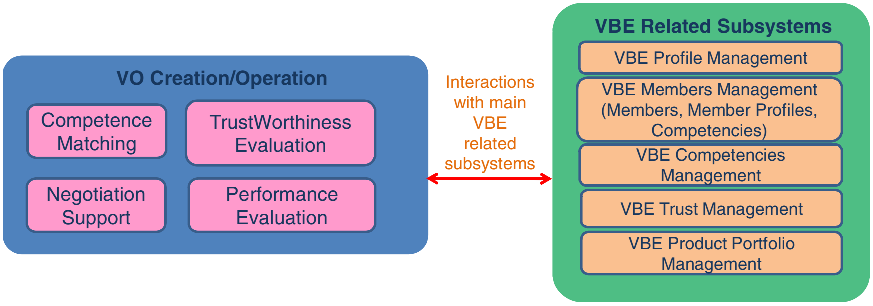

Fig. 2. Components of the VO Creation/Operation System

4 An Example Case (Intelligent Buildings)

This section provides an example from the intelligent buildings domain (based on [21]) to illustrate the main outputs of the innovation process. For space reasons, only the main steps of the innovation process and a partial sample list of competencies are addressed here.

Imagine the following being considered by some innovators. In buildings, each occupant has his/her own preferences related to the temperature and light. An advanced service supported in an intelligent building system, which consists of sensors (e.g. temperature detectors) and devices (e.g. heaters), may learn these preferences over time. When a person enters a room in a building, it should be detected who entered the room, so that the temperature and the light parameters can be automatically adapted according to his/her preferences. In simpler cases, such as in the case of an environmental change (e.g. the weather gets dark) the conditions should be adapted accordingly. For an intelligent building, it is also important to react rapidly and correctly in an emergency situation. For example, when a fire starts in a room, this needs to be immediately detected and shared with other parts of the system in other rooms, which requires that all sensors and devices are connected through a network. Similarly, if the weather is dark during a fire situation, the light level needs to be increased for faster evacuation.

Based on the scenario explained above, the following main goal corresponding to the innovative idea can be defined by the innovators:

Goal: The rooms of a building should adapt both to the needs of its occupants and the circumstances, including adapting the lighting and temperature, to support the needs of the person currently in the room as well as to better respond to an emergency situation, such as a fire.

Then, the following subgoals can be defined by innovators:

Subgoal 1: Ensure that a person entering a room can be identified.
Subgoal 2: Ensure that temperature and lighting preferences/needs of persons living in the building are learned over time.
Subgoal 3: Ensure that a room can automatically adapt to its current occupant's light and heat parameters, so that the occupant is satisfied in the environment.
Subgoal 4: Ensure that a fire situation can be immediately diagnosed and reacted upon, by providing a more suitable lighting.

After subgoals have been defined, a market research is carried out to identify the functional and non-functional requirements for the intelligent building systems (not addressed with more details due to space limitations). Then, draft solutions for the systems are designed to meet the requirements. Different solutions may result in different subproducts needed for its realization. For example, one solution may need sub-products including: Agents, Sensors (temperature, light level, movement, smoke), Effectors (heating, lighting, doors, windows, alarm), Network connection, and Software (to gather information from sensors, to generate a response).

After a solution has been selected, required competencies are identified by innovators in order to achieve the corresponding subgoal. An example list of competencies is: 1) Software design, 2) Development, 3) Testing, 4) Mobile robot control techniques, 5) Sensor manufacturing, 6) Sensor development, 7) Networks supporting.

Table 1. Competency Matching and Potential VO Members Identification

Results of Competency Matching **(Defined competency;VBE Competency)**	**Which Organizations have which VBE Competencies**	**Potential VO Members**
(Software design;Software analysis and design) (Development;Software development) (Testing;Software testing) (Mobile robot control techniques;Mobile robots) (Sensor manufacturing;Sensor manufacturing) (Sensor development;Sensors development) (Networks supporting;Computer networks)	Software analysis and design: A, B Software development: A, B, C Software testing: A, B, C Mobile robots: D Sensors manufacturing: E, F Sensor development: F, G Computer networks: H	A, B, C, D, E, F, G, H

Then, the competency matching software component helps to automatically match the innovators' specified competencies to the VBE competencies. Based on the match results, a preliminary list of VO members is identified. In relation to this example, we assume that VBE competencies are the ones shown after the ";" symbol, in the first column of Table 1. We also assume that organizations *A, B, C, D, E, F, G,* and *H* have those VBE Competencies that are shown in the second column of the table.

Due to space reasons, we do not discuss the remaining steps of the innovation process, as these are related to the operation of the VO.

5 Conclusion and Future Work

An agile innovation framework is proposed in this paper. This framework is especially meant for innovators supported by business incubators and aims to guide the innovators through the innovation process on what to do and which tools / mechanisms to use at each step. Considering the many benefits that VBE and VO provide for the innovation process, they form the base of the framework.

As part of the future work, the plan is to implement the Competence Matching Component and to make the necessary adaptions to the Trustworthiness Evaluation and Negotiation Support Components developed in the ECOLEAD Project. Then, the Performance Evaluation Component is planned to be implemented. For that purpose, first the KPIs will be defined, which will then be used by the Performance Evaluation Component to compute the innovativeness of the VO members. The related data stored during the life cycle of a VO can then be used when developing the future VOs, in the same way that trust data are used.

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Pillars and Elements to Develop an Open Business Model for Innovation Networks

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Abstract. Innovation networks are seen as an important opportunity for organizational performance by facilitating the creation of new knowledge, not just transferring existing knowledge. Collaboration in innovation between manufacturing companies and research centers is a trend that continues to grow in importance linked to business success. Embedded in the literature on business models in the context of networks organizations, this paper propose key pillars and elements required in order to support the establishing of open business model for innovation networks. Subsequently the use of these elements in practice was verified through empirical research evidence in a case study.

Keywords: Open innovation, Innovative Networks, Open Business Model, Value Creation, Value Capture.

1 Introduction

The success of many companies can be attributed to the way they have innovated in their businesses; challenging established organizations and changing the rules of competition [1]. Currently, although the advantages and benefits of the paradigm of networks are well known, the research focused on developing a business model for organizations in networks is still at a nascent stage and represents a gap in research. An organization's business model is its driver for success, because it operationalizes the entrepreneurial opportunity that creates competitive advantages for the organization in its market [2], [3]. In this paper we take a business model as the logical representation of a firm's choices to create; delivery and capture value [4].

In the context of networked organizations, one of the main challenges to ensure their survival in the market is the ability create a business models that allows operating the opportunity of entrepreneurship identified in the market and generate revenues under changing environmental [5]. Therefore, the intended study in this paper aims to answer the need for empirically based research that contributes to the management of networks organizations, specifically of innovation networks by identifying a pillars and set of elements that enable them to establish an open business

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model. With this, we intend to highlight that there are key components that define an open business model differentiating them from closed and static models.

This paper is organized as follows. Section 2 reviews the literature about *Innovation Networks* (IN) and open business model definitions in order to build a theoretical background that supports the identified business model elements for IN. Section 3 presents the research methodology and section 4 the paper's theoretical contribution by describing the six main pillars and the fourteen elements of an open business model for IN. Evidence from a pilot case study is presented and discussed in Section 5. Finally, section 6 concludes the paper.

2 Literature Review

2.1 Innovation Networks

Innovation has become widely recognized as the cornerstone that makes businesses successful [6]. But, studies also highlight the importance of networks for innovation success [7]. This premise is also supported by the open innovation literature that stands the importance of external agents in fostering innovation [8]. Through *Open Innovation*, organizations can access to novel technology, product, or new markets that extend beyond of their actual core businesses and that would be difficult to discover in individual form [9]. Open innovation is defined as a distributed innovation process based on knowledge flows managed across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model [10]. Hence, components like networks of innovators and knowledge transference between firms and research institutions have become significant contexts for innovation. Although there are a wide variety of research works focused on the emerging area of collaborative business networks, there are few contributions on the management processes in the context of innovation networks [11]. In this sense, further research is needed in this area that is growing in importance and becoming relevant for managers, due to the impact in the fields of science and technology, also the variety of actors involved [12].

In general, innovation networks approach reflects the vision of the conjunction between innovation, technological opportunities and user necessities. According to Landsperger [13], innovation networks are an organizational solution that enables companies to deliver complex products or innovative services, through the integration of different organizational skills. Product innovation results from the assembly of dispersed resources, knowledge and capabilities embedded in a range of firms. Incentives for participating in networks are sharing risk, granting access to complementary assets, generate economies of scale, shared knowledge and facilitating collective learning. In order to develop the business model for innovation networks important aspects must be considered: the value captured in a network of innovation depends on the volume of knowledge exchange, the alignment of the objectives of the network and how the resources of the participants are combined and managed within the network.

2.2 Open Business Model

Business model has been the subject of a growing number of studies. However, researchers and practitioners have not developed yet a common and widely accepted language on the topic. Actually, looking into the literature, we find several different constructs of the concept. Various definitions of business models are presented in Table 1.

Table 1. Definitions of business model in literature

Definition	Source
"A business model is a concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets".	[14]
"A business model elucidates how an organization is linked to external stakeholders, and how it engages in economic exchanges with then to create value for all exchange partners".	[15]
"A business model is the heuristic logic that connects technical potential with the realization of economic value".	[16]
"A business model is a set of choices and the set of consequences arising from those choices". These set of choices are developed by an organization to achieve profit.	[17]
"A business model describes the rationale of how an organization creates, delivers and captures value.	[18]

It is noteworthy that the basic function of business model is to describe the design of the value creation and capture mechanisms needed to achieve profit by combining the firm's internal and external factors [15], [19]. In the literature, it was observed that most of the works on the business models are explored from a traditional perspective, i.e., the designs focus on a single company [18], [20], [21], that has a linear value chain and develops within a stable and predictable competitive landscape; this scenario represents a static concept of business models. Traditional approaches of business models face difficulties to cover the wide scope required for organizations structured in flexible and dynamic networks, because the result might not be efficient [22]. Innovation networks are developed in a context of open innovation, which involves capture to phenomena such as the commercialization of intellectual property, integration of server and client, collaborative processes of R&D [23]. In this sense, the construction of their business model cannot be seen from a perspective of a single firm, nor can be considered static; being necessary use a new approach that considers an open business model focused on external resources as key contributors to a firm's value creation process where the value for the customer is co-created between actors in a network [24].

Thus, developing an open business model for innovative networks would imply that each member of the network open its business model, by actively researching and the exploiting of external and internal ideas, allowing their unused internal technologies to flow to the outside [16]. This context provides new sense to develop a business model where traditional business models components have to be coupled with the development of relational capabilities and the capacity to manage networks of actors.

There are still few contributions on the development of business models from the perspective of network organization [22], [25], [26]. Among existing previous works can be indicated the proposal by Palo and Tähtinen [26] who developed an empirically grounded conceptualization of a networked business model. The authors identified the generic elements of a business model in the field of technology-based services and propose to use these elements to build a networked business model. On the other hand, Helander and Rissanen [27] developed a theoretical study in which they highlighted that in a network context the business model of a company must be linked to the business model of the other companies involved in the partnership. In addition, Komulainen et al. [28] identified three core elements for a network business model: product/service, business actors and their roles, and value-creating exchanges among the actors. Other important contribution in business model for collaborative networks is the work of Loss & Crave [22] who explores the concept of Agile Business Models that enable a fast reaction and better adaptation of collaborative networks into dynamic markets, this research work also includes the identification of innovation levers and barriers when designing business models for collaborative networks. Also, we highlight Romero´s contribution that provides the guidelines to define a VBE business model considering a multi-value system characterization and a multi-stakeholder perspective, proposing at the same time the main elements to be concerned in approaching a VBE governance model [29].

In an attempt to address the phenomenon of open business models, the challenge in this paper focused on the issue of identified key pillars and elements to setting up an open business model that allows the co-creation of value between the various actors in the network, considering its possible heterogeneity.

3 Research Methodology

This research aims to analyse which are the relevant pillars and elements for setting up an open business model of an innovation network? To answer this, we utilize an exploratory methodology, which was conducted in two phases. First, we used the literature search method to integrate multiple bodies of literature on areas of open innovation, networked organizations, innovation networks and business model development; in order to identify and select the key pillars and set of elements suitable to develop an open business model according to the innovation networks perspective. Second, based in a case study approach, we carried out a pilot study to verify if the pillars and set of business model elements proposed are considered in practice.

The unit of analysis is an innovation network and the data collection method used was two semi-structured interviews, one with the IN coordinator and the other with IN members. Interviewer bias was countered with the use of an interview guide, the presence of two interviewers and tape recording of the interviews. For data analysis it was performed content analysis in order to facilitate the perception of the business model elements present in the network under study. The data of the interviews was combined and structured and inductively coded into six main pillars and fourteen elements. In the next sections we introduce the pillars and the set of business model elements proposed and present the pilot case study.

4 Pillars and Elements to Develop an Open Business Model for Innovation Networks

Through a qualitative analysis of the proposals of 57 authors who contributed from different perspectives, either through definitions of business model, either by identifying specific components for a business model, or propose taxonomies, tools, or others; were identified six main pillars of a business model: Customer, Network Value Creation, Network Actors, Network Value Exchange, Network Value Capture and Network Governance; and fourteen elements to represent an open business model for IN, based on qualitative analyses of existent approaches of different authors in literature about business models and open innovation, networked organizations and innovation network's approach. In Table 2 are defined each business model element.

Table 2. Definitions of the business model elements

Element	Definition
Customers	
Customer needs	Problem that a customer intends to solve with the purchase of a good, service or product-service systems.
Network Value Creation	
Value proposal offered	Promise of a collection of goods, services and product-service systems. to be delivered by the IN to the customer in order to solve his/her problem.
Core competencies	Specific skills and technologies of each member.
Network Key Activities	The most important activities carried out by the IN members in order to execute the value proposition.
Network Actors	
Actors and roles	Members of the IN, and role each partner plays within the IN. Describes each actor positioning and the value it creates in the IN.
Partners Evaluation Criteria Definition	Criteria used to accept or exclude a member in the IN.
Network Value Exchange	
Shared Resources	List of resources and activities that are shared among IN partners in order to create competitive advantages.
Shared Information	Type of information to be exchanged among partners for efficient management of the IN.
Technology Support	Information and communication software supporting the functioning and management of the IN.
Network Value Capture	
Cost	Expenditures that the IN members have in creating (providing a good or service and coordinating with the other partners) and distributing the offered value.
Revenues	The way a IN generates its income.

Our proposal considers structural and behavioral aspects to facilitate a better understanding of an open business model. Pillars such as Customers, Network Value Creation, Network Actors and Network Value Capture have a structural nature, which defines the relevant elements and their relationships. The behavioral aspect defines how these elements interact. The Network Value Exchange and Network Governance pillars belong to this group. These components bring dynamism to the business model. Where firms interact with one another, weaving an ever-changing network of interactions into which they can embed themselves or getting out in any time. A representation of pillars and set of elements and their linkages that form the basis for open business model is showed in Figure 1.

An essential element is the identification of the *customer's needs* of the network, in order to define the value offered to a customer through an innovative solution. The definition of the *Value proposal offered* is a key element of the Networked Value Creation pillar. This element is the basis to define the *Network key activities* and *the core competences* required for development the product offered by the network. *Actors and roles as Partners Evaluation Criteria Definition* are the elements of the pillar Networked Actors. Based in the matching of requirements and competences, actors with complementary skills are selected in order to reach a maximum of synergy between the different processes and transfer knowledge.

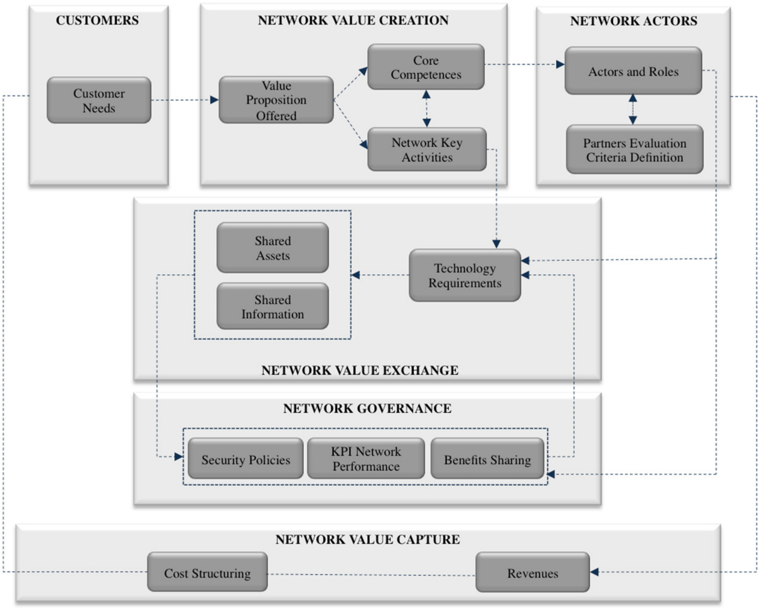

Fig. 1. Representation of pillars and set of elements and their linkages

Network Value Exchange depicts the transactions (transfer and transformation) and the effective combination of the different information and assets (resources, capabilities, know-how, goods/ services) between all the actors, showing how they create value, not only for the network's end customer but also for the network's partners [29]. The important elements to be considered are: *shared assets, shared information and technology requirements.* Network Value Capture or value appropriation, according to

West [30], explains how the value creation is captured in order to sustain the business activity. The Network value capture elements identified were: *Cost structure* that considers all expenditures involving with creating, offering, and distributing goods and services; and *Revenues* source generated [26].

Network Governance refers to the different instruments that assess the performance level of the network, maintain a strict control of information, resources and capabilities of all actors in the network. The Network Governance elements identified were: *security policies, KPI network performance and benefits sharing.*

5 Case Study

The goal of the following case study is to understand and validate the applicability of the envisioned business model elements. Our study concentrates on an Innovation Network created in the Northern region of Portugal in order to develop new products derived from cork material, and maintain its successful performance in the international market. The network offered products with applications in different areas such as footwear and accessories, home and office design and transportation industry. Currently the network has some products in development phase and others in production phase. We choose to study the partnership established to develop a new material to be applied in footwear industry. The network value proposition is to offer an innovative cork fabric that intends to be positioned among animal hides and synthetic fabrics. This fabric can be used in an infinite number of forms, shapes and purposes, especially in products where the cork application is a totally new concept. Actors, roles and task descriptions are clear in the network. Organization consists of (a) Company "A" who is a responsible for providing rolls and cork panels to form cork blades with increased strength and flexibility. This company had the initiative to form the network and plays the network manager role and is responsible for selecting the best-suited partners to develop this new material. (b) Company "B" is a graphic industry who defines the type of inks that can be used on new cork material (c) Technological research center, which is responsible for technological testes in order to ensure that the new material is suited to applications for which it was developed and reaches ISO levels. (d) Company "C", footwear industry, is the one that coordinates the network and verifies the compliance with the specifications and requirements of the developed material.

The criterion for the choice of network members is the credibility demonstrated by results and information obtained from previous projects. The network manager emphasized that the selection of partners through personal networks facilitates trust between network members, moreover to surpass obstacles as time and bureaucracy. Sharing the know-how and interdisciplinary actions of partners contribute favorably to the development of new technologies, industrial processes and capabilities of employees. This enables the creation of a new cork based product (vegetable leather) for use in specific applications in footwear industry. Due to a lack of standards for this innovative process, the network performance evaluation has been done in a very informal way. Aiming to ensure the governance of the network, the network´s coordinator signs specific agreements for each company member, and monitors the flow of information between participants. Cost structure involved internal and external activities; services and human resources cost and uncertainty cost of the external activities related to the value-added process. These costs are allocated in the planning phase for each member. The allocation of revenues is based on the participation level during the value-creation process. Among the expected benefits, the network partners believe that working in collaboration in the form of the so-called innovation network is essential to create credibility in the market. Without collaboration, this cork product would be released to the market without a substantial and solid base of knowledge and would not be accepted by the target markets.

Evidence from the case study shows, that the defined business model elements are present in this case. However, further research is needed to validate these elements in more complexes networks.

6 Conclusions

New organizational structures based on networks and collaboration led to adopt new perspectives to build business models, which are based on openness. The understanding of these open business models in the literature is still quite low and dispersed.

While most previous studies have focused on traditional business models (static based on an individual company), our study aimed to identify key pillars and elements to setting up an open business model that allows the co-creation of value between the various actors in the network considering its heterogeneity. In this way our research, considering the existing literature and the empirical study, allowed us to identify fourteen elements classified in six main pillars: Pillar: Customer (Element: Customer Needs); Pillar: Network Value Creation (Elements: Value proposal offered by network; Core Competences; Network Key Activities); Pillar: Network Actors (Elements: Actors and Roles; Partners Evaluation Criteria Definition); Pillar: Network Value Exchange (Elements: Shared Assets; Shared Information and Technology Requirements); Pillar: Network Value Capture (Elements: Cost Structuring and Revenues); Pillar: Network Governance (Elements: Security Policies, KPI Network Performance and Benefits Sharing).

Through the development of the pilot case study we were able to collect evidence, which suggests that the defined business model elements are present in innovation networks. However, we invite future research to further explore this young field of open business model, because more research is needed for building dynamic architectures that support network organizations.

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System Thinking to Understand Networked Innovation

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Abstract. Today, knowledge and the capability to create and utilize it are considered to be the main source of a company's sustainable competitive advantage. Within this assumption, the present paper aims at discussing the advantages of applying a system thinking approach in order to deepen the understanding of the factors that leverage or constrain knowledge transfer to support co-innovation, and its impact at a member level, for instance, in terms of the capacity of generating new ideas, processes and products. The paper's empirical section is based on one case study pointed to the largest highway concessionaire in Portugal.

Keywords: System Thinking, Innovation, Knowledge Transfer, Collaborative Networks.

1 Introduction

Nowadays, globalization has been the main driving force that makes companies run after high levels of performance and competitiveness [1]. According to several authors the business environment has faced dramatic challenges in recent years, where one of the most relevant sources of competitive advantage is innovation capacity [2]. The development of complex products or services requires access to several distinct types of knowledge that companies do not usually hold [3] [4]. As a result, companies can improve their knowledge either from their own assets, making sometimes-high investments, or from the knowledge that may be mobilized through other companies based on a collaborative process [5]. However, recent studies point out that a growing number of innovations introduced in the market come from networks of companies that are created based on core competences of each company. In fact, there is an intuitive assumption that in a turbulent market companies can develop emerging business opportunities and deal with cost/time competitively through an open-innovation environment.

However, it has been difficult to prove its relevance due to the lack of models that support the tools that explain the synergies created in a collaborative environment, which may lead to the reinforcement of innovation flows in a "healthy" collaborative environment [6].

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 327–335, 2014.

The aim of this paper is to present a case study of a Portuguese collaborative network, Brisa co-innovation network, and to discuss the appropriateness of the system thinking approach to understand the dynamics of the processes for innovation in depth.

2 Knowledge Transfer to Support Co-innovation

Knowledge has always played an important role in the economy, but only over the last few years has its relative importance been recognized, exactly when its value started growing. Currently, knowledge and the capability to create and utilize it are considered to be the main source of a company's sustainable competitive advantage. to the centrality of knowledge in contemporary society, a shift in our understanding on innovation in business organizations - whether technological, product or strategic innovation, or organizational innovation - is required [7]. Innovation is strongly connected to knowledge: it can be an outcome of novel pieces of knowledge or a novel combination of existing pieces of knowledge; it can also be created during the process of innovation. For example, innovation is a fundamental way of organizational knowledge creation, since it is a process in which the organization creates and defines problems and then actively promotes new knowledge to solve them. As argued by Choo and Bontis [8], a company generates knowledge value from what it knows, through the organizational processes of knowledge creation, knowledge transfer and use of knowledge. Actually, the last decades have shown a generalized concern on the study on how companies create knowledge and how they operate its transfer, in particular.

In knowledge creation, a company generates new knowledge from the conversion and externalization of its tacit, embedded knowledge. The knowledge transfer is shared with a business organization through different functional groups, geographical locations and time periods. Knowledge is transferred between organizations through alliances and networks as well. In terms of knowledge use, the company integrates and coordinates its different types of knowledge in order to produce goods and services. Tacit knowledge plays a crucial role in knowledge creation; codified or explicit knowledge facilitates knowledge transfer; “common knowledge” (common language, shared meanings, overlapping knowledge) or common understanding of the goals and purpose orients knowledge use.

Over time a company incorporates a set of knowledge and skills that is unique to its learning and experience. This stock is the company’s intellectual capital, and it includes human, structural and relational capital that exists within its employees, organizational routines, intellectual property and relationships with customers, suppliers, distributors and partners. The stock of intellectual capital is continuously improved through new learning on multiple levels: the individual, the organization and networking organizations of which the company is part.

Moreover, there are contexts where knowledge sharing and transfer constitute a strategic move. Business organizations that belong to highly networked and strongly linked industries, where technologies and markets are still evolving, may strategically share knowledge in order to (1) promote and enable the development of complementary products and services, (2) influence the development of common platforms, dominant designs and de facto or formal standards, and (3) increase a critical mass of customers and users. Industries that experience externalities, where the value and the usefulness of a good or service depend on the installed base of connected users, may choose to share knowledge with customers, competitors and collaborators [8]. In addition to network externality effects, companies sharing knowledge may also gain the advantage of increasing benefits by developing a dominant position in an industry or by being an early market leader. The strategic challenge, then, consists on knowing what knowledge to transfer and retain as part of the company's value.

3 System Thinking Approach to Understand Innovation Dynamics

The tendency to apply tools where the analysis of reality is mainly based on a linear approach, where the system behavior and its dynamic is explained based on a series of events of one-way relationships, as well as the predisposition to ignore feedbacks and delays might be an obstacle to understand the dynamics of processes for innovation in depth. Furthermore, in a co-innovation context where someone changes a component without considering the interrelationships can cause fixes that backfire, and instead of solving the original constraints, unconsciously increases the barriers to innovation. According to several researches [9,10], the behavior of any system is determined by causal structure rather than specific events. The complexity associated to the behavior of a system usually arises from the interactions (feedback) among the components of the system and not from the complexity of the components themselves. Based on this approach, any system can be described by a set of components that have complex interrelations occurring between them, many of which take the form of feedback loops. It means that a component *A* may influence a component *B*, which in turn influences component *A* at a later point. The feedback loops can be positive (or self-reinforcing) or negative (or self-correcting). However, either types of loop can be good or bad, depending on the perspective in which it is analyzed. In order to support the analysis of system behavior, the system thinking approach includes a number of tools that cover several purposes and can be classified in four categories [11], as shown in Figure 1.

Brainstorming tools	Dynamic thinking tools	Structural thinking tools	Computer-based tools
Double–Q (QQ) Diagram– similar to Cause and effect diagram	• Behavior Over Time Diagram (BOT). • Causal Loop Diagram (CLD) • System Archetypes	• Graphical Function Diagram • Structure Behavior Pairs • Policy Structure Diagram	• Computer Model • Management Flight Simulator • Learning Laboratory

Fig. 1. System Thinking Tools

System Archetypes

The system archetypes provide a basic form to describe generic stories and scenarios that can be applied to distinct contexts and environments. Each archetype is built based on a causal loop diagram, and offers a common language to understand the behavior and dynamics of a particular system over time.

According to some authors [12,13], the most common system archetypes and their storyline are the following:

Success to the Successful - This archetype suggests that the success of a company, project, product, and so forth does not always come from competences but might be due to an initial or starting condition. When two entities compete for a common and limited resource, the entity that initially received the majority of the allocation of resources, fostering in this way its initial success, will receive more resources in the future, increasing its success at the expense of the other. Consequently, the entity that is initially less successful starves for resources and eventually fades out.

Limits to Growth (also known as Limits to Success) - In most real cases, there are commonly some constraints that limit growth, such as resource limits, market saturation, knowledge constraints, and so forth. This archetype suggests that an effort may be initially the cause of the success of an entity. However, the effort reaches a constraint that is inhibiting further growth, slowing down the overall performance over time.

Accidental adversaries - This archetype describes a scenario in which, initially, two entities begin a relationship with the best of intentions, with the purpose of maximizing their respective strengths and minimizing their weaknesses, and based on a "healthy" collaborative environment in order to carry out an objective that cannot be achieved separately. However, the problem arises when one or both parties take action, which in their perspective seems perfectly reasonable, and accidentally undermine their partner's success. The impact of these harmful actions may simply create a sense of frustration and antipathy between the parties, though still partners, or it may get to the point of turning them into hostile adversaries.

Tragedy of the Commons - This archetype describes a scenario where several entities acting in rational self-interest perform activities with the purpose of maximizing their benefits by depleting a common resource. The "tragedy" occurs when the resource capacity is exceeded. The impact of these damages on the Commons may either limit the benefits to the level at which the resource is replenished, or lead to the collapse of the activities performed by all entities in the system.

Growth and Underinvestment - This archetype suggests that when a resource approaches its limit, as market saturation, the life cycle of a product, technology or process is reaching an end. The growth of an entity can only be sustained with investments on more capacity - for an enterprise it means the development of resources, capabilities, competences, and so forth in order to ensure its competitive advantage. However, assuming that the decision not to invest was immediately made and during this period performance degradation occurred; if this pattern is not recognized, the decrease of performance might be used as a justification not to invest in the needed capacity.

Attractiveness Principle - This archetype suggests that, in most real cases, there are multiple restrictions inhibiting the growth or development of some activities, such as in an innovation process, and the solution is to manage the attractiveness of each. Since it is usually impossible to deal with restrictions in the same way and/or all cannot be addressed due to limited resources, it is necessary to decide which restrictions should be eliminated first.

Fixes that Fail (also known as Fixes that backfire) - This archetype illustrates a scenario that occurs when a problem symptom exists, and a quick fix is applied with positive results in the short term. However, the solution adopted creates side effects that were not evident at first, worsening the problem in the long term and consequently requiring more fixes.

Escalation - This archetype describes a scenario where the parties believe that just one of them can benefit (win), even in a co-innovation process. In this scenario, there is no absolute goal but instead a relative goal of staying ahead of the other members with the purpose of protecting and/or furthering the company's own best interests. The impact of this harmful behavior may either create a sense of frustration and antipathy between the parties, though still partners, or get to the point of harming their organizations and reducing the value to customers and stakeholders, or even turn them into hostile adversaries.

Shifting the Burden (also known as Addiction) - This archetype illustrates the tension between a solution to solve a problem symptom based on a short-term approach, which solves temporarily the problem (symptomatic solution), and a long-term approach based on a fundamental solution. However, there is frequently a tendency to apply a temporary solution since it is relatively quick and low cost, while a delay is associated to the fundamental solution due to the development of competences, financial limitations, or other constraints. Nonetheless, the implementation of the temporary solution reduces the symptom, which might induce the development of unforeseen side effects, dissipating the need to use the fundamental solution.

Figure 2 illustrates the potential relationships between some "classic" system archetypes discussed above and adapted from [13] for co-innovation.

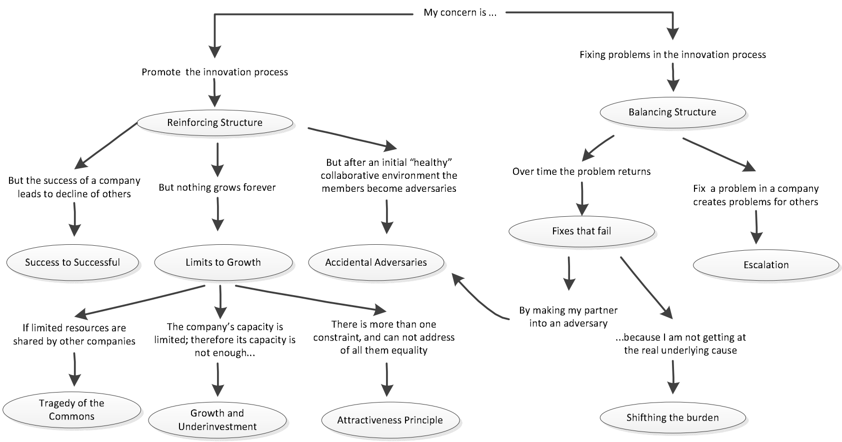

Fig. 2. System Archetype relationships

4 Innovation Dynamics Analysis Using the System Thinking Approach

Methodology

The research has been developed at the largest Portuguese highway[1], and is based on two main projects developed by Brisa, namely E_TOLL – Electronic Tolling System and ALPR – Advanced License Plat Recognition.

Brisa identified E_TOLL and ALPR as the most relevant projects in terms of innovation. On a first stage, companies and other institutions (technology centers, universities) involved in the projects were contacted and invited to cooperate with our research. Empirical data stems from two main sources: in-depth interviews conducted with key participants belonging to the network, and a brief survey. The involvement of various partners in the network is critical in order to foster a spirit of openness and cooperation in this fundamental process.

***Brisa Case Study*.** The Brisa company currently operates a network of eleven highways on a concession basis, with a total length of around 1096 km, constituting the main Portuguese road links. Given its importance and dimension, Brisa owns several companies specialized in motoring services and aimed at improving the quality of the service provided to customers and increasing its own operating efficiency. The Brisa co-innovation network is a long-term collaborative network.

In order to analyze the sustainability of Brisa co-innovation network, as first approach, an effort to find some similarity to the most common aforementioned system archetypes was made. Taking into account the data collected and the archetypes' causal loop diagram, the choice fell on Shifting the Burden archetype, whose causal loop diagram is illustrated in Figure 3a, and on an adjustment of the Tragedy of Commons, whose causal loop diagram is illustrated in Figure 3b.

The application of Shifting the Burden archetype to Brisa supports the proposition that in order to respond to market demands (problem symptom) Brisa had to make a choice between a symptomatic solution that was based on product and service purchase, or develop competences to support innovation (fundamental solution).

However, the development of competences requires access to several distinct types of knowledge that Brisa needed to develop, and this process has a significant time delay before it has an effect on the original problem symptom (respond quickly to market needs). This disadvantage led Brisa to choose the acquisition of products and services (symptomatic solution). Over a long period of time, Brisa's managers believed that the problem symptom was supposedly solved by applying the symptomatic solution as the acquisition of products and services caused a decrease in the original problem symptom, keeping it in balance. Additionally, the recurrent use of the symptomatic solution induces the development of unforeseen side effects, which reinforce the justification not to invest in the fundamental solution. However, in order to increase its competitiveness, Brisa's managers decided to invest in the

[1] The present results are based on research work developed under the project – DIINOV DINÂMICAS DE TRANSFERÊNCIA DE CONHECIMENTO EM REDE DE INOVAÇÃO, FCT/UNL, BRISA, ISEL/IPL, 2014.

fundamental solution, promoting new knowledge from their own assets as well as from knowledge mobilized through other companies and organizations, such as universities and government institutes based on an open-innovation environment. Nowadays, Brisa co-innovation network is a long-term collaborative network that has more than 30 members from several domains and business activities (e.g., research institutions, universities, associations, governmental entities, start-ups, business angels, and suppliers), and its sustainability can be explained based on an adjustment of the Tragedy of the Commons.

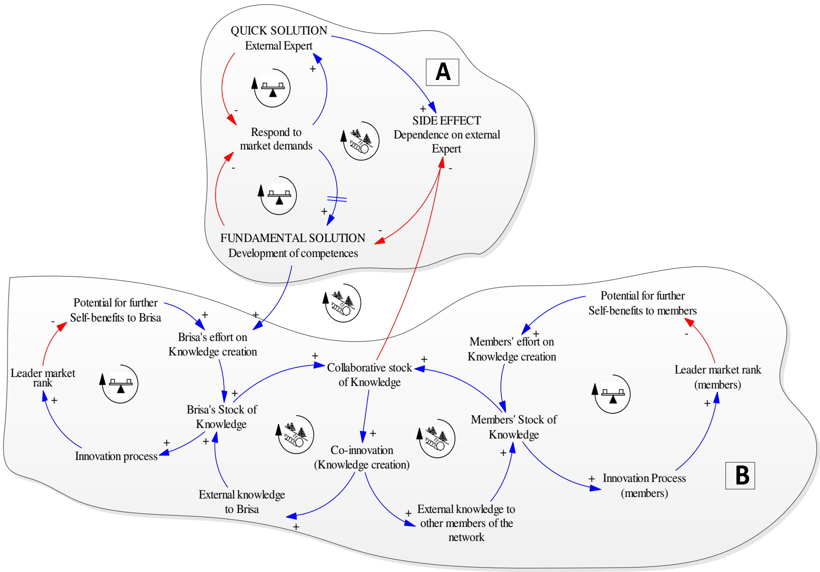

Fig. 3. (a, b) – Causal Loop Diagram

The original causal loop diagram that explains the pattern of this archetype, previously described, includes two reinforcing loops on the outside that represent individual efforts and benefits, and two balancing loops on the inside that represent collective efforts and benefits. However, an adaptation of this archetype can illustrate another useful scenario where the synergies created in a collaborative environment lead to the reinforcement of innovation flows, and the co-innovation benefits (knowledge creation) are greater than the sum of individual knowledge creation due to the establishment of a concerted effort. In this adapted archetype the reinforcing loops are on the inside and represent collective efforts and benefits, and the balancing loops are on the outside and represent individual efforts and benefits.

Furthermore, from the aggregation of the two archetypes a reinforcing loop arises (side effect, fundamental solution, Brisa's effort on knowledge creation, Brisa's stock of knowledge, and collaborative stock of knowledge), which reinforces the justification to invest in the fundamental solution.

5 Conclusion

This work discussed the system thinking approach and the general system archetypes applied to co-innovation in a collaborative context.

The development of models to understand the dynamics of co-innovation processes in depth in collaborative environments will not only help to better understand this area, but also contribute to a wider adoption of the collaborative network paradigm as a way to develop capabilities that will enable companies to respond quickly to market needs.

Some preliminary steps in this direction, inspired in system thinking concepts, were presented. Initial results illustrate the applicability of the suggested approach. The application of archetypes to Brisa network reinforces the choices made by the company. The results seem to bring benefits in terms of developed synergies in a collaborative environment, which promotes innovation flows.

Further steps are necessary toward the elaboration of a robust tool as well as to its validation.

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Forward - Green Virtual Enterprises and Their Breeding Environments: Sustainable Manufacturing, Logistics and Consumption

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Abstract. Green Virtual Enterprise Breeding Environments and their Forward-Green Virtual Enterprises, represent a promising paradigm to face the sustainable manufacturing, logistics and consumption challenges towards a Circular Economy. This paper explores the 'build-to-order supply chain management' paradigm and the customers involvement in sustainable supply chains to support the creation and operation of goal-oriented supply networks capable of responding to the two-sided market demands of the Circular Economy by means of sustainable offers by industry and sustainable demand by society.

Keywords: Collaborative Networked Organisations, Green Virtual Enterprises, Breeding Environments, Industrial Ecology, Sustainable Manufacturing, Sustainable Logistics, Sustainable Consumption, Circular Economy.

1 Introduction

Circular Economy (CE) is a generic term for a new and more sustainable industrial economy in which material, energy and waste (MEW) flows are closed-loop [1] [2]. In a *CE,* two types of *cyclic flows* can be identified: a) *quasi-cyclic flows* in where there is a certain degree of cycling in resources circulation through an industrial system, which reduces the need for external resources input and waste output, and b) *cyclic flows* which have the highest degree of cycling (self-sufficiency) with closed-loop circulation of resources within an industrial system [1] [3]. Developing a *CE* is about optimising industrial systems, and *eco-industrial chain models* are the prerequisite and basis for running *eco-industrial systems* [4] [5].

An *Eco-Industrial Chain (EIC)* refers to a closed-loop model of economic activities creating feedback cycles of resources → products → renewable resources, following the '3R' principles of the *CE* (Reduce, Reuse, Recycle) in the processes of production, logistics and consumption in order to achieve *eco-industrial systems* with improved economic activities and environmental benefits [4] [5].

The '3R' principles are at the core of the *CE* development strategy: *Reduce* refers to the input of resources usage, aiming at reducing the input materials and energy in the production and consumption processes; *Reuse* is concerned with processing, and

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promotes a higher utilisation rate of resources by reusing raw materials, by-products and used-products, so products' lifecycle can be extended and the waste created in production processes can be minimised; finally, *Recycle* is concerned with output, which requires that waste be turned into secondary resources replacing virgin resources input [6]. Nevertheless, building a *CE* in the *industrial landscape* is not enough, since *consumerism* can have a big impact on the environment and consume large amounts of energy. As a result, *consumers* in the marketplace play a crucial role to achieve a *sustainable economy,* since "*CE* is not just about sustainable production models and products, but also about sustainable lifestyles and societies sustaining them" [7]. This research will explore *Forward - Green Virtual Enterprises* and their *breeding environments* [8] [9] within the 'build-to-order supply chain management' paradigm [10] in order to support the creation and operation of goal-oriented supply networks capable of responding to the two-sided market demands of the *CE*, sustainable offers by industry and sustainable demand by society.

2 Green Virtual Enterprises and Their Breeding Environments

A *Green Virtual Enterprise Breeding Environment (GVBE)* is a long-term strategic alliance of green enterprises[1] and their related support institutions aimed at offering the necessary conditions (human, financial, social infrastructural and organisational) to support the rapid and fluid configuration of *GVEs.* From a 'socio-economic and technical' point of view, *GVBEs* support the creation of an adequate environment for the establishment of cooperation agreements, common operation principles, common interoperable infrastructures, common ontologies, and mutual trust among others, with the objective of preparing their members to collaborate in potential *GVEs* that will be established when a green business opportunity arises (e.g. identified by a *GVBE member* acting as a broker). From an 'ecological' perspective, *GVBEs* promote the sharing and recycling of resources such as information, materials, water, energy and/or infrastructure with the intention of achieving sustainable development in a collaborative way (e.g. industrial symbiosis[2]) [8] [9].

Green Virtual Enterprises (GVEs) are short-term and dynamic coalitions of green enterprises that may be tailored within a *GVBE* to respond to a single cooperation opportunity, through integrating the green technology (skills or core-competences and resources) required to meet or exceed the quality, time and cost frames expected by the customer with a low ecological footprint, and that dissolve once their mission/ goal has been accomplished, as whose cooperation is supported by computer networks [8] [9].

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[1] A *Green Enterprise* is an enterprise that strives to meet the triple bottom line by ensuring that all products, processes, manufacturing and logistics activities in its business operation address the sustainability principles [8] [9].

[2] *Industrial Symbiosis* can be defined as an industrial ecology strategy based on collaboration and synergetic possibilities, aimed at sharing/exchanging information, materials, water, energy and/or infrastructure (e.g. services) among industrial actors in order to increase economic gains and achieve sustainable development in an eco-industrial network [2] [11].

Depending on its delivery or recovery goal, a *GVE* can be tailored to become a *dynamic forward supply network* for delivering new green products (virgin or used/recovered) to the market, or a *dynamic reverse supply network* [12] for recovering the products sold under the *GVBE brand* (product stewardship) for service provisioning, product recovering or for safe disposal [8] [9].

GVEs as *dynamic reverse supply networks (R-GVEs)*[3] are temporary alliances of green enterprises that come together in order to better respond to a business opportunity based on a sustainable reverse logistics and end-of-life manufacturing approach for recovering products, parts, subassemblies and/or scrap through the most efficient use of their complementary skills or core-competences and shared resources for their direct-use (re-use), repair, refurbishment, re-manufacture, recycle or safe disposal - within a *GVBE.*

In this research work, authors will focus on the case of *GVEs* as *dynamic forward supply networks (F-GVEs)* operating as temporary alliances of green enterprises that come together in order to better respond to the market demands through the most efficient use of their complementary skills or core-competences and shared resources, for developing and delivering in a sustainable way new products (goods and services) to the customer with a minimal environmental impact (see Fig. 1) [8] [9].

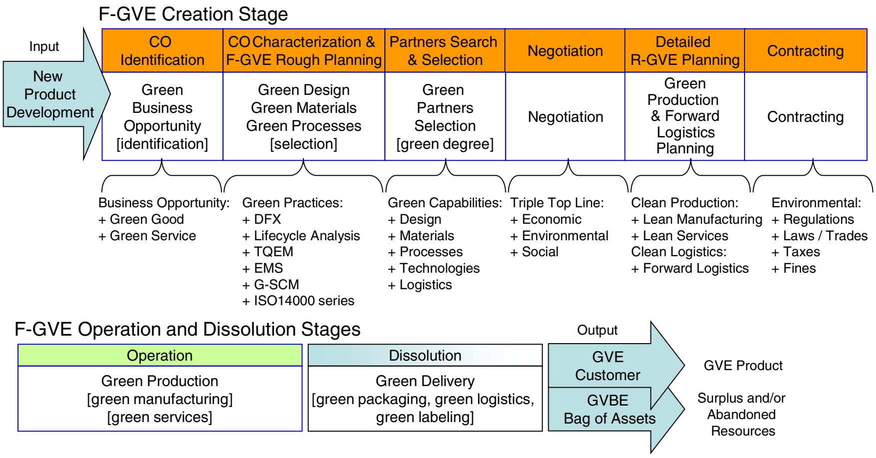

Fig. 1. Forward Green Virtual Enterprise Lifecycle: Dynamic Forward Supply Network

Furthermore, *F-GVEs* can be sub-tailored to become *Green Virtual Manufacturing Enterprises* compromising different kinds of resources, manufacturing processes and knowledge needed for designing, engineering and manufacturing sustainable goods for the customer; *Green Virtual Service Enterprises* sharing knowledge and skills to fulfil different customer requests in after-sales services in a sustainable way; and *Green Virtual Product-Service Enterprises* integrating manufacturers and service providers in order to support a sustainable customer lifecycle based on a combination of sustainable goods and their related value added services (see Fig. 2).

[3] For additional information on R-GVEs please refer to [12].

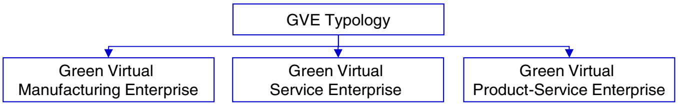

Fig. 2. Forward Green Virtual Enterprise Typology

3 Sustainable Manufacturing and Logistics: Build-to-Order Supply Networks

When judging the rationality of economic development in the past and looking into the future, if a *sustainable economy* is the goal, it is important to understand that the industry of the 21st century will not be the same as the mass-production model throwaway economy of the 20st century [7]. The emerging *CE* will rely on new sustainable (mass-) customised products (goods and services) [13] and production and service provision models [14], as well as their related sustainable business models [15], to support (mass-) customisation, sustainable production and logistics and on-demand manufacturing/service provision as enablers of a sustainable industry: 'Delivering not what the market wants, but what specific customers want'... 'Producing green products just when the customer needs them and only in the quantity they are needed'.

Sustainable Manufacturing is defined as "a systems approach for the creation and distribution (supply chain) of innovative products (goods and services) that minimises resources utilisation (inputs such as: materials, energy, water, and land), eliminates toxic substances, and produces zero waste that in effect reduces greenhouse gases (carbon intensity), across the entire lifecycle of products" [16]. *F-GVEs* aim to bring forward an emerging sustainable manufacturing and logistics mode of operation focused on compromising high levels of customisation, high customer-driven design, volume flexibility (not quantity restricted), short-cycle time, zero-inventory costs, minimal total cost and high supply chain integration for offering and delivering green products to the market in a sustainable way [17].

F-GVEs focus on implementing mass-customisation and personalisation in a sustainable manufacturing and logistics paradigm empowering sustainability through eco-friendly and high flexible product designs (goods and/or services), production and/or service systems, and supply chains/networks.

The *Build-to-Order (BTO)* operation model [17] aims to incorporate the key advantages of different operation models to become an attractive sustainable strategy for manufacturing and service enterprises. The *BTO model* takes the characteristics of 'high level customisation' and 'customer driven design' of the Engineer-to-Order (ETO) model, the 'volume flexibility' of Make-to-Order (MTO) model, the 'short-cycle time' of the MTO and Assembly-to-Order (ATO) models, the 'zero-inventory costs' of the ETO model, the 'minimal total cost' of the Make-to-Stock (MTS) model, and the 'supply chain integration' of the Configure-to-Order (CTO) model towards more sustainable supply networks operations [17]. Nevertheless, the *BTO model* implementation challenges the capacity and capability of a single enterprise calling for a 'network of enterprises' to gain access to its sustainable benefits and competitive advantage. Therefore, *F-GVEs* and their *breeding environments* represent a well-suited model to guarantee the agility, leanness, greenness, flexibility, collaboration and specialisation levels [9] needed to deploy the *BTO model* successfully (see Fig. 3).

A *high level of customisation* can be achieved by means of the *F-GVE partners'* green capabilities and capacities integration, thus avoiding design, engineering, manufacturing and/or logistics competence and/or resource restrictions to develop sustainable (mass-) customised products (goods and/or services) [4] [17] [18]. *F-GVEs* will be always created with the most suitable *GVBE members* for fulfilling any special request of a green customer or for guaranteeing the requirements of a given green business opportunity [8] [9]. Moreover, (mass-) customisation offers the opportunity to develop true sustainable products (goods and services) with a high performance when it comes to meet the customer needs and being environmental-friendly within an affordable price [13].

High customer-driven design is in the nature of *F-GVEs,* being 'goal-oriented supply networks' driven by the aim of grasping a single green customer request or green business opportunity [17] [18]. *F-GVEs* are customer-oriented entities where a 'network of enterprises' focuses on a 'customer-centric collaboration' to co-create a green product (whether of the goods or services type) [19]. By avoiding or reducing the risks involved in forecasting the right production mix, *F-GVEs* can save a great number of resources (e.g. raw materials, energy, water, etc.) related to unsold products, and conserve also such input resources for a longer time till the moment they are truly needed (e.g. just-in-time) [8] [9].

Volume flexibility is satisfied by adding/aggregating *F-GVE partners'* production capacities and accommodating the proper volume of work accordingly to the task to their production capacity availability [17] [18]. Such *flexibility* allows a sustainable manufacturing where the required amount of products will be produced, and any waste related to unsold products be avoided (resources conservation) [8] [9].

Short-cycle time, or shortest-cycle time possible, is attained by the analysis of different *F-GVE partners* topologies and work-breakdown-structure configurations during the *F-GVE creation* in order to create the right partnership and schedule (critical path) to meet or exceed the time-frame (lead time) expected by the green customer [17] [18]. *F-GVE partners'* search and selection process [20] [21] will guarantee always the best possible forward supply network configuration in terms of cost-efficiency, flexibility, responsiveness and lowest ecological footprint to manufacture and deliver a product [8] [9].

Zero-inventory costs are realised since *F-GVEs* don't need to have an inventory before any manufacturing order is launched [17] [18]; *F-GVEs* operate under an on-demand manufacturing/service provision paradigm which can be considered a resources conservation strategy [8] [9].

Minimal total cost is accomplished due to the cost savings gained throughout the forward supply network [17] [18] by means of selecting the most cost-effective *F-GVE partners* for the manufacturing and logistics value added activities needed to be performed and efficient *F-GVE operation* [8] [9].

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[4] *Sustainable (mass-) customised products* can be defined as goods or services capable of fulfilling engineering and customers' requirements including environmental, economic and social constrains [13].

A high supply chain integration is reached thanks to the *GVBE* role as long-term strategic network [17] concerned with facilitating the adoption of common operation principles and interoperable infrastructures in advance to improve communication, cooperation and coordination between *GVBE members*; when members are selected to become *GVE partners*, they will behave as an integrated whole, therefore enhancing their overall agility, flexibility and productivity to collaborate in a *F-GVE* [8] [9].

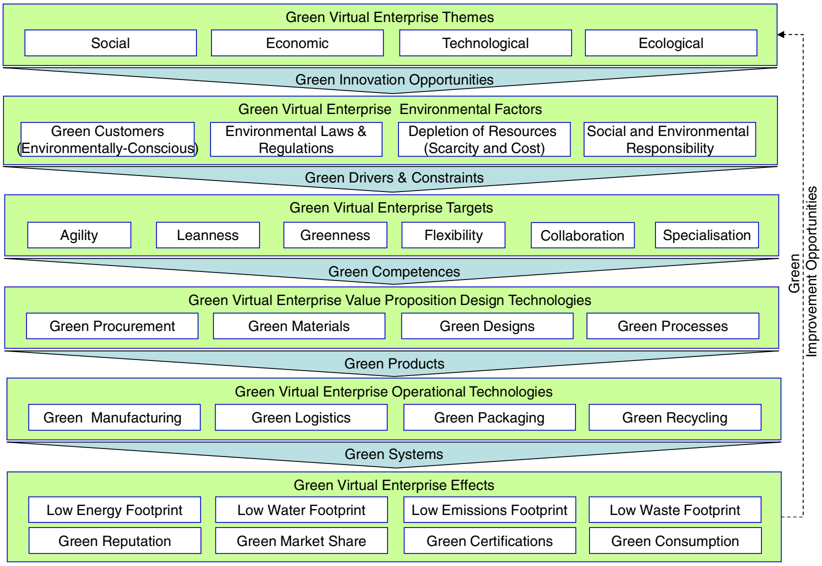

Fig. 3. Forward Green Virtual Enterprise Vision-based Framework

4 Sustainable Consumption: Customer Communities

Sustainable Consumption is defined as "the consumption of goods and services that have a minimal impact upon the environment, are socially equitable and economically viable whilst meeting the basic needs of their target customers, without jeopardising the needs of future generations" [22].

Customers and, *customer communities,* play a vital role in contributing to a sustainable production and consumption in the industrial landscape and marketplace, being the ultimate target of a 'sustainable supply network'. Their involvement and empowerment in sustainable supply networks is of key importance for driving the demand for sustainable products (goods and services), since customers are those who initiate the creation of any given product. First, customers influence *what* goods and services are being produced and offered (e.g. green products), and partially *how* products are being produced, delivered and disposed (e.g. green manufacturing and logistics). Second, *how* products are being consumed, which drives or constrains any product lifecycle extension strategies (e.g. products with recycled materials, second-hand products, refurbished/ upgradable products, repaired products). Third, customers influence each other in their consumer decisions of *what, how* and *how many* products are consumed (e.g. green purchasing and usage recommendations).

Customers' role in sustainable production and consumption will continue growing in the coming years, as advances of the 'social' Internet empower green consumers to actively participate in different sustainable practices (e.g. recycling) [19] [23]. *BTO supply networks* [17] (e.g. *GVEs* and their *breeding environments* [8] [9]) offer the opportunity to meet green customers' demands and to manage their involvement in the co-creation/co-innovation [19] of sustainable (mass-) customised products [13] [14] and sustainable business models [15]. Sustainable (mass-) customisation may trade-off lead time for environmental-friendliness, but pays back the customer with a certain level of personalisation/customisation of his/her goods or services and a truly sustainable product lifecycle [13] [14].

In order to explore customers' role in achieving sustainable supply networks, authors have chosen Sarkis [24] framework for outlining the operational processes of a sustainable supply network with the customer involvement [adapted from 23]: Starting with *green designing,* customers education and awareness in (co-) designing and demanding sustainable products can incentivise manufacturing and service enterprises to look into more sustainable designs for their value propositions. This effect is also magnified by green (virtual) customer communities that collect, share and disseminate information about the sustainable performance of products, and customers increased interest to co-create/co-innovate sustainable products and business models [19]. *Green procurement* is the most obvious customer influence in a sustainable supply network since customers can choose their own goods manufacturers and service providers according to their sustainable performance (e.g. eco-certifications and environmental standards). Also, customers can influence procurement by eliminating and/or attenuating resources use by providing their own resources (e.g. self-service) and/or by helping to reuse or share resources (e.g. reuse programs) [23]. *Green production* and *Green logistics* are influenced by the customer consumption behaviour, which challenges manufacturing and service enterprises demand management, considering now the expected lead time by the customer in order to support sustainable production (e.g. dematerialisation, slow fashion, on-demand manufacturing/service provisioning, packaging reduction, product longevity) [25] and (collaborative) logistics practices (e.g. route planning, intermodal solutions, smart distribution, cargo consolidation, shared warehousing) [26]. *Green purchasing, consumption* and *marketing,* as the three main relationships of the firm with its customers, drives manufacturing and service enterprises to ethically promote their products (goods and/or services) by reinforcing customers' sustainable lifestyles using different sustainable marketing practices (e.g. rewards, discounts, eco-labels, demarketing, remarketing) in order to develop a mindful consumption mind-set [25]. Lastly, there is the *green recycling* achieved through different product recovery opportunities [12] that involve bringing back customers who have already purchased a product to restart a new supply network cycle presumably with greater efficiency and lower resources use (e.g. reuse, repair, refurbish, re-manufacture, recycle) [23] [25] (see Fig. 4).

Increasingly, the sustainable production and consumption of products (goods and services) in the industrial landscape and marketplace will involve a mix of long- and short-term collaborative networks, strategic and goal-oriented networks [27], and

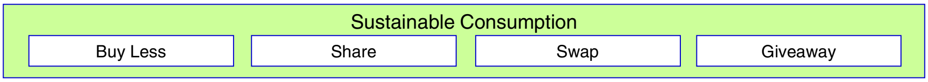

Fig. 4. Green Customers Sustainable Consumption Profile

networked enterprises and customers communities [19], making *GVEs* and their *breeding environments* [8] [9] a suitable collaborative environment and sustainable development model for customers' involvement and other stakeholders in the process of collaboratively creating new products in a sustainable way and meeting customers' needs and preferences.

5 Sustainable Business Models: Interplay Networks

A *Sustainable Business Model* is defined as "a business logic that seeks to create balanced social, environmental and economic value through integrating sustainability more fully into its business model and value proposition(s)" [28]. The development of *sustainable business models architectures* [15] is fundamental for the adoption of new sustainable production and consumption paradigms. In this sense, nowadays we can find some practical examples from an industrial perspective such as different *product-service systems (PSS)* variants aiming to deliver functionality rather than ownership through: 'product oriented approaches' based on maintenance and extended warranties; 'use-oriented approaches' based on rentals, leasing or sharing; and 'result-oriented approaches' based on pay per use or functional use; and various *product recovery networks* variants aiming to create new forms of value and/or capture the value missed in a product lifecycle based on reuse, repair, refurbish, re-manufacture and/or recycle strategies. From a customer perspective there are examples such as: self-service, do-it-yourself, co-design, co-creation and co-innovation. In both cases, these existing business models have further development opportunities for creating more sustainable industrial ecosystems and consumer markets. Understanding and supporting the growth of green networked enterprises and green customers' communities' interactions is a current challenge but a need towards a sustainable production and consumption [29] and a *Circular Economy* (see Table 1, Fig. 5, and [19]).

Table 1. A Business Model Framework for Sustainable Production & Consumption

Building Blocks	**Description**
Value Proposition(s)	• Green Products • Green Services • Green Product-Service(s)
Customer Segments	• Green Customers • Green Consumers • Green Communities
Customer Relationships	• Green Purchasing • Green After-Sales Services
Channels	• Green e-Marketplace • Green Brokers
Key Partners	• Green Manufacturers • Green Service Providers • Green Brokers
Key Activities & Resources	• GVBE Management Systems • GVE Management Systems
Cost Structure	• Green Costing Models (e.g. Green Loans, Green Taxes)
Revenue Streams	• Green Profit Models (e.g. Green Market Share)

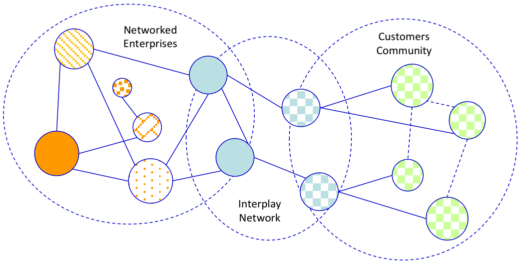

Fig. 5. Interplay Networks as a base for Sustainable Production and Consumption

6 Conclusions and Further Research

Dynamic *F-GVEs* represent an intelligent integration of green enterprises' competences, best practices and technologies for creating and managing sustainable BTO supply networks in response to the development of sustainable (mass-) customised products.

GVEs and their *breeding environments* [8] [9] represent a promising collaborative environment for enhancing green enterprises and green-minded customers' readiness for collaboration in more sustainable industrial ecosystems and consumer markets needed for a true sustainable development [2]. A multitude of options exist for the development of more sustainable industrial ecosystems and consumer markets, but sustainability of such strategic options needs to be based on new sustainable business models in order to guarantee their success [15] [28], nevertheless this is a research are currently in a maturing stage.

Future research aims to refine the *F-GVE - dynamic forward supply network - model* introduced, and the study, development and validation of its related business models for sustainable production and consumption.

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Sustainability and Trust

Organizational Sustainability and Value Creation in Collaborative Networks

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Abstract. Collaborative Networks are becoming ever more important as a lunchpad for the achievement of competitive advantages and for the creation of socio-economic benefits. According to the relational view theory, joint efforts can indeed generate relational rents. However, task coordination is not a sufficient means for value creation. Indeed, Collaborative Networks have to create a link between several aspects, such as trust, culture of collaboration, knowledge sharing, managerial processes, incentive systems, ethical code and so on in order to create cooperation and, thus, value. Aim of this work is to analyze how these aspects affect each other and how they affect value creation within collaborative networks. In order to do so, we develop a model, based on UML and e3value, in which the main factors impacting on value creation and value exchanges within CNOs are represented. After the description of the model, we analyze a case study of a CNO.

Keywords: Collaborative Networks, Value Creation, Sustainability, e-3 value, Value exchanges, Relational rents.

1 Introduction

In the actual economic context, Collaborative Networks (CNOs) represents a lunchpad for the enhancement of firms' competitiveness and for the creation of socio-economic and environmental benefits. CNOs can be seen as a system made by several "*entities that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals […]*", enabled by new technologies [1]. In this scenario, nodes of a CNO share information, resources and competencies with the aim of create new value through the broadening of enterprise boundaries.

However, the sustainability of CNOs, from not only a financial perspective but also from the organizational one is the premise for value creation. Indeed, collaboration implies mutual trust and commitment, giving relevance to behavioral and managerial principles, ethic codes, collaboration culture and incentive systems. Several authors have studied the role of trust and commitment in inter-organizational settings [2, 3], however, at the best of our knowledge, no one of them studied these factors with a systematic approach that led to modeling and requirements. Nonetheless, CNOs are

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complex entities, whose understanding is not immediate, therefore it becomes necessary to understand and model the determinants of value creation in CNOs [4].

In this work, we propose a model of sustainability and value creation within CNO. In particular, we represent these aspects by means of UML and e3-value, an ontology based methodology used to define requirements for software systems taking into account the value exchange among different individuals. In this way, we were able to model and analyze value exchanges and co-creation in Collaborative Networks.

The works is structured as follows. Section 2 is for the analysis of related works concerning the use of e3value. In Section 3 we pose the basis for our model, which we present, by means of a visual representation, in Section 4. In Section 5 we propose a case study. Finally, in Section 6 we discuss our model and the application to the case study and we draw conclusions.

2 Related Works

The advent of e-business has led to the necessity of the development of e-business models. The e-business model has to address the formulation of requirements through a rigorous method [5]. In this scenario, Gordijn and Akkermans [5, 6] proposed a multi-viewpoint approach for the business model development: a) value viewpoint, that represents the value creation and exchange process; b) process viewpoint, that represents business process and tasks; c) Information System viewpoint, that describes the Information Systems required for business processes.

From a value point of view, e3-value is commonly used for the modeling of value exchanges. The e3-Value is in fact an ontology-based methodology for defining business models for business networks [5] incorporating concepts from requirements engineering and conceptual modeling (including a graphical notation). Its main focus is on identifying and analyzing how value is created, exchanged and consumed within a multi-actor network. Hence, taking the economic value perspective and visualizing what is exchanged, i.e. which kind of economic value, and by whom [7]. An economic value exchange, and consequently the e3-value ontology as a whole, is based on the principle of reciprocity emphasizing the dual character of business transactions. This "give and take"- approach, described by means of specific "value-exchange diagrams", denotes that every actor offers something of value, such as money, physical goods, services, or capabilities, and gets a value in return. In this scenario money-exchange aspects are included in the value-exchange diagrams, and this semi-formal description is very useful for business analysis [5] but also for requirement specification on ePayments and for other aspects (decision making, user profiling, market segmentation, …) directly connected to monetization in eServices. This approach can bring several benefits, such as better communication among actors, improvement of the decision making process and a more complete view of business operations and business perspective. In particular, when applied to CNOs can help in the understanding of value exchanges among partners and external actors, thus extending existing reference models, such as ARCON.

3 A Collaboration Model: Theoretical Foundation

In literature, several types of partnerships among firms have been identified, characterized by the deepness of the sharing relations and by the integration level of firms. In particular, Camarinha-Matos and Afsarmanesh [1, 8] identified the following integration levels: (a) networking, which consists of the information exchange for mutual benefits, with no common goals; (b) coordination, which consists of the coordination of autonomous tasks, connected to a common goal; (c) cooperation, which consists in resource and information sharing, with the aim of achieving compatible goals; (d) collaboration, which is the highest integration level and consists of the sharing of information, resources and responsibility in order to organize and develop activities for a common goal.

Only in this last sense we can talk of collaborative network which have been defined as "*a network consisting of a variety of entities 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*". [1]. CNOs enable several benefits, among which the increase in the success rate of enterprises, also in turbulent markets, and the increased capability to achieve shared goals [1]. Indeed, through alliances, it is possible to enhance enterprise size, gain access to new markets and to external know-how, create synergies, share resources and risks, integrate firms' resources with the ones of partners and enhance innovation processes, with a result of increased value creation [9]. Collaboration among enterprises enable the finding of resources not easily accessible on the market or that cannot be easily created. Also, the interactions among partners can be generated the relational capital [10], defined as a set of relations among firms which facilitate the exploitation of economic activities. Resources are exchanged when this is mutually convenient and there is mutual trust, which exists when: a) partners confide in a reliable and transparent exchange of resources; b) a firm believes that other partners are pursuing actions that are beneficiary also for the firms itself and c) that these actions are not prejudicial [11]. Indeed, trust has been seen as "*the cornerstone of strategic partnership*" [12], whereas the lack of trust can bring to the failure of the alliance [13] and whereas if associated with commitment can bring to "*outcomes that promote efficiency, productivity and effectiveness*" [14].

In the field of strategic alliances, trust is often a cognition-based trust, which comes from rational choices based on information, rather than from emotional bonds between individuals (affect-based trust), that follow in case of recurring interactions between firms. In particular, cognition-based trust comes from previous interactions, reputation on the market, ecological and ethical responsibility, organizational context, similarities in firms' characteristics. The searching for trust based relations have to rationales: a) CNOs with a high level of trust are more likely to succeed and to create value; b) relations among partners with a high level of trust requires much less time and commitment to be managed [15]. For these reasons, the partner selection is often based on previous interactions, reputation and potential degree of conflict [15].

Recognizing the importance of model frameworks for CNO, the ARCON model was developed by [4, 16]. In the model, four endogenous elements are analyzed, namely structural dimension, componential dimension, functional dimension, behavioral dimension. The behavioral dimension regards the principles, policies and rules of governance that guide who operated within the CNO in order to make it more efficient [17]. Indeed, CNO governance is particularly relevant, since it's a requirement for the effective monitoring and control of relations. Inter-organizational relations create a not-planned operative context, which at the same time is not entirely spontaneous [18]. Moreover, another relevant element is risk, which has been analyzed towards three perspectives. In [19] firms choose to collaborate in order to face market risks; in [17] risk is the result of CNOs, while in [20] trust derives from risk and, at the same time, is affected by trust. However, cooperation could lead to a reputational risk, coming from non-socially responsible behavior of partners that could affect the whole CNO.

In short, the advantages of CNOs are fully exploited only when there is trust among partners, an adequate governance, ethical codes and a culture of collaboration.

4 SuMCNOs: A CNOs Sustainability Model

4.1 Method

For the development of our model, we selected UML as means to represent general factors and variable, and e3-value for the analysis of value exchanges in CNOs, since it's a business ontology specifically designed for the analysis of value constellations [5]. After reviewing more than 50 papers related to CNOs, published on international conferences and journals, we identified three variables that have a great impact on value creation. We modeled these variables with a UML class diagram. To this purpose, we considered the nodes of the networks, the CNOs and the variables that impact on value creation as classes, since a class is an abstraction of things (or instances): in other words, classes represent a whole set of objects that share methods and attributes [21]. Moreover, we analyzed the value exchanges within networks by means of e3value. To this aim, we modeled CNOs as composite actors made by other business actors. Accordingly to e3value standard notation, we show the value activities that contribute to reaching the CNOs goals as value activities, while the value exchanges have been depicted as connection between value ports, assigned to each actor. Finally, we applied this model to a case of study, for which we draw the corresponding e-3 value diagram. All the diagrams are drawn with Microsoft Visio and e3value Editor.

4.2 Model Representation

This section provides a representation of our proposal, in order to exemplify our modeling approach. In the first part of the model, based on UML, we represent the determinants that impact on value creation and exchange within CNOs. As stated in the theoretical foundation section, the main aspects concern trust, resource sharing and commitment. For the purpose of this study, we intend value as the result of the activities of the individual firm and of the collaboration with other entities. In this sense, the value refers not only to financial benefits, but also to socio-environmental ones.

In Fig. 1, we represent the candidate classes and the candidate associations of our model. In particular, each `Node` is part of a `CNO`; both `Node` and `CNO` are children of the parent class `BusinessEntity`, which is a generalization of their concepts. Also, nodes share `Resource`, which is a generalization of `TangibleResource`, `FinancialResource` and `IntangibleResource`. To the primary association between `Node` and `Resource`, we tied an association class `Sharing` since the association is, in turn, associated with other classes. In a similar way, to the primary association between `Node` and `CNO`, we tied an association class `Participating` since the association itself has some attributes, namely `Trust`, `Commitment` and `RelationalCapital`. We choose to represent these attributes as classes, in order enable the association with other classes. In more detail, `Trust is affected by` several factors, whereas the `Factor` class is a generalization of `InternalFactor`, which is an attribute of the association class `Participating`, and `ExternalFactor`. `RelationalCapital`, which is an attribute of `Participating`, is also associated with the class `BusinessEntity`. Tying `RelationalCapital` both to the class `Participating` and to the class `BusinessEntity` enables its attribution to the level on which the information is available.

Moreover, `RelationalCapital` is enabled by:

- `Trust` and `Commitment`, which are attributes of the class `Participating`: this relation doesn't need to be represented, since are all attributes of the same association class, therefore the association it's implicit;
- The `Sharing` of resources: if nodes don't share their resources, it's difficult to find relational capital, since it's strictly linked with how much firms work togheter.

The associate class `Sharing`, in turn, is enabled by `Commitment` and `Trust`, as explained in Section 3.

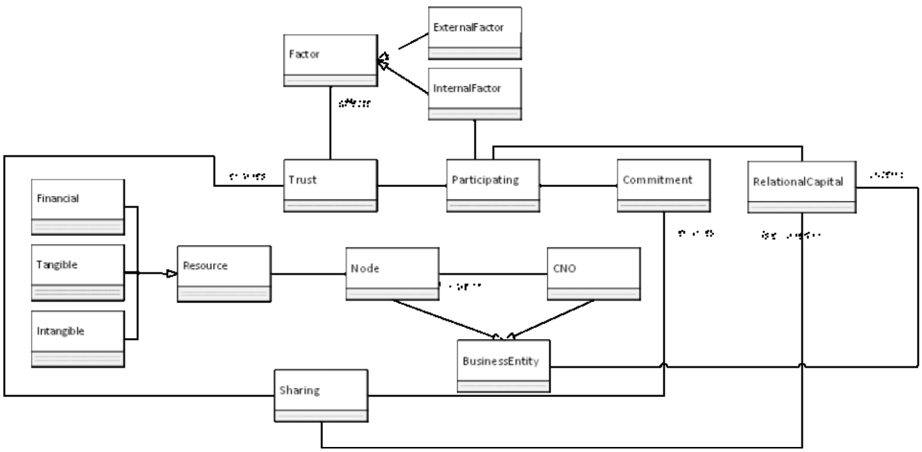

Fig. 1. UML class diagram representing value creation in CNOs

The second part of the model is represented by means of e3 value ontology, through which we depict the value exchanges inside and outsides the collaborative network. To this purpose, we take into account two types of CNOs and, in particular, a supply chain and a horizontal strategic alliance.

In Fig. 2, value exchanges in a supply chain are represented. `SupplyChain` is a composite actor made by the actors `Supplier` and `InternalCustomer`. Supplier has a value activity `Production` and sell its products and services (value link) to `InternalCustomer`, who in exchange pay the price (money) to the supplier. `Supplier` also sells its product towards `ExternalCustomer`: the benefits of the CNO with respect to a market-driven environment is that products and services within the alliance can be sold at a lower price or can be more specific for the customer's needs. Also, `InternalCustomer` has a value activity `Production` and sell its final products and services to `FinalCustomer`. The social benefit is that `CNO`, under certain circumstances, enhance products quality and reduce prices.

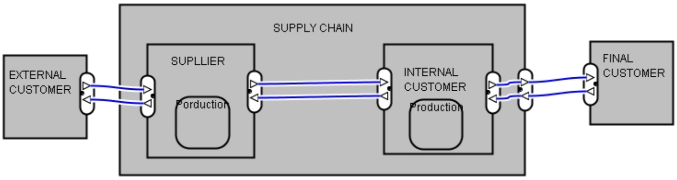

Fig. 2. Representation of value exchanges in CNOs

Moreover, exchanges within a horizontal alliance are represented. As depicted in Fig. 3, the value exchanges don't happen between the partners of the CNOs, but between the nodes and the CNO itself, whereas the benefits for nodes are usually intangibles.

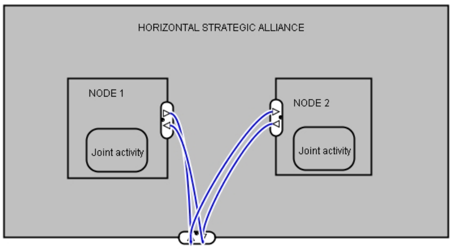

Fig. 3. Representation of value exchanges of horizontal strategic alliances

5 Case Study

The Network of Bathing Establishments of Viareggio is a collaborative network born in 2011 with the aim of increasing the competitiveness of the participants (85 bathing establishments). The main objectives of the network include (a) the increase of security on the beaches, (b) the improvement of environmental sustainability and (c) the coordination in supplying services.

For the purpose of the analysis of value creation, we will analyze a specific project realized by the CNO regarding the safety of bathing establishments. The projects enabled services of medical aid and first support with AED (Automated External Defibrillator). In order to achieve this result, the network bought 41 defibrillators and offered courses for about 150 staff operators. As depicted in Fig. 3, `Node1` and `Node2` pay a fee in order to access to the project, whilst `NetworkOfBathingEstablishments` buys from `AEDSupplier` 41 defibrillators and from `CouseErogator` a service (course offering), under the payment of a fee. Finally, `NetworkOfBathingEstablishments` offers this service and the defibrillators to `Node1` and `Node2`. This enables `Node1` and `Node2`to offer more services to their clients, which in return will get a safer environment also for elderlies and for people with health problems.

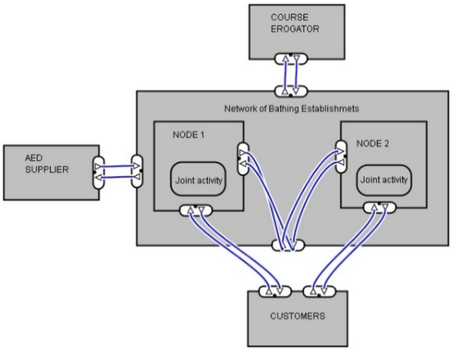

Fig. 4. Representation of the value exchanges in the Network of Bathing Establishments

In this case, trust mechanisms between nodes have been enabled by the continuous interaction among partners and by the network manager, who helped in the switch from a internal-based culture, where every external entity is a competitor, towards a collaborative culture, where each node is seen as relevant part for value creation for the CNO and for the creation of social benefits.

6 Discussion and Conclusions

In this paper, we propose a model for collaborative networks that takes into account both the factors affecting value creation and the value exchanges within the network. In particular, we described by means of UML the role of commitment and trust in the participation relationship and the variables that affect these two factors. Also, we analyzed through e3value the value exchanges within CNOs taking into account two different scenarios, namely a supply chain and a horizontal strategic alliance. Finally, we used e3value ontology in order to describe a case study of a horizontal network between bathing establishments. Whilst previous research only analyzed single enabling factors or value chains, we jointly examined these perspectives and we developed a model, named SuMCNOs, which can be easily applied to different cases in order to understand the sustainability of CNOs. Future works will include the extension of the scenarios investigated.

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Experimentation of Rational Trust Evolution and Sustainability in Dynamic VOs

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Abstract. Piloted semi-automated mechanisms for monitoring and managing Virtual Organizations (VO) on the bases of established trust for collaboration that has already started need to be developed. Various researches in dynamic VOs have not established a semi-automated solution to manage the changing trustworthiness of the partners in the collaboration. The experimentation on semi-automated analysis of dynamic trustworthiness of VO indicates that a statistical standard deviation model promises more to be used to assess partners who sustained trust or failed to sustain trust in a period of time. This paper proposes a semi-automated TrustSEv (Trust Sustainability and Evolution) system for assessing partner's trust sustainability in the VO during evolution phase. Further, the paper establishes a linear relationship between objective trust level of the individual partner constituting the VO, and the strength of the VO itself.

Keywords: trust evolution, trust sustainability, VO, trust experimentation.

1 Introduction

Smooth operation of the VO needs to be supported with properly established trust relationships among partners as a bonding factor for enhancing co-working. Although there are a number of forms of trust that can be established, rational trust which is established on the basis of factual performance has been mentioned to be the sustainable bonding factor for business collaboration [5]. Established rational trust among organizations using mechanisms that are formulated based on measurable factor can enhance partner's confidence on a specific partner of the VO to execute its assigned roles appropriately and thus contribute in achieving the common goal(s). Despite the different and opposing perceptions of trust to different actors, in this paper we perceive rational trust in VO as the objective-specific confidence of a trustor in a trustee, based on the results of rational (fact-based) assessment of trust level of the trustee [4]. For our developed mathematical base mechanisms, the main input into trust analysis is measurable organization's performance data [1]. The factual performance data obtained from the analysis of objective trust plays a significant management role towards various reasons driving the collaboration.

Organizations collaborate and cooperate for a number of reasons including enhancing preparedness, saving time and decreasing development process, sharing

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costs and risks with partners, improving resource utilization, and gain access to new markets through partnership [6]. For these advantages of collaboration to be gained it has been stated in research and observed in practice that participating organizations must rationally trust each other throughout the collaboration period. However, although can be established at the VO creation, trust of the VO partner does not remain static, but evolve depending on many influencing factors including actual partner's performance in the VO. The dynamic trust can result in either rise or fall of the trust level of a specific partner with respect to time.

It is therefore important to note that trust of an organization is dynamic and evolves over time. The dynamicity nature of trust needs comprehensive analysis and measurement approaches, particularly for the collaboration which is already in progress. The dynamic nature of trust cannot be assessed conventionally, especially for short-term collaborations, because conventional approach to build trust among business partners has proven to be inefficient [7]. Such convectional approach in building trust, is what we refer to as subjective trust. Therefore, when subjective trust is inefficient, then objective trust assessment provides a promising solution for measuring dynamic trust.

This paper describes classification of trust (section 2) and background of Trust Management (TrustMan) system (section 3). The specification and architectural design of Trust Sustainability and Evolution (TrustSEv) system are discussed in sections 4 and 5, respectively. The pilot setup of the TrustSEv system (section 6), experimentation and discussion (section 7) are presented, and we finally provide conclusion of our paper in section 8.

2 Classification of Trust

Trust can be classified in two aspects, namely; Subjective trust, and Objective trust. In the past, trust used to be perceived as subjective (opinion-based); posing difficulties in its evaluation and formal reasoning on analysis of its results, due to the use of opinion-based data, thus being risky as it is biased [5]. In subjective trust aspect, a trustee is evaluated based on opinions, suggestions, recommendations, and sometimes polling. It is a biased trust due to the difficulty in reasoning about correctness and rationality of the assessed trustworthiness. Objective trust is the results of the rational (fact-based) assessment of the trust level [2]. It is trust based on organizational performance data (fact-based), and provides results which an individual can reason about using the formal evidence.

Trust in the past was measured statically and did not consider the variation of trustworthiness with time as the collaboration continues. Such dynamic behavior of trustworthiness accounts for existence of Trust Evolution which needs to have proper sustainability mechanisms. We thus refer to Trust sustainability as the process whereby a VO partner maintains their trustworthiness to the specific trust level to enable it remains acceptable in the VO during execution of the activities that lead into achieving the common goal of their collaboration [1]. Each VO partner maintains its trust level at or above the acceptable value, namely the required specific trust level for the VO. If the trust level falls below the specific trust level of the VO then the VO partner is not trustable on capacity to execute its roles. When such an organization fails to sustain its level of trust, the VO can undergo evolution for which new partners are selected from pool to fill the gap of departing partner with poor trust. When new partners are added in the VO the trust level of others will change because of the comparative analysis and measurement which is applied in our developed mechanisms. This process is referred to as trust evolution.

3 The TrustMan System

The objective trust presented in section 2, require proper conceptualization and modeling in order to address its measurement factually. The varying perception of trust accounts for a complex modeling of trust measurement. When the objective trust is a concern, then formal approaches are important so that trust can be processed and executed by computer systems. The rational results from such kind of measurement can be used to objectively configure a new consortium, by selecting members from Virtual organizations Breeding Environment (VBE). In a study conducted by [3], a HICI (Hierarchical, Impact and Causal Influence) was used to model trust measurement. The assessment of trust employed data from organization's performance for every VBE member. The automation of assessment mechanisms were presented through TrustMan system. The TrustMan system is prototypical software that was used to configure the new VO, for a new business opportunity realized. The VO is formed based on specific objectives, by selecting partners from VBE members, whose trustworthiness are objectively assessed to be satisfactory. The TrustMan system was used as source of data for TrustSEv system.

4 Specification and Analysis of TrustSEv system

In designing our system we have adopted Service Oriented Architecture (SOA). The SOA is an architectural style employing the principles of loose coupled interacting components, for the purpose of providing the intended service to the consumer. While designing the TrustSEv system, integration and interoperability was our forethought, in order to improve information flow for service provision. The SOA architecture used, allows new applications which are capable of interacting with the existing components through the defined interfaces. Therefore, the TrustSEv system provides five (5) integrated services as described in Table 1, to support management of dynamic trust in VOs. The services offered by TrustSEv system are coded as "S".

5 Architectural Design for the TrustSEv System

The TrustSEv system provides services specified in Table 1, through employment of two architectural styles, namely: (1) the Interoperability Architecture, and (2) the Four-layer Componential Architecture. In order to provide the promised services systematically, accurately and comprehensively, the TrustSEv system interacts with other systems as illustrated in Interoperability Architecture (Figure 1).

Table 1. Specified Services of the TrustSEv System

Code	Service Name and Description
S1	***For input of basic information related to VO:*** This service supports VO coordinator to enter basic information related to partners of the said collaboration. The coordinator is appointed among partners who can solely be a prime partner.
S2	***For input trust values and trust level:*** This service supports requesting trust values and related data from *TrustMan* system after activation by the participant observer into *TrustSEv* system. A participant observer is a human user (say, VO coordinator). This is an administrative service and it is accessed by the VO coordinator.
S3	***For forecasting target goals for the next period of assessment:*** This service provides target agreements customizable to every participating VO partner. Since trust is dynamic, the target is a range defined by lower limit and upper limit trust values, in which a healthier partner's trust level is optimally allowed to oscillate.
S4	***For assessment of sustainable trust value and trust level:*** This service provides a mechanism for assessing trust level of VO partners. This is a limited administrative service and is thus accessed by the VO coordinator and the VO partner.
S5	***Defining, authorizing and assigning rights to other users****:* The service supports defining user access levels for VO partners and guests with different privileges. It is a highly administrative service and thus only VO coordinator can access it.

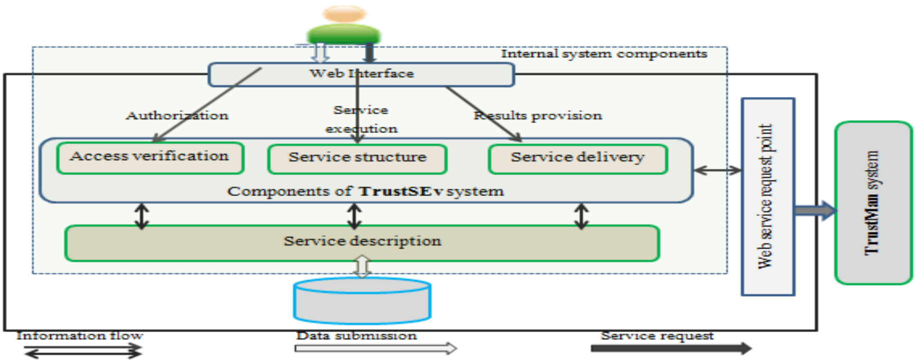


Fig. 1. Interoperability Architecture of TrustSEv System

Such interaction is mainly for two purposes, namely; (1) acquiring trust values and trust levels data from TrustMan system and (2) supporting human user access to deliver the requested services. The further purpose behind this TrustSEv interoperability architecture is to guide developers during the implementation of modules supporting the required external interactions. External interactions into TrustSEv system are supported by internal components classified into three groups, namely: (1) access verification, (2) service structure, and (3) service delivery. The components for access verification provide administrative functionalities to both human and system users interacting with TrustSEv system. They also classify the services that can be requested based on privileges for each specific user in the system. The components for service structure provide the internal mechanisms, namely the choreography related to business logic functionalities based on service request. The components for service delivery provide requested response to users, or when failure a feedback and cause of failure.

The componential architecture of TrustSEv system (Figure 2) comprises of four layers, namely: (1) the presentation layer, (2) the process layer, (3) the description layer and (4) the message layer. Presentation layer links process layer and human user. It is a platform where data/information from human user/TrustSEv system is exchanged in human readable form. Consequently, it deals with transformation of data from process layer into human readable text. Further, in order to protect sensitive information from exposure to the third party, the web services are designed to support user access rights in three levels, namely, public, restricted and protected interfaces.

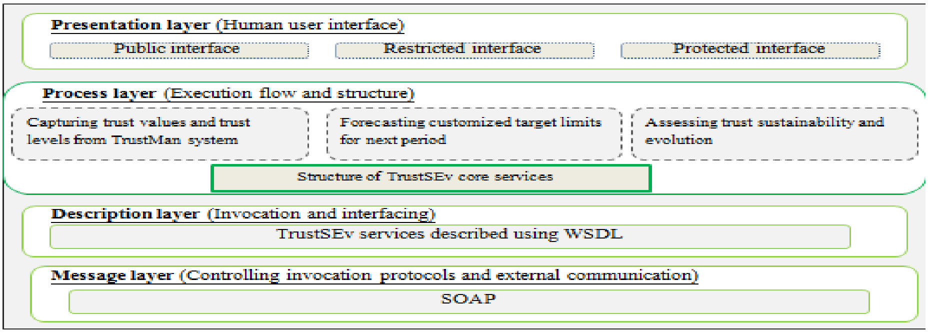


Fig. 2. Four-layer Componential Architecture of the TrustSEv system

Process layer is the core heart of the business logic processing in which various modules and components are executed, for services provision. The process layer is constituted of process scheduling referred to as orchestration and choreography. The description layer provides grammatical and dictionary-like specifications of services in order to create supportive invocation by external and remote components, and employs Web Services Description Language (WSDL). The message layer is responsible for specifying communication protocols among both, the internal and external components. The layer controls invocation protocols internally, and communicates externally by using Simple Oriented Access Protocol (SOAP) standard protocol for web services.

6 The Pilot Setup of the TrustSEv System

The experiments were conducted in four specific defined periods, with the assumption that every VO coordinator had collected required performance data for each partner. The experimental method was meant to the statistical based mechanisms which are implemented in the TrustSEv system [1]. The model predicts acceptable range in which trust values of an individual VO partner is optimally allowed to oscillate. The experiment used organization's trust values that were computed by TrustMan system using the performance data at the highest level of granularity, termed as trust criteria. Trust criteria are well described in the wheel of general trust elements [2].

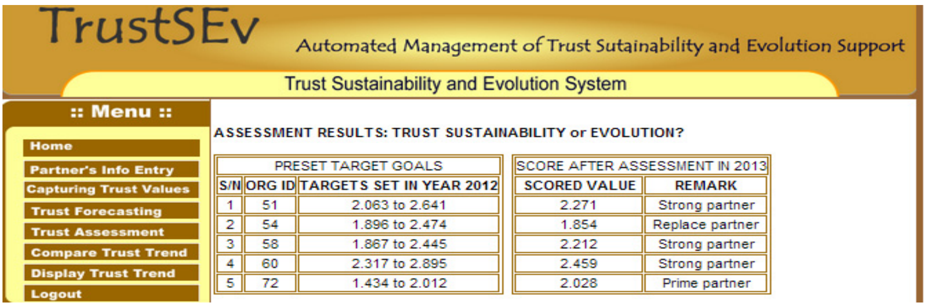
The TrustMan system is capable of measuring partner's trustworthiness through organization's performance data at a specific point in time [4]. However, the TrustMan system does not have services that can track the variation of the trustworthiness and thus assess the sustainability of trust in a range of period [1]. Therefore, the time-point computed trustworthiness are captured and stored in the TrustSEv system in form of textural description and numeric scores. For each specified period of time the TrustSEv computes the evolution of trustworthiness based on the captured data from TrustMan system. The operations, design and development of TrustMan system are published in [2] and [4]. Furthermore, in the experimental setup using TrustSEv system, the assumptions for applied terms, namely: *(1) Base period, (2) Target goal, (3) Assessment Period,* and *(4) Trust Value Standard Deviation,* are defined in [1].

7 Experimentation of TrustSEv System

To conduct assessment of trust sustainability and evolution, a VO coordinator specifies a base period. Then, the coordinator executes a forecasting service which determines target goal of each individual VO partner. The target goals are custom-set based on individual partner's capacity expressed as organization performance. The individual planned target goal results are expressed in a range, as defined in [1]. For this experiment, two six month periods was assumed to be between 2012 and 2013 as assessment period. Therefore the settings established in 2012 were used to assess the trust sustainability in the next two periods, which is the year 2013.

7.1 Forecasting Trust Target Goals

This service supports the VO coordinator to set target goal on trust values that VO partners must sustain in order to remain trustworthy in collaboration. For example, in Figure 3 the coordinator was forecasting target goals for year 2013 using organization's performance data of the year 2012.



PRESET TARGET GOALS			SCORE AFTER ASSESSMENT IN 2013	
S/N	ORG ID	TARGETS SET IN YEAR 2012	SCORED VALUE	REMARK
1	51	2.063 to 2.641	2.271	Strong partner
2	54	1.896 to 2.474	1.854	Replace partner
3	58	1.867 to 2.445	2.212	Strong partner
4	60	2.317 to 2.895	2.459	Strong partner
5	72	1.434 to 2.012	2.028	Prime partner

Fig. 3. Assessment on trust sustainability and evolution from TrustSEv system

For instance, the organization with Identity (ID 51) had its target goal in terms of trust value set to lie between 2.063 and 2.641 inclusive for the year 2013. Then after a lapse of a two six month period, organization's performance data for each partner is submitted to the VO coordinator. Then the values are fed into TrustSEv system for assessment, by diagnosing to whether the current trust value lies within preset custom target goals. After assessment, the partner with ID number 51 had its performance score in 2013 found to be 2.271, which implies that such partner maintained its trust level within the acceptable limits. Contrary, a partner with ID number 54 had its target goal preset to lie between 1.896 and 2.474 inclusive, but managed only to score a trust value of 1.854. The partner had failed to maintain its trust level.

Such failure implies partner's low ability to collaborate, because it cannot be trusted in execution of her duties. Since the partner has starved, then it is recommended for replacement. Such replacement of the failed partner accounts for overall change in trust level set by the VO. The change brings new reconfiguration in trust value, termed as *trust evolution.*

7.2 Discussion of Pilot Results

A strong collaboration will always comprise of partners whose trustworthiness strengths bear slight differences. Where the collaboration may result in risk, such risk is likely to be shared among the VO partners, thus increasing accountability towards full execution of the assigned roles. Such facts are evidenced in Figure 4 to depict the trend of *trust value lower limits*. The trust value lower limits used in Figure 4, were drawn from Figure 3 for a consecutive experimentation, in a period of four years.

The trust value lower limits are dependent on *trust value standard deviation (Vsd)* variables as presented in [1]. It is observed that where the standard deviation in trust value is set small, the difference in lower limits of the trust value become small values and vice is also true. Scattering of lower limits trust value is determined by the size of trust value standard deviation. In standard deviation statistical model [1], the closeness in terms of partners' strength is observed through the size population standard deviation. High size standard deviation implies low precision and large deviation among data sets and vice versa is also true. The graphical presentation of lower limits trust value trend is depicted in Figure 4.

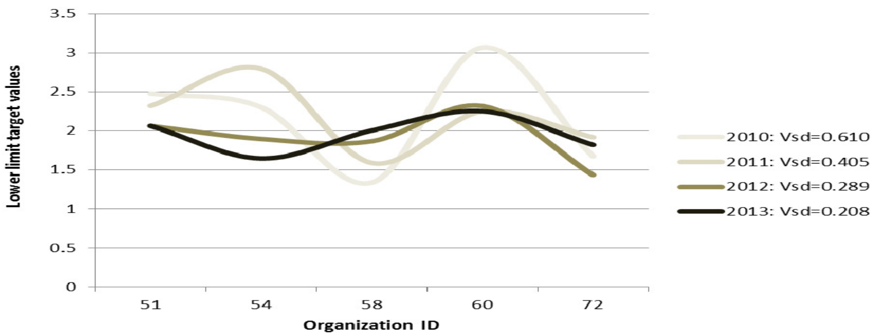


Fig. 4. Impact of trust value standard deviation size on strength of collaboration

For example, for the target goals settings for years 2010 and 2013, the trust value standard deviation is 0.208 and 0.610 respectively. The graphical line for 2013 is closely scattered than that of 2011. These statistical implications reveal an important knowledge on management of dynamic VO. That, the operating VO with partners, whose strengths in terms of trust value differ significantly, is likely harder to achieve its goals. Because, the collaboration contains both, stable and weak partners such that the weak partners are doubted on their ability to fulfill their roles. On the other hand, the operating VO whose partners' trust values have low differences becomes very stable as similar strengths encourage team spirit and objective confidence trust among the partners.

8 Conclusion

The management of trust sustainability and evolution in dynamic VOs, whose collaboration is live, represents an important factor and enabler of VO success. We have shown that trust acquired during VO formation is not static and it changes with time, due to internal and external factors that may influence the partner's performance. Since the overall trust level of the VO partners is subject to change, such situation requires management of dynamic trust in terms of trust sustainability and evolution. We have presented the specification, designing and piloting of the TrustSEv system as statistical based semi-automated system for assessment of dynamic trust in partners in VO.

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Additive Manufacturing: Current Status and Future Prospects

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Abstract. The potential implications of additive manufacturing or 3D printing technology are being recognized across a number of different industries. In developed countries where the traditional manufacturing sector has experienced decline, the developments in additive manufacturing present potential opportunities for growth. The paper presents the outcomes of preliminary data analysis from an exploratory survey of senior managers working in the additive manufacturing sector in the Australasian region. The analysis suggests that while there has been progress, there is scope for improving technologies and reducing costs in order to facilitate wider adoption of and greater business value from 3D printing.

Keywords: additive manufacturing, 3D printing, business model, sustainability.

1 Background

In an environment of increasing competition from developing countries, manufacturers in western countries are increasingly focusing on high-end products or unique production processes or environmentally sustainable product lines [1]. There is growing interest in applications of innovative manufacturing technologies across a number of sectors. This paper focuses on one type of advanced manufacturing practice – additive manufacturing or 3D printing and presents preliminary findings from a survey conducted in the Australasian region.

1.1 Trends in Additive Manufacturing

Three-dimensional (3D) printing is an example of additive manufacturing that is becoming increasingly popular [5][6]. In 2012, the global market for additive manufacturing products and services grew to over USD 2 billion and the unit sales of industrial systems reached around 8000 units. A recent report from the UK [2] suggests that although additive manufacturing provides an attractive option for organizations seeking to continue to be competitive in manufacturing, the technology currently has

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 365–372, 2014.

less than 8% market penetration. While this is due to a combination of lack of greater awareness within the global manufacturing community and shortcomings of existing technology, there is a great scope for future growth in this area.

Three key industries, automotive, aerospace and medical, have adopted and seen developments in additive manufacturing technology for various reasons [7]. The automotive sector has used the technology to get new products to market quickly and in a cost effective manner, thereby achieving savings in the overall development of vehicles. The aerospace sector has adopted the technology for its ability to produce very complex, high performance products especially in the context of carbon composite aircraft designs. The ease of converting 3D medical imaging data has made additive manufacturing attractive to the medical industry. However, speed, accuracy, nonlinearity, material properties and system costs remain as limitations of the technology. There are currently several 3D printing machines available to potential and existing commercial users. These printers can work with various materials to produce parts that can be used in rapid prototyping applications [8].

An overwhelming attraction of additive manufacturing is its ability to meet customer requirements for product customization and product immediacy [3]. However, while the rapidly developing technology is well documented, the business implications for manufacturing organizations adopting/using additive manufacturing appears to have received limited attention in the academic literature. This paper aims to address this gap in the literature in the Australasian context.

2 Research Method and Data Collection

This paper reports on the Australian data from an exploratory survey of users of additive manufacturing conducted in Europe, North America and Australasia by a collaborating team of researchers in the Australasia and the UK. The Australasian users of additive manufacturing (organizations and key contact points) were identified with the help of the Advanced Manufacturing Cooperative Research Centre in Australia. Of the 42 users invited to participate in the study, 17 responded but 13 (31%) actually completed the online survey. The online survey contains both Likert scale questions as well open-ended questions allowing users to describe their experiences with additive manufacturing and their understanding of the current and future of uses of the technology. Although the response rate in Australasia was considerably lower than that in Europe/North America, the data provided useful insights for future in-depth case study based research. The users represented various sectors including consumer durables and disposables, industrial components and products as well as consultancy services (indirect users); ten of the 13 respondents held senior management roles. Most of the organizations (61.5%) have been involved in additive manufacturing for less than five years. Others (23.1%) had been working in the area for five to 10 years or 10 to 15 years (15.4%). A majority of the manufacturing firms were found to be using non-metals in their production processes. The proportion of respondents involved in different types of additive manufacturing applications is shown in Table 1 below.

Table 1. Respondent involvement in additive manufacturing applications

Additive manufacturing applications	% of Respondents
Rapid prototyping for new product development	69.2
Rapid manufacturing (complete products)	7.7
Rapid manufacturing (product components that subsequently become part of a complete product)	38.5
Other	7.7

3 Findings

3.1 Current Status of Additive Manufacturing

A number of potential benefits of additive manufacturing have been noted in the press and the academic literature. In this study, a high proportion of respondents (77%) strongly agreed that the reduced time lag between design and production was a benefit of this type of manufacturing. This is aligned with common assertions in the press in relation to this technology. The top three benefits identified by respondents are shown in Figure 1 below.

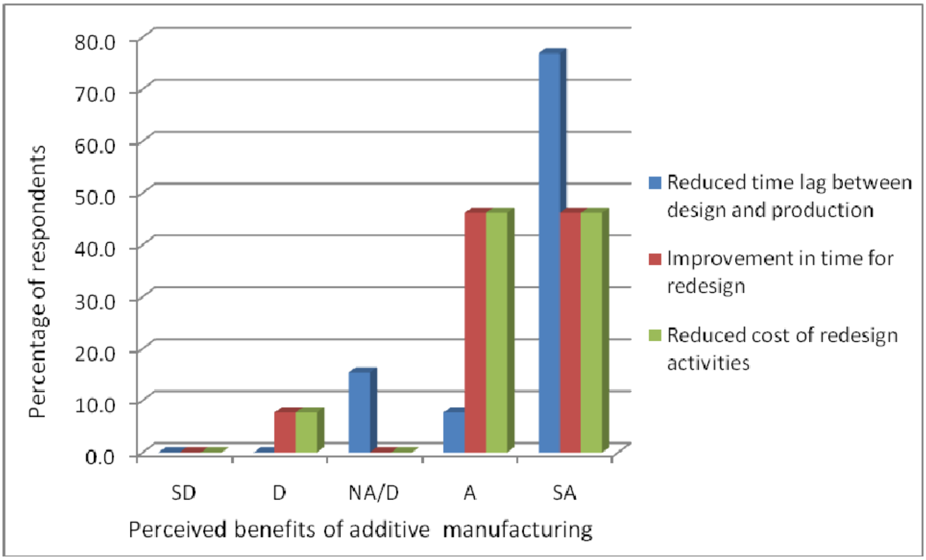

Fig. 1. Benefits of additive manufacturing based on the experiences of respondents (SD= strongly disagree, D=disagree, NA/D=neither agree nor disagree, A=agree, SA=strongly disagree)

When describing their experiences with output quality from additive manufacturing, majority of the respondents (69%) were positive while noting issues with materials, machines/platforms and outputs. One respondent made the following observation on platform and material issues while noting the quick turnaround time: "*We have just completed an extremely busy two months. There is no way we could have met demand with out our additive manufacturing system. Consistency is dependent on understanding the accurate areas on the printing platform. Printing the same file on different areas of the platform will result in dimension differences. The surface finish is consistently better than hand made prosthetics, in the majority of parts. The part material we use is an acrylic. It is a little brittle*." Another respondent noted the process improvements that had occured over time while observing that the technology had a long way to go: "*We have been using additive manufacturing for 15 years in a prototyping function. The quality of the processes is improving in our experience and we can prototype parts which appear very close to the production equivalent. However we are yet to see an additive process that can replace traditional production processes in terms of physical material properties - strength, durability, stability. This is especially true for processes which involve work hardening or internal stress loading".*

The adoption of additive manufacturing has impacts on a business through the requirement for additional resources and staffing/training as well as value creation through improved turnaround times and positive changes in business-to-business interactions. One respondent from heathcare manufacturing provided the following insights: "*Two thirds of our production line required retraining. Interest in our business increased, so the profile of our business attracted more attention from our current customers, new customers and competitors. Subsequently this opened new revenue sources. We are subcontracting to new clients who were previously competitors. We are building a network of Dental laboratories in Australia and New Zealand that we will be training to utilize additive manufacturing in their businesses. Our business has now international markets, where previously our market was restricted to domestic Dental Laboratories*." Another senior respondent from the automotive sector noted: "*Additional facilities and staff added, increase in products developed with reduced turnaround times. Quality of our tool makers has increased dramatically; now 3D assembled parts can be sent to them before tooling starts as it allows them to visualize parts we are developing as a whole, this helps deliver a better quality part as well as speeds up tooling process. Rapid prototyping is now one of the company's biggest marketing assets with every potential customer being given a site visit and being shown the prototype machines' potential*."

3.2 Future of Additive Manufacturing

When asked to identify the usefulness of potential developments in additive manufacturing equipment/materials, a high proportion of respondents (75%) strongly agreed that further decreases in printer cost would be useful to them. The top four useful potential developments identified by respondents are shown in Figure 2 below.

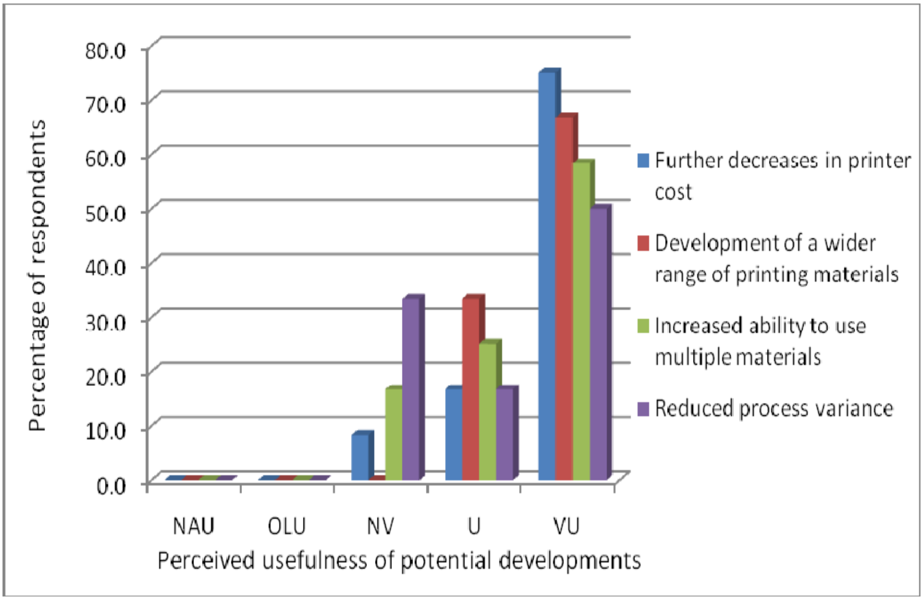

Fig. 2. Usefulness of potential developments in additive manufacturing equipment/materials (NAU=not at all useful, OLU=of limited use, NV=neutral view, U=useful, VU=very useful)

Additive manufacturing was viewed to be an environmentally sustainable approach by 77% percent of the respondents. Respondents identified reduction in material wastage and energy usage as key reasons why this approach to manufacturing was a greener solution. Reduction in transportation related energy usage by manufacturing at the point of use was also noted.

Respondents were divided as to the potential for additive manufacturing to increase on-shoring/re-shoring of manufacturing actives in the near future. Around 46% of respondents believed that additive manufacturing creates opportunities for local suppliers. While noting volume limitations, one respondent reported positive changes in their own practices: "*Unless the quality of finished parts improves for volume manufacturing we will continue to largely use the technology for prototyping....having said that we are now getting prototype parts done locally where they were regularly manufactured offshore so a net benefit.*" However, the developments in additive manufacturing in China (e.g., [4]) have led to counterarguments from other respondents: "*We find that for our purposes this is not a consideration. Rapid prototyping is based on speed of TAT [turnaround time] and quality of the result. We regularly use Chinese manufacturers for this.*"

Most respondents (77%) agreed that given President Obama's announcement of funding for a National Additive Manufacturing Innovation Institute (America Makes) in 2012, other governments should invest in more additive manufacturing research activity. Reflecting on the Australian context, one respondent made the following observation: "*To become competitive and stay competitive in the changing world, we must be leaders in technology. There is still so much to learn and so much to be* *gained by becoming a global leader in additive manufacturing. It is unfortunate Australia has missed the boat in the early years of Additive Manufacturing technology. But there is still much to be learned, I have many questions that cannot be answered. I have much to learn. How will I continue to develop my underpinning knowledge with no resource tools? Additive Manufacturing is the future. If we want to be a part of the future we must invest in the future*." However, others raised issues such as the consequences of too great a concentration of funding on one type of technology at the expense of others and the need for any research/development in the area to be industry led. Irrespective of their views on funding of relevant research activities, all respondents identified a number of future applications of additive manufacturing as listed in Table 2 below.

Table 2. Respondent perspectives on future applications of additive manufacturing

Industry	Future applications
Healthcare	Low volume manufacturing/prototyping; full and partial dentures, splints, surgical guides, orthodontics; rapid prototyping; custom components specific to patent, e.g., based on biometric detail
Automotive	Low volume spares and tooling; new product testing and trialing; spare parts; rapid production of replacement parts for repair shops as well as rapid prototype
Aerospace	Complex parts at low volumes; production parts that only have material when required, in shapes that can only be produced by this method of manufacturing
Consumer durables	Custom components specific to a consumer e.g. based on environment, user etc.; possibility of "making your own parts" by using printing machines and files thus reducing inventory and freight costs
Specialist consumer products (e.g., apparel)	Ability to make unique design apparel without tooling costs; jewellery; many applications some of which are already here: mobile phone cases; shoes and glasses etc.
Tools for assembly purposes	Ease of manufacture of tooling without setup costs of traditional manufacturing methods
Other	Consumer customized products; applications in every industry not just manufacturing

4 Discussions

This paper presents the outcomes of a preliminary analysis of data from an exploratory survey on current practices and potential future development in the additive manufacturing sector from the perspective of users of the technology in the Australasian region. The findings suggest that users recognize the benefits of additive manufacturing as well as the developments required in future in order for the technology to continue adding value to their businesses. Adoption of the technology appears to bring with staffing, training and other resource needs but it has the potential to change the way companies grow and interact with their customers and suppliers. All respondents in this study seemed to recognize that the technology is here to stay despite its current shortcomings and believed there would be a range of potential applications.

A recent article in The Guardian describes the developments in metal 3D printing as furthering a second industrial revolution [9]. These developments include the availability and decreasing costs of metal 3D printers for home use, 3D printers that can build themselves, current research on 3D printers that can produce nutritious food for astronauts, affordable 3D scanning and 3D printing as a service. The fact that many 3D printing patents will soon expire is also expected to create opportunities for greater innovation [10].

The potential of the technology to revolutionize manufacturing has been recognized by governments, the private sector and university researchers. As noted by the respondents in this study, the technology is still being used largely for prototyping purposes. Overcoming the limitations of the technology in order for it to be used for high-volume manufacturing remains a challenge for all interested stakeholders. Addressing the challenge will require collaboration across different sectors. In 2012, America Makes was established in the US as a network of around 100 academic institutions, companies, government agencies and non-profit organizations in order to make the country's additive manufacturing industry globally competitive. [11] In the UK, three companies, Renishaw, Hieta and Sysemia, are collaborating to address the mass-production related limitations [12]. The project is funded by the Technology Strategy Board, the UK government's innovation agency.

As the technology becomes more scalable, small businesses that are adopting the technology in Australia will be able to experience significant market growth. On-demand manufacturing may also become more common. Companies such as Sculpteo [13] and Shapeways [14], for instance, are already at the forefront of creating online marketplaces around 3D printing. The range of business impacts of the developments in additive manufacturing will become clearer over the next few years. This paper is an initial exploration of these developments in additive manufacturing. The authors expect to conduct further research to understand the impacts of collaborative research in additive manufacturing as well as the implications of these developments for business models.

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Reference and Conceptual Models

A Metamodel for Collaboration Formalization

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Abstract. This paper presents a metamodel formalizing collaboration of heterogeneous entities (organizations, agencies, companies, intelligent agents…). Initially developed to support crisis management, this metamodel has been extended to any objective driven work of collaborative networks (CN). This formalism embeds all concepts (and inter-relations between them) required to represent any collaborative situation aiming at meeting some CN's objectives using sets of capabilities provided by each involved stakeholder. This metamodel is the keystone of a model driven decision support system (under development) designing collaborative processes that can optimize the coordination of collaborative stakeholders. The metamodel expressiveness is briefly illustrated through a use-case.

Keywords: knowledge representation, collaboration modeling, metamodel, heterogeneous collaborative networks, crisis management.

1 Introduction

As a result of evolving security market needs, new societal challenges and advances in the information and communication technologies, collaboration of organizations has been significantly transformed in the last decades. In order to efficiently seize the various opportunities offered to them, entities structure themselves as collaborative networks (CN) [3] which may be composed of organizations, agencies, companies…

Those CNs can achieve objectives that no individual entity of the network can achieve on its own. Nevertheless, due to the systems of systems nature of this type of structure, new challenges have to be overcome. Indeed, involved stakeholders are often heterogeneous (at cultural, functional and technological levels) and poorly, if at all, trained to work together. This inevitably leads to critical collaboration issues (poor data management and partners' coordination for instance) that may strongly limit the efficiency of the CN's actions. In fact, it is generally quite complex to fill the gap between the willingness to collaborate to seize an opportunity and the design of an effective collaborative process to reach the targeted objectives.

The research project described in [2] aims to produce a system designing semi-automatically such collaborative processes through a model driven approach. In order to realize this system, it is necessary to (i) formalize the entire problem in such a way

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that it can be easily modelled by the CN's members and be processed by a computer at the same time. Then, it became possible to (ii) reason over this knowledge to design processes to be executed by the CN to reach its goals. The work presented here focuses on the knowledge representation formalism required to model a collaboration problem and its solutions.

The organization of this article is the following: first, a literature review highlights concepts and methods used to represent knowledge as well as related works. In the third section, a collaboration metamodel is proposed. Its expressiveness is illustrated with a use-case in the following section. Next, a concluding section suggests some perspectives for this study.

2 Literature Review

2.1 Knowledge Representation and Reasoning

Metamodelling is the keystone of knowledge representation. A metamodel is a set of concepts and rules referring to those concepts used to build models. In this work, five models are designed over the proposed metamodel: three of them depict the collaboration problem (*collaborative situation*, *objectives to achieve* and *partner's capabilities models*) and the two others refer to its solutions (*collaborative processes* and *evaluation models*).

Moreover, a metamodel can be intrinsically considerated as a model of a domain of interest. Therefore, it describes an ontology defined as "an explicit specification of a conceptualization" [5]. Consequently, it means that instances of the five previously models can be injected into an ontology thus building a knowledge base for collaboration of heterogeneous entities. Ultimately, a system such as the one mentioned in section 1 can reason on this knowledge base.

2.2 Related Work and Contribution beyond the State of the Art

Two metamodels respectively dedicated to enterprise collaboration [10] and collaborative crisis management [12] have been realized in some previous works. A collaborative metamodel (CMM) generalizing these two studies has also been proposed [8]. The metamodel presented in this article is based on this CMM and uses many of its fundamental ideas.

Main contribution of this work is taking into account new concepts leading to a metamodel with more expressive power than existing ones. Involved concepts are resources and emergent behaviours, feedbacks from past collaborations and multiple criteria decision analysis core notions [1]. Moreover, amongst all existing formalisms representing actions and their effects (see [11] for a comprehensive review), dynamic logic (DL) [6] has been adopted. Even if it is outside the scope of this paper, it is worth mentioning that as a modal logic, DL can infer more expressive statements than those used in previous works when reasoning on the collaboration's ontology.

3 Collaboration Metamodel

3.1 Metamodel Proposition

To be as generic and reusable as possible, the proposed metamodel is structured following two dimensions: layers and modules (see figure 1). One can conceptualize layers as a vertical dimension with a root layer describing relevant concepts for any form of collaboration that can be extended through domain specific layers. Modules are much more like a horizontal dimension with a core module encompassing the concepts required to describe the collaboration essence that can be extended by functional modules focusing on specific aspects of a given collaboration.

Thanks to this architecture's flexibility, one can formalize broad collaboration needs by choosing relevant modules and layers. Moreover, it is possible to extend existing modules and layers or to create new ones. The rest of this paper focuses on the root layer description. See [8] for an extension of the root layer into a domain specific layer for road crisis management.

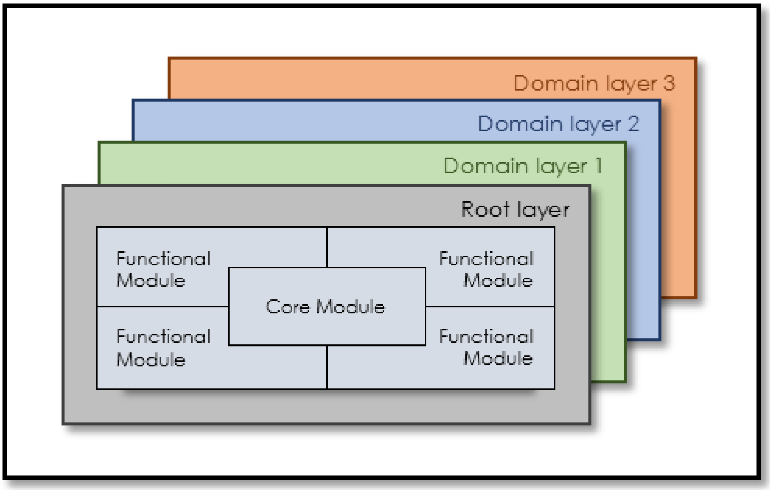

Fig. 1. Metamodel architecture

Figure 2 represents six modules of the *root layer*. *Core, situation representation* and *process modules* embed the main concepts of the metamodel as they respectively formalize the CN and its objectives, the collaborative situation and the CN's capabilities to execute in order to achieve targeted objectives from the initial situation. They are completed by the *evaluation module* describing required concepts to assess *process module* elements. *Experience feedback* and *emergent capability modules* are considerably more specific modules: one formalizes the CN's emergent behaviour and the other represents experience to be capitalized to improve future collaborations.

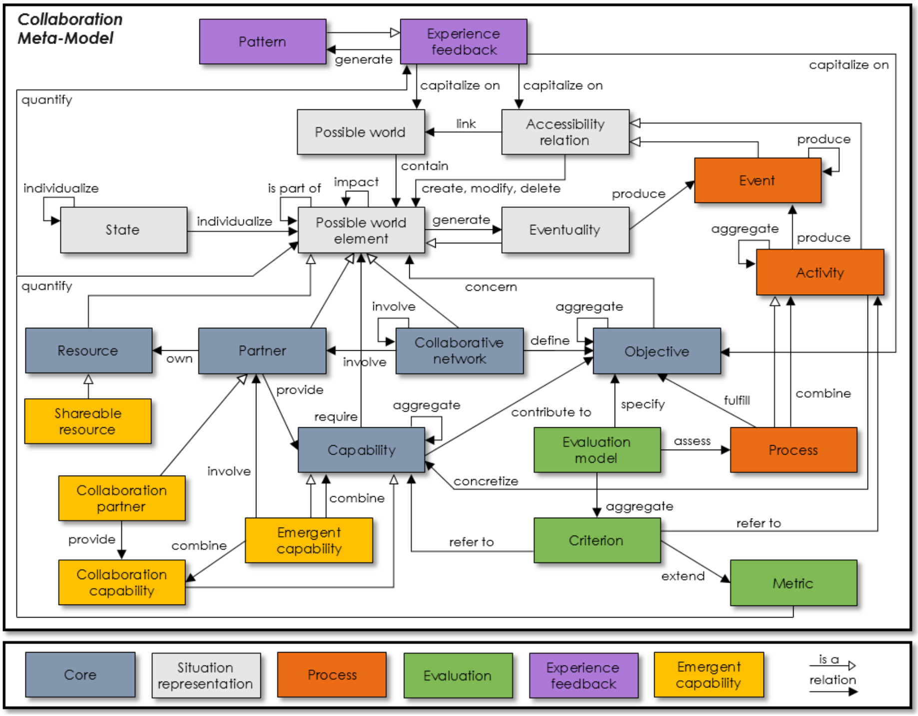

Fig. 2. Collaboration metamodel

3.2 Metamodel Glossary (sorted by module)

Capability. Both partner's ability to create, transform or delete possible world elements and availability of the resources required to concretize this ability

Collaborative Network. A set of partners collaborating to achieve an objective

Objective. Effect that a collaborative network wants to produce on a possible world

Partner. Stakeholder of a collaborative network (organization, agency, company, other collaborative network…)

Resource. Possible world element sizing the capability concretization of a partner

Accessibility Relation. Activity or event transforming a possible world into another one

Eventuality. Opportunity or threat that might impact possible world elements

Possible World. "The maximally inclusive situation encompassing all others: things, as a whole" [9]

Possible World Element. Element constituting a possible world

State. Characteristic individualizing a subset of a possible world element

Activity. Capability concretization

Event. Fact impacting possible world elements when it occurs

Process. Series of activities. Is collaborative if activities are performed by several partners

Criterion. Preference relation on a metric interpretable as a degree of satisfaction

Evaluation Model. Criteria hierarchy and its associated aggregation functions providing a score to a solution, so supporting decision-making over a set of alternatives

Metric. Variable which has a qualitative relation over its domain of definition

Experience Feedback. Capitalization of elements characterizing a collaboration

Pattern. Best practice stemming from experience feedback

Collaboration Capability. Capability of a collaboration partner

Collaboration Partner. Partner (potentially virtual) supporting the coordination of other partners

Emergent Capability. Collective capability emerging from the collaboration of several partners

Shareable Resource. Resource possibly usable by different partners, whose management by the collaborative network can be relevant according to its granularity

3.3 Metamodel Description

Core Module. Formalizes concepts required to define a collaboration: some *partners* providing *capabilities* and *resources* group together to form a *collaborative network* targeting *objectives*. Note the aggregate relation over capability allowing partners to expose their capabilities with the granularity of their choice.

Situation Representation Module. Encompasses concepts describing situations using the dynamic logic formalism. *Possible worlds* depict a static viewpoint of a situation using *possible world elements* that may be characterized through various *states*. *Eventualities* are generated by possible world elements and may impact the world if they occur. *Accessibility relation* brings a dynamic viewpoint to the model formalizing transformations of a static viewpoint (a possible world) into another one.

The paradigm underlying the design of this module is provided by the dynamic logic. In DL, a directed graph (called a Kripke frame) is generally used to describe situations. Each node of this graph (*possible world*) is characterized by the truth value of a set of propositional variables (formalized through *possible world element*). An edge (or *accessibility relation*) from a node *n1* to a node *n2* indicates that executing some defined actions in *n1* possibly or necessarily leads to the possible world *n2*.

Process Module. Describes the collaborative processes that the CN may execute to achieve its objectives. A *process* is a series of *activities* that can transform a possible world into another one. Moreover, activities may produce some *events* impacting a possible world.

Evaluation Module. Formalizes concepts required to assess collaborative processes. Some *metrics* built upon various measures quantify the process aspects that decision-makers expect to evaluate. A *criterion* is formed by coupling a utility function and a metric. Such functions indicate the degree of satisfaction associated to each metric value. Finally, the *evaluation model* is defined by combining together many criteria using an aggregation function.

Experience Feedback Module. This module describes experience feedback gathering to improve future collaborations. *Experience feedbacks* are capitalized on the situation description, the decision-makers' objectives and the process executed to achieve these objectives. Some *patterns* for an efficient collaboration may be generated from them.

Emergent Capability Module. Detail concepts used to formalize the emergent behaviour of the CN. *Collaboration partners* are special stakeholders whose role (not operational) is devoted to optimize coordination between partners. They provide *collaboration capabilities* and may be virtual such as an information system managing the CN's *shareable resources*. An *emergent capability* is a capability involving several partners that combines operational and collaboration capabilities.

4 Illustration

The metamodel expressiveness is illustrated on a use-case through two models: the *collaborative situation* (figure 3) and the *objectives to achieve* (table 1) *models*. The use-case concerns a chemical company which suffers a massive cyber-attack dealing numerous damages: (i) the reactor's sensors of a plant have been manipulated removing its self-regulation feature; (ii) an intrusion on a data-center has leaked some strategic documents; (iii) defamatory content have been added to the company website by exploiting a cross-site-scripting security breach.

The collaborative situation model contains possible world elements required to describe the parts of the company under attack (plant, reactor, sensors, datacenter, data, website) as well as other elements related to the cyber-attack (corporate identity, strategy and market value of the enterprise). Moreover, the various states of these elements are also formalized (reactor's sensors are untrustworthy, some data are leaked, datacenter and website are hacked). States implicitly subset the possible world element they refer to thus allowing reasoning over a specific part of a possible world element if necessary. Eventualities threatening the company (the reactor's explosion, additional data leaks and corporate identity degradation) are also included in the model.

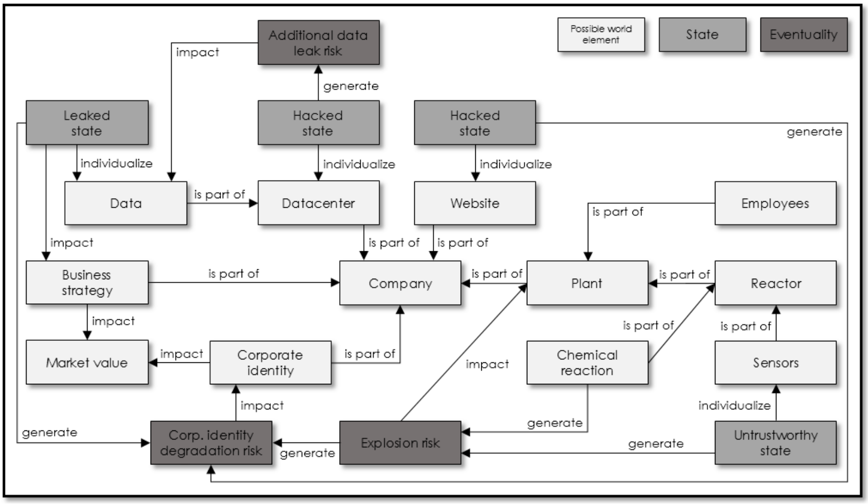

Fig. 3. Collaborative situation model

Decision-makers objectives represent effects the CN wants to produce on the world, and therefore are formalized through possible world elements.

Table 1. Objectives to achieve ranked by priority

1	Add *evacuated state* to employees
2	Remove plant's *explosion risk*
3	Remove *additional data leak risk*
4	Add *off-line state* to website
5	Remove datacenter *hacked state*
6	Add *press release* possible world element
7	Remove website *hacked* and *off-line states*
8	Remove *untrustworthy state*

5 Conclusion and Future Work

The metamodel presented throughout this article is dedicated to formalize any collaboration of heterogeneous entities with common goals. Its two-dimensional architecture (based on layers and modules) grants him a great potential of flexibility and reusability. Thanks to the root layer's modules, one can formalize the fundamental aspects of a collaboration (see *core*, *situation representation*, *process* and *evaluation modules*) as well as more specific ones (refer to *experience feedback* and *emergent capability modules*).

Future works will include conception of an axiomatic theory of collaboration based upon this metamodel, using dynamic logic and possibly benefiting from logics for cooperation and preferences [7]. This theory will transform users' inputs gathered through the proposed metamodel into a planning problem. An algorithm coupling automated planning techniques [4] and multiple criteria decision analysis [1] will be defined to design and propose collaborative processes solving this problem.

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Designing a S^2-Enterprise (Smart x Sensing) Reference Model

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Abstract. The definition of the concept of S^2-Enterprise (Smart x Sensing) reference model is presented. The S^2 Reference Model (S^2-RM) is targeted to assist in the system specification and development of future computer based systems, which support the creation of this concept. It is a hybrid reference model that includes Enterprise Integration Engineering Concepts and Interoperability models. The Reference Model for Open Distributed Processing or RM-ODP is used as the basis to define S^2-RM because it allows the definition of the structure and characteristic of the Smart and Sensing systems in terms of five different views (enterprise, information, computational, engineering and technology). The importance of using reference models for the definition, design and implementation of S^2-Enterprise systems is outlined. A pilot system has been developed using a micro-factory concept and a collaborative networked organization.

Keywords: Sensing Enterprise, Smart Enterprise, reference model, RM-ODP.

1 Introduction

Research that is currently being undertaken by several research laboratories to address issues of Enterprise integration and interoperability has been reported in [1]. The aim of all these research is to move from highly data-driven environments to a more cooperative information and knowledge-driven environment in order to design and create the concept of an enterprise, which is smart and sensing [2].

Sensing Enterprise is described as "an enterprise making use of the sensing possibilities provided by interconnected 'environments', anticipating future decisions by using multi-dimensional information captured through physical and virtual objects, and providing added value information to enhance its global context awareness" [3].

A Smart Organisation is defined by [4]: "A smart organization is understood to be both, internetworked and knowledge-driven, therefore able to adapt to new organizational challenges rapidly, and sufficiently agile to create and exploit knowledge in response to opportunities of the digital age."

Smart and Sensing systems are highly complex and the activity of coordinating and structuring their design and development necessitates the use of formal methods for their representation. The development of complex integrated and networked

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environments, such as a Smart and Sensing Enterprise, requires that system developers and the users are able to hold meaningful discussions and share a common understanding of underlying goals and ideas. The use of reference models in such complex tasks has been proven successful [5].

A key issue in the research presented here is the development of a S^2-Enterprise (Smart x Sensing) reference model to provide a framework to support the development of new integrated enterprise concepts and hence the implementation and interoperability of networked enterprises by establishing a generic set of viewpoints. Methodologies and tools are recommended to assist in the specification, development and analysis of each view (e.g. UML, Petri-nets, Artificial Hydrocarbon Networks). This will ensure that certain key issues are considered during the design of a system, and that standardized methods are used for the design and documentation of the system. In the S^2- Reference Model (S^2-RM), a combination of reference models, methodologies and computer tools have been defined, to enable to address the complexity and interoperability of such systems.

In this paper, the next section offers a general overview of reference models and their major characteristics. Section 3 describe the issues involved in the definition of the S^2-RM. Section 4 describes a pilot system that has been develop using the S^2-RM to design and create a micro-factory and a Manufacturing Collaborative Networked Organisation. Finally conclusions are proffered about the authors' experiences on the use of reference models.

2 Reference Models, Frameworks and Architectures

Reference models provide general representations of different aspects (views) of a system, for example [6]: Function, Information, Resources and Organization (CIMOSA); Safety, Environment, Compatibility, Performance, Operability, Maintainability, Reliability, Qualifications and Description (ISO/TR 101314-1: 1990); Enterprise, Information, Computational, Engineering and Technology (RM-ODP). These representations can be referenced to assist in the development of a system during various stages of its life cycle (e.g. requirements, design, implementation, operation, decommission).

A reference model must be [7]:

1. Structured: based on readily available and acceptable terminology, methodologies or standards.
2. Flexible: able to be applied to wide range of systems within its domain of applicability and at different stages of the system life cycle.
3. Generic: independent of any existing implementation.
4. Modular: open-ended in its ability to be extended in order to incorporate new concepts and technologies.

In Manufacturing, reference frameworks and architectures used for developing information systems have been based on concepts delineated above. The terms framework and architecture have been used ambiguously within the manufacturing domain to denote reference models that assist in the development of an information system during different phases of, or throughout, the complete life cycle.

The Reference Model for S^2-Enterprise presented in this paper is based on the framework concept defined by [7] which describes a representation of characterized situation types that occur during an information system life cycle for enterprise integration. Enterprise in the context of this research is also a Collaborative Networked Organization (CNO) as described by [8]. Therefore the reference model could be used and applied in the creation of Smart and Sensing Collaborative Networked Organizations.

3 A Reference Model for S^2-Enterprise (Smart x Sensing)

The authors believe that a Reference Model for S^2-Enterprise (Smart x Sensing) should assist the users and developers in the following three tasks:

1. Identify the Enterprise requirements to support the concepts of Smart an Sensing Enterprise
2. Guide the design and implementation of the enterprise system itself.
3. Organize the process of implementation (people, methods and tools) to evolve the Smart and Sensing system towards the desired level of integration and automation.

The research into the development of a reference model for S^2-Enterprise has embraced issues related to distribution and sharing of information, integration of application by means of networking and multimedia environments, incorporation of new paradigms (Smart and Sensing), use of standards languages and modelling techniques, and the provision of services for co-ordination and collaboration. These systems are open in nature to allow the incorporation of a wide range of technologies, and distributed, to enable the interaction among remotely located people.

3.1 The Rationale of S^2-RM Based on RM-ODP

A well-documented standard related to these issues is the one concerned with open distributed systems, known as the Reference Model for Open Distributed Processing or RM-ODP [9]. This reference model was chosen to describe, design and implement the S^2-Enterprise concepts, due to the fact that the RM-ODP allows to represent an open and distributed information system from different viewpoints: Enterprise, Information, Computation, Engineering and Technology. Each viewpoint represents a specific aspect of the S^2-Enterprise and system at any required level of detail. Therefore the use of the RM-ODP views allows a complex system to be described from a number of perspectives (see Figure 1).

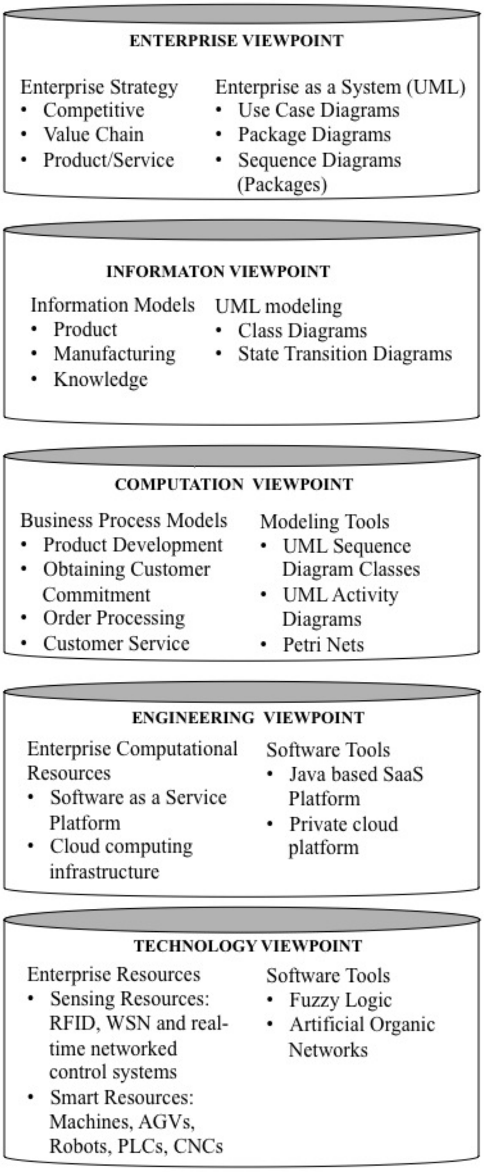

Fig. 1. S^2- Enterprise Reference Model (Smart x Sensing)

The S^2-Enterprise Reference Model (S^2- RM) enables the successful support the tasks defined above i.e. identification of requirements and guidelines for system development. However, the organization and management of the timely incorporation of people, methods and tools to evolve a Smart and Sensing environment towards the desired level of integration and automation requires further definitions at the different levels of integration, therefore models such as Petri Nets [10], Interoperability systems and control systems such as SaaS [11] are used.

The S^2-RM aims to support the development of existing and new systems by establishing a generic set of viewpoints that should be used to analyse any such system. Each viewpoint is represented by a view in the reference model. A view depicts the system from a known perspective. Methodologies and tools are recommended to assist in the specification, development and analysis of each view. This will ensure that certain key issues are considered during the design of a system and that standardised methods are used for the design and documentation of the system, hence enabling the comparison of different integrated and interoperable systems at different levels of abstraction.

The use of S^2-RM enables the generic structures and characteristics of systems to be compared. The reference model facilitates comparison by providing a standard representation format for system structure and characteristics. The measures against which the systems are compared are still in the domain of the comparator and have not been included in the reference model structure. This is because each user group will have a different specification for a Smart and Sensing system that best suits their needs and priorities e.g. a requirements definition model. Using this model as a driver the S^2-RM allows a system designer to select from a range of concepts the ones that most adequately fulfil their need and then for the system developer to be guided to the tools and methodologies that will most helpfully assist the integration of elements that realise the concepts.

The S^2-RM has been used to represent two distinct levels of system design i.e. concept and implementation. At the conceptual level the generic building blocks of systems are defined using UML [12]. It is possible that, depending on the requirements made of it; a given system may not require all the concepts that are modelled. This is perfectly reasonable as one of the key aims of the model is to provide a comprehensible representation that aids the description, understanding and discussion of system solutions with developers and users. It is also possible that a viewpoint may exist that is not adequately reflected in the current structure of the reference model. The modular nature of the reference model enables different viewpoints to be included as and when they become appropriate. At present the viewpoints are treated as distinct elements that can be considered independently. The reference model needs to be extended to map the relationships between the viewpoints more completely. This will improve the clarity of the reference model concept and its use.

At the implementation stage of a system the S^2-RM is useful because it defines the boundaries between software and hardware interfaces, the relationships between them, and it specifies the tools that should be used for the modelling of these elements. Wherever possible international standards have been followed in order to promote standardisation.

The reference model that is under development is designed to be applicable to smart and sensing systems. Many of the concepts can be applied to a reference model for any open, distributed computing system, however, the incorporation of the conceptual building blocks defines the specialisation e.g. product model, manufacturing model, integration environment, etc. By altering these building blocks the reference model could be adapted to suit a wide range of domains.

The definition of the S^2-RM is independent of vendor software and hardware systems. The reference model is a general description, which is acceptable to both users and developers. It is based on the principal that the whole function of Smart and Sensing systems can be represented in totality by a series of models, each representing one particular viewpoint. Instances of the S^2-RM would represent real systems.

Therefore the Reference Model can be used to define, design and create a Smart and Sensing Enterprise by defining the different levels for Enterprise requirements (UML), information/knowledge models (UML), computational interactions among all process and systems Petri Nets, infrastructure required to support distribution (Interoperation, Integration, communication protocols – SaaS platform) and Technology - RFID, WSN – Wireless Sensors Networks/Mobile Devices/Virtual Technologies.

3.2 The S^2-RM: Models, Methodologies and Tools

The S^2-RM is a five level model that is intended to represent open distributed systems (Figure 2). To achieve this, the following five levels have been defined based on the RM-ODP: Enterprise, Information, Computation, Engineering, and Technology.

The Enterprise Viewpoint is associated with the specification of requirements for ODP systems. Nevertheless, the scope of the information described, and the level of detail contained in the Enterprise View remains a point of debate. There are two main schools of thought regarding what the Enterprise viewpoint should represent. These are to:

1. Represent a model of the organisational environment, in terms of engineering functions and the relationships between them, in which Smart and Sensing systems could be used
2. Represent the functional capability of Smart and Sensing system concepts

In order to define a more flexible S^2-RM, the authors have agreed, to represent at the Enterprise Viewpoint the functionality that Smart and Sensing Enterprise is intended to achieve. In this research Enterprise also means a Virtual Networked Organization. Therefore, the Enterprise View is modelled using the EIE Framework and toolbox defined in [13] to describe strategies (competitive, value-chain, production/service), extended/virtual enterprises models and business performance measures. For the case of Collaborative Networked Organizations the concept of the Virtual Enterprise Broker is used at this level to design the type of CNO to be designed and created [14]. Also UML modelling is used to support a formal representation: User case diagrams, Package Diagrams, and Sequence Diagrams (Packages).

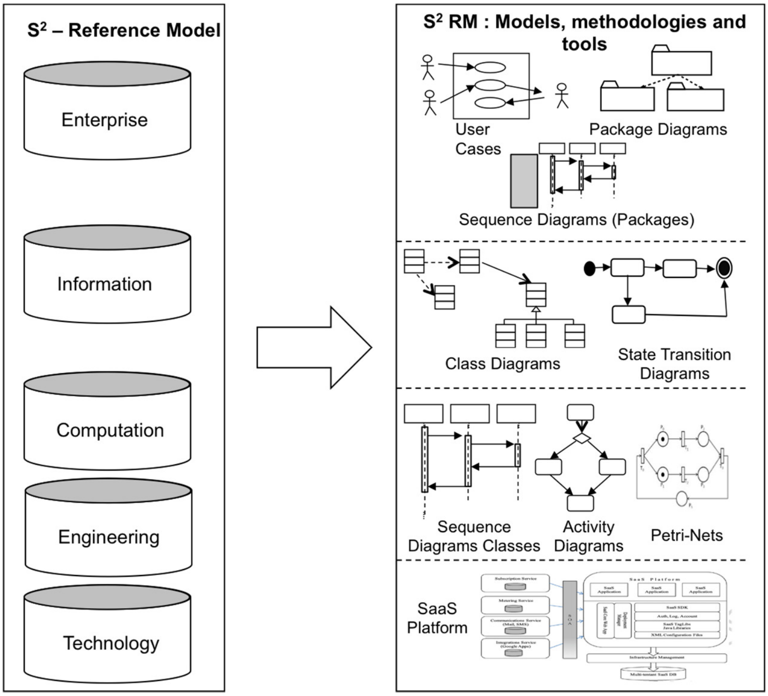

Fig. 2. S^2- reference model: Models, methodologies and tools

The Information Viewpoint focuses on describing the semantics of information and information processing functions in the system. Three information models are required in an Enterprise to describe all information and knowledge namely: Product, Manufacturing and Knowledge models [15]. In the S^2-RM this viewpoint is defined via a combination of UML descriptions of class diagrams and activity diagrams. This combination of models allows the description of the information flows together with the structure of the information elements, their relationships and quality attributes.

The Computational Viewpoint focuses on the representation of the functional decomposition of the system into objects, the activities that occur within those objects and the interactions between the objects. This level represents the Core Business Process (New Product Development, Obtaining Customer Commitment, Order Processing, Customer Service). Therefore UML (Sequence Diagram Classes, Activity Diagrams) and Petri Nets are used to model this this view.

The Engineering Viewpoint focuses on the infrastructure required to support distribution and interoperability. This view enables the specification of the processing, storage and communication functions required to implement the system PyME CREATIVA (Software as a Service Platform – Cloud Computing Infrastructure) and Software tools (Java based SaaS Platform and Private cloud platform), for more detail [16, 17].

Finally, the Technological Viewpoint focuses on the selection of the necessary technology to support the system. In this research the technologies for sensing resources used are RFID, WSN and Real-time networked systems [18]. For smart resources: Machines, AGVs, Robots, PLCs, CNCs with Intelligent Control systems based on Fuzzy logic and Artificial Organic Networks [19, 20].

The top levels of the reference model (enterprise, information and computation) are non-software specific and so they provide a base level description for system development. Although the S^2-RM allows the thorough description of a Smart and Sensing system from different views.

4 Pilot Demonstrations

Pilot demonstrations of a S^2 - Micro Factory / S^2 - Collaborative Networked Organization (CNO) have been developed using the S^2-RM to corroborate how the reference model can guide the design and implementation of a Smart and Sensing systems (Figure 3). The micro factory may be used to produce work parts based on machining parts. The CNO for manufacturing additional to machining process capacities, it has an entity (Virtual Enterprise Broker) which executes the process of Marketing, Product Development and Logistics.

4.1 Scenario 1: Micro – Factory (Make to Order)

A MTO Micro-Factory has been designed to produce machining components that are produced based on a product catalogue. The strategy for this facility is Operation Excellence where manufacturing should be executed in minimum time and cost. It also is organized as a Strategic Business Unit with all its operations embedded in one business entity and factory. Information models used to operate the Micro-Factory are Product, Manufacturing and Knowledge Model.

The product model is a catalogue of products that can be manufactured in this facility. Descriptions of all the products that can be manufactured in the catalogue are presented in e-marketing page.

The Manufacturing Model includes manufacturing resources and processes that can be performed with these resources. The detailed list of micro factory resources is: two mechanical kit (RmMT assembly); two storage spaces (store raw materials and finished products); two spindle (NAKANISHI AM-300 R); two air pressure regulator (NSK Air Line Kit AL-0201); two air control (NAKANISHI E2530); two linear actuator clamp (Firgelli PQ-12. 25 mm); six lineal actuator axes (PI M-111.2DG); two assembly toolkit (screwdrivers, wrenches, hoses, cables); one compressor (Truper 21/2 hp); one work station (UNC); three cutting toolkit (drills, cutters, polishers); one robotic arm with two metal gear motors, three servo motors, two kit encoder, one proto-board; and one acquisition card (PIO-D48U). Wireless sensors networks are used to sense vibration/noise/movement in the Micro-Factory, also RFID to track products has been implemented.

The Knowledge model includes strategies, procedures and rules to operate the facility. Also Fuzzy Logic and Artificial Organic Networks are used to implement intelligent control and automation algorithms. The core process to be executed at this factory is Order Processing that allows the customer to order any product in the catalogue.

PyME CREATIVA software enables the operation of the facility with the following e-services: e-marketing, e-brokerage, e-supply and e-productivity. PyME CREATIVA runs on the SaaS platform [21].

4.2 Scenario 2: Collaborative Networked Organization (Build to Order)

The manufacturing CNO has been implemented to satisfy the Build to Order paradigm with a mass customization strategy. Key performance measures for this model are time to respond and customer satisfaction. A pilot case of multiple sites of manufacturing facilities has been created to demonstrate the concept of a Virtual Enterprise Broker and Manufacturing Collaborative Network of manufacturing competencies. The CNO is configured of three manufacturing facilities (drilling, turning, milling), and a Virtual Enterprise Broker to execute product development, logistics, assembly and quality assurance processes [14]. The level of customization is implied in terms of time to deliver, volume, and configuration options. The Broker model works in a collaborative way with the customer; the customization will be measured as the capacity to respond to customer requests i.e. Customer Satisfaction.

The Virtual Enterprise Broker (Broker) is responsible for searching business opportunities and enabling the creation of Virtual Enterprises. In this scenario a Virtual Enterprise is the network of manufacturing facilities that will be required to produce a customized product. The Virtual Enterprise Broker performs the processes of partner search and partner selection, and configures suitable infrastructures for Virtual Enterprise formation/commitment i.e. physical, legal, social/cultural, and information. To achieve its goal the Virtual Enterprise Broker is supported by the services provided by the manufacturing facilities. The Broker model allows achieving Build To Order (BTO) strategies through the aggregation the manufacturing capacities and capabilities of each of the different facilities in the network. This aggregation of capabilities together with the core process of the Broker as an entity reaches the BTO flexibility required, and makes an adaptable model that can be applied to different kinds of companies and industries.

The activities of the broker include searching and selecting business opportunities and partners, developing products, logistics, and quality assurance to ensure that the final product is delivery to the customer. While on the other hand, the activities of the facilities are related to the manufacturing capabilities necessary for the manufacturing of the final product.

The core processes of the Broker are supported by the use of PyME CREATIVA in terms of e-services. Some of the e-services that support the operations are [16, 21]:

- e-Marketing intelligent web-portals for promotion of products and services of each member of the CNO and integrates a unique catalogue of products.
- e-Brokerage integrates software to enable the selection, evaluation and configuration of manufacturing facilities to produce an specific product.
- e-Supply integrates services related to e-factory, e-logistics for importing/exporting materials and products, ERPs, supply chain management and manufacturing execution systems.
- e-Productivity integrates technologies for the diagnosis, planning, evaluation and monitoring of manufacturing facilities.

All these e-services support the collaboration activities among all the facilities in the manufacturing network.

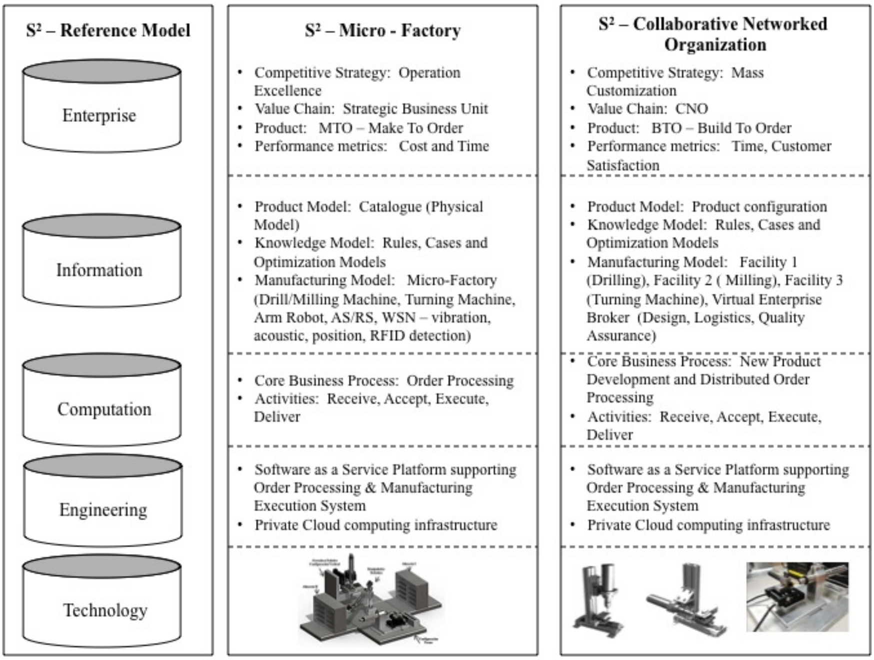

Fig. 3. S^2- Scenarios: Micro-Factory and Collaborative Networked Organization

5 Conclusions

In summary, this paper highlights the importance of using reference models for the definition, design and implementation of Smart and Sensing systems. The use of such reference models within modelling frameworks is being explored. A reference model for S^2-Enterprise has been defined to guide the design and creation of Smart and Sensing Enterprises. The reason for the choice of the RM-ODP has been explained.

Two pilot cases using a micro-factory and Collaborative Networked Organization have been created to demonstrate the use of the S^2- Reference Model

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Collaborative Systems in Crisis Management: A Proposal for a Conceptual Framework

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Abstract. This article aims at presenting a three-dimensional framework dedicated to structure the domain of crisis management. The approach is based on a formalized vision of crisis (the danger / risk / consequence chain) that is used to define the *what*, *when* and *where* of crisis management. These three basic questions allow describing the management, time (life cycle) and localization dimensions of crisis management. The obtained framework is also compared with a simple vision of collaborative networks (the information / function / process interweaving) to identify some requirements and expectations for collaborative networks in crisis management context. Furthermore, this very "static" framework is also exposed in a "dynamic" manner to support agility of collaborative network in crisis management.

Keywords: Framework, Crisis management, Collaborative network, Conceptualization.

1 Introduction

The word "crisis" comes from the old Greek word "krisis" (κρίσις), which refers to the notions of "judgment" and "decision". There are a lot of definitions for the concept of crisis [1, 2]. These definitions can be studied to suggest the following one: *a state of a system, which reveals instability and discontinuity and which requires a specific treatment to deal with the unwanted consequences and to obtain a new acceptable state of the considered system*.

Crisis management directly refers to the mentioned treatment in the previous definition and can be defined as: *the governance mode that is applied to bring the system from the crisis state to a (potentially new) stable and acceptable state*.

Anyway, crisis management is a very complex domain with a lot of constraints, points of view and heterogeneous aspects to take into account. Consequently, it is very difficult to get a global overview of such a domain. This article is mainly dedicated to present a framework for crisis management. The initial questions are the followings: how to define such a framework? What should be the significant elements to take into account? What are the points of view and dimensions that should be considered to structure this framework?

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 396–405, 2014.

Obviously, the framework presented in this article does not claim nor to be the optimal one, neither to be able to fit absolutely all cases of crisis situations. However, the overall objective is to be covering of the crisis management field as much as possible and after all also to be partially usable (some crisis situations might be characterized only according to one or two of the proposed dimensions). The proposed framework, not so far from FTA (Fault Tree Analysis) principles [3], is based on the following concepts chain: *Danger / Risk / Consequence*. Furthermore, Danger, Risk and Consequences may be considered as causal sources (in a waterfall structure) that must be formalized as models to help decisions makers (close to models/decision graphs).

This article is structured according to the following sections. In section 2, an overall vision of *crisis* is presented in order to initiate and legitimate the framework description process. In section 3, the three-dimensional crisis management framework is presented. In section 4, the consequences of such a framework for collaborative network are studied. In section 5, elements regarding dynamicity of crisis management are also introduced (especially to deal with the question of agility). Finally, a conclusion describes some perspectives and ways to exploit this framework.

2 Main Concepts of Crisis Management

2.1 Crisis Primary Modeling

Schematically, and in a "reverse" mode, crisis may be seen as a set of *negative facts* (presented as *consequence* in the following picture). Each of these *negative facts* is due to one (or several) *event*(s) that trigger(s) one (or several) *risk*(s). This (or these) *risk*(s) occur(s) because the considered area/system is concerned by one (or several) *danger*(s) that affect(s) one (or several) *stake*(s).

Figure 1 presents this *danger (and stake) / risk (and event) / consequence* chain:

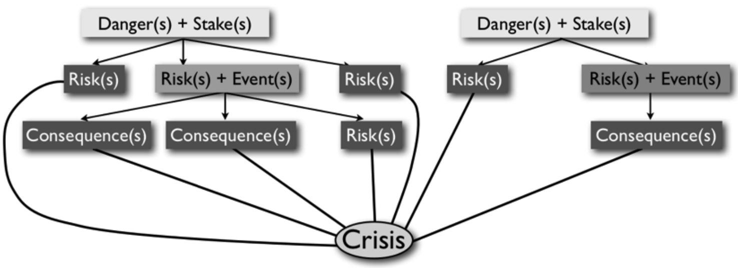

Fig. 1. Danger/Risk/Consequence chain for crisis description

In this schema, *danger* is a characteristic of the considered system while *risk* is a potential manifestation of this *danger* regarding some concerned *stakes*. If one *risk* might occur it would be due to some *events*. The following picture illustrates this:

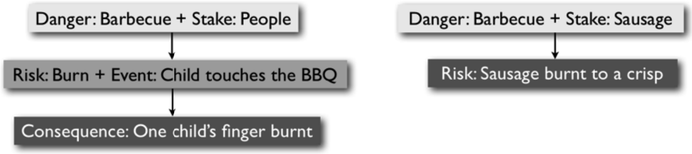

Fig. 2. A first illustration of the Danger/Risk/Consequence chain for crisis description

Cooking with a Barbecue is a *danger* for two main *stakes*: people around (the *risk* is that they could be burnt) and the meat (the *risk* is that it could be badly cooked). The next figure also illustrates this general schema by providing a simple vision of the Fukushima crisis:

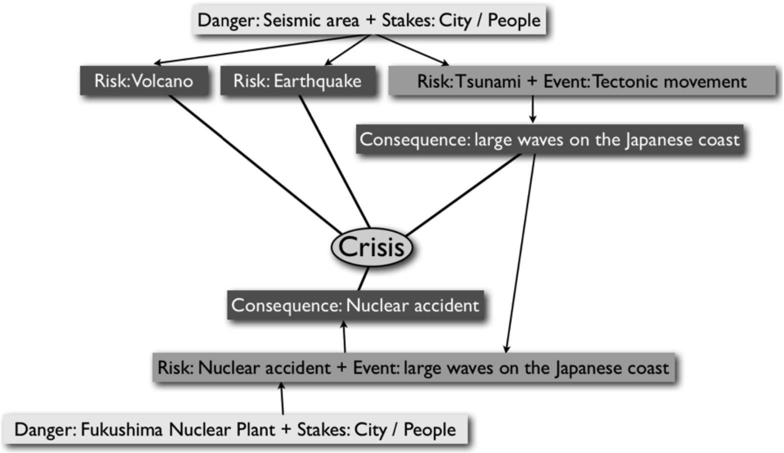

Fig. 3. A second illustration of the Danger/Risk/Consequence chain for crisis description

One main element of this illustration is the fact that *event* might be due to a *consequence* or even a *risk*: a *consequence* is an *event* by nature and the appearance of a new *risk* is also an *event*. One *danger* in Japan is that the local area is a seismic area that can affect *stakes* (such as people, goods, city, natural sites, etc.).

The *risks* are volcanic eruptions, earthquakes and tsunamis. Concerning the Fukushima crisis, the tsunami risk occurs due to a specific *event* (tectonic movement).

The *consequence* was large waves hitting the Japanese coast. This *consequence* was also an *event* that triggers the *risk* of nuclear accident on the Fukushima Daiichi nuclear plant.

Obviously, the previous model could be really more detailed considering the failure of the cooling process of the nuclear reactor as a *consequence* (and also an event), considering also the *risks* of fusion, explosion, etc. That shows how this general principle might be considered according to different granularity levels (in a fractal mechanism).

It is also to be mentioned that *risk* is often considered as a *probability*. This is compliant with the previous model: *risks* are presented in the model only if the *probability* of their occurrence is significant (*i.e.* not too low). Besides, *risks* are also often evaluated through the *probability* x *gravity* matrix. This is also compliant with the presented model as far as *gravity* is assessed thanks to *stakes*.

2.2 Consequences of Such a Model for Crisis Management

Considering the previous simple model for crisis and also the definition of crisis management (*i.e.* the governance mode), it appears that crisis management requires dealing with risks and consequences. The main goal is to prevent existing risks and to treat existing consequences. Existing risks might have been identified before the crisis itself or might have appeared due to some events during the crisis. Similarly, consequences might be the concretization of risks existing before the crisis, or appeared during the crisis.

These considerations will be used in the remainder of this article to refine a very classical three-dimensional approach: crisis management may be considered according to: *what?* (What are the management types/levels to consider?), *when?* (What are the different steps/phases/times of crisis management?), and *where?* (What are the concerned physical areas/perimeters?).

3 A Framework Proposal

3.1 The Management Dimension

The main statement for this first dimension of crisis management is that crisis management requires:

- *Decisions* to deal with the objectives to reach (mainly risks to prevent and consequences to treat).
- *Actions* to perform risk prevention or consequence treatment according to decisions.
- *Resources* to support actions.

Consequently, the management dimension can be considered according to standards from industrial world [4], which describe three abstraction levels for processes cartography: *decisional*, *operational* and *support*. Nevertheless, this structure might be questionable as far as crisis management, as a very critical context, could be slow down by this formal structure. However, it is also noticeable that a lot of organizations (even military ones) are nowadays using this structuration levels to organize their management.

The management dimension of the framework includes three levels:

1. Decisional level: dealing with strategy and choices to make. This dimension embeds the classical "operational" (different from the next "operational" level of point 2), "tactical" and "strategic" horizons of decision-makers.

2. Operational (or Realization) level: dealing with concrete actions dedicated to prevent a risk or to treat a consequence.
3. Support level: dealing with resource management, supply chain and all the second order processes.

3.2 The Time Dimension

According to the *Danger/Risk/Consequence* chain and the main objectives (*risk* prevention and *consequence* treatment), crisis management includes, on a given system (area, perimeter, world, etc.):

1. *Before the beginning of any crisis:* (i) Listing all the risks due to the dangers inherent in the consider system and define preventive actions (actions that prevent the risk occurrence) and curative actions (actions which deal with its consequences if it occurs), (ii) applying the defined preventive actions while there is no crisis (to prevent any crisis).
2. *If a crisis occurs:* (i) Applying the defined curative actions (to deal with the actual problems) and still preventive actions (to try to prevent any aggravation of the situation), (ii) and defining on-the-fly new actions adapted to potentially emerging unknown risks or consequences.

This is very compliant with the classical phases of crisis managements as described in [5–7] :

1. *Prevention* (improving the system vulnerability): this phase is to be linked with the previous point (1.i).
2. *Preparation* (organizing the system in case of expected negative events): linked with point (1.ii).
3. *Response* (steering of the response system): linked with points (2.i) and (2.ii).
4. Recovery (research for a stable state and capitalization): this phase is complementary to the previous ones and concerns the (often very long) time required to bring the system into a satisfying state (on various points of view such as political, economical, social, etc.).

3.3 The Localization Dimension

This last dimension is more obvious: there are *crisis site(s)* (on the field where the *risks* and *consequences* might be localized) and the *crisis cell(s)*. *Crisis site* is a sub-part of the world impacted by the crisis situation (*i.e.* the geographical perimeter containing people, goods, or any other staked affected by the crisis). *Crisis cell* is the command center where is performed the “high level/granularity” crisis management.

The crisis cell may be distributed horizontally (for geographical reasons) or vertically (for hierarchical reasons). Obviously, *operational* and *support* processes concern the *crisis site(s)* but a lot of the decisions (not all the decisions but, depending on the considered crisis, most of them) are taken in *crisis cell(s)* (including decisions regarding *operational* or support actions).

Consequently, these two crisis management poles (crisis cell and crisis site), even if potentially divided into several sub-poles (multi-sites or dedicated cells) are connected with each other: instructions are "going down" from the *crisis cell(s)* while reports are "going up" from the *crisis site(s)*. Therefore, even if the localization dimension might be considered as a continuous one, it can definitely be discretized according to the three following levels:

1. The level of *crisis cell(s)*, which concerns actions and exchanges inside a *crisis cell* or between *crisis cells*.
2. The level of *interaction between crisis cells and crisis sites*, which concerns the exchange modes between the *crisis cells* and the *crisis sites*.
3. The level of *crisis site(s)*, which concerns actions and exchanges between partners on the crisis field.

3.4 Graphical Representation of the Proposal of a Crisis Management Framework

The following picture presents a graphical vision of this framework:

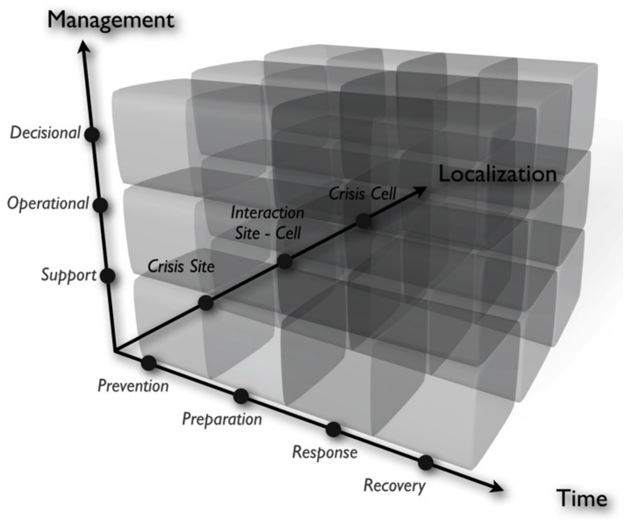

Fig. 4. A three-dimensional framework for crisis management

4 The Crisis Management Framework and Collaborative Networks

The ability to define and set an efficient collaborative network, in the context of crisis management, is one of the key factors of success to help the stakeholders to solve (or at least reduce) the crisis situation [8]. Mainly, collaborative networks, established through the ISs of the collaborative partners, are in charge of three main functions [9]:

- *Information* management: Based on *data* storage, transformation and exchange but also knowledge extraction from data.
- *Function* sharing: Based on identification and invocation of *service*, *software* and *application* including *interfaces* for human tasks.
- *Process* orchestration: Based on *workflow* execution and monitoring.

This simple vision of collaborative networks allows projecting this model of collaborative networks into the crisis management framework in order to extract requirements and expectations for collaborative networks in crisis management context.

By considering the Information / Functions / Processes vision of collaborative networks in the three-dimensional framework of crisis management, it is feasible to identify a set of specific requirements. The following table presents some of these requirements:

Table 1. Collaborative networks requirements extracted from the framework

Dimensions	Levels	Requirements for Crisis Management collaborative networks
Management	Decisional	Appropriate circulation and movement of data
	Operational	Orchestration of processes must be relevant
	Support	Functions must be available (depending on resources)
Time	Prevention	N/A
	Preparation	Configuration: identification of functions and information (mainly as inputs and outputs of functions) + partial definition of processes (patterns and plans)
	Response	Run-Time: final definition of processes depending on the specificities of the considered crisis and non-functional requirements (availability, reliability, etc.)
	Recovery	Capitalization and continual improvement
Localization	Crisis site(s)	Multi-devices and material requirement (robustness, MMI, etc.)
	Interaction Site-Cell	Network and telecom efficiency
	Crisis cell(s)	Interoperability and integration with existing tools

These requirements show that the establishment of a relevant collaborative network in crisis management is dependent on the localization of the specific situation into the crisis management framework. For instance, the following cases show how requirements may be extracted from table 1 according to the specificities of the considered crisis situation:

- In the case of the collaborative network of decision makers in the crisis cell in charge of the strategic aspects, it is required that (i) information could circulate easily (especially on an organizational point of view, *i.e.* actors agree on sharing the knowledge they collect from the field), (ii) the collaborative behavior should be well defined in order to orchestrate the collaborative situation (according to the situation and expected performances) and (iii) partners IS should be interoperable and efficiently connected.
- In the case of preparing actors to work altogether and deploy their operational competencies during training sessions of crisis situation (through exercise for example), it is required that the collaborative network provides (i) clear and identified individual capabilities of actors, (ii) availability of these capabilities and the associated resources and (iii) patterns or schemas of processes that can be tested to demonstrate how some elementary objectives could be achieved by using the available capabilities.

5 Dynamic Aspect of Crisis Management within the Framework

Regarding the previously presented framework, it is obvious that crisis management should be considered as covering several (and potentially all) areas of the 3D cube. Resources and stakeholders should be evaluated and trained during preparation phase, the crisis should be driven according to the decisional, operational and support levels, etc. Consequently, crisis management must move inside the framework (in position, in shape and in size), just like a protean structure inside the 3D cube. This is a way to show how agility of crisis management can be represented on a tangible and physical point of view.

Agility is a crucial concept in a collaborative situation such as crisis management. [10] draws the line between this concept and reactivity, flexibility and adaptability. There are four main aspects to this vision: the system must be able to change its structure (*flexibility*) according to a relevant understanding of the situation (*analysis)* and its requirements (*efficiency*) and this should be done in a hurry (*reactiveness*). In the context of this article, these four facets of *agility* have also been considered according to two orders: first order represents the main components of agility while second order concerns the features of these main components. Consequently, agility has been defined, on first order, as the capacity of a system to (i) *detect* any (potentially unexpected) situation that requires the system to change and (ii) *adapt* its global structure/behaviour to that situation. Regarding second order, two other attributes may be considered: first, the *dynamicity* of agility might be crucial (performing *detection* and *adaptation* too slowly may disrupt agility) and secondly, the *relevance* of the *detection* and *adaptation* may also be critical (wrong *detection* and *adaptation* could be fatal for the significance of agility). Consequently, this vision may be simply and roughly formulated as:

Agility* = *(Detection* + *Adaptation) × *(Reactiveness* + *Efficiency).*

Such a formula [11], although not scientific at all, is a structuring scheme that allows the study of agility to be partitioned according to these three properties. Finally, *detection* and *adaptation* may be considered as the main attributes of *agility* while *reactiveness* and *efficiency* are the attributes of *detection* and *adaptation* (second order).

Based on this definition, agility in crisis management may be considered as the ability of the treatment collaborative network to *detect* any change (*i.e.* the next relevant position inside the framework) and to *adapt* the management (*i.e.* to make the management move to that next position). Considering also the *danger / risk / consequence* chain (including the fact that risks and consequences are treated through response processes and activities), this vision of agility could also include the necessity to detect:

1. If the crisis situation (or the perception of the situation) has changed (new risk or new consequence).
2. If the crisis situation is still the same but the collaborative network has changed (new resources, unavailability of a partner, etc.) that is to say activities or processes are not available any more or could be improved.
3. If the crisis situation and the collaborative network are unchanged but an activity or a process did not perform efficiently.

The presented crisis management framework and the *danger / risk / consequence* chain finally allow to refine the concept of agility into the three previous cases that significantly reduce the issue of agility management in crisis situation.

6 Conclusion

The presented framework might be considered as a formalizing reference table dedicated to support the understanding of crisis management (or any correlated concept). The main uses may be the following: connecting research works that belong to the same location in the framework, identifying scientific or technical needs for a crisis management support system (potentially IS) according to the location in the framework.

This framework is compliant with the *danger / risk / consequence* chain that also help to formalize the knowledge in crisis contexts. The next promising exploitation of these guidelines for knowledge management in crisis managements is the design of knowledge bases and deduction rules to manage data and information coming from the crisis situation, in order to deal with the crisis response and the agility of that response. Besides, the question of granularity levels in the various dimensions of the framework is also a promising issue: scale up / scale down for users, aggregation and split of information in the decision frame, etc.

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Conceptual Reference Model for Virtual Factory: Potentials for Collaborative Business

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Abstract. The concept of combining the power of several independent factories to achieve complex manufacturing processes as so-called virtual manufacturing enterprises is not new and has been addressed by several research projects in recent years. However, there is still a need for adequate methodological support and tools for modelling, structuring and controlling of the next generation of manufacturing systems, such as the virtual factory. In this research, a conceptual virtual factory reference model is presented with the goal to provide companies with general guidelines to manage and monitor the business processes that are needed to create, execute, and dissolve a virtual factory. The virtual factory reference model was built taking into account industrial's requirements and by reviewing the literature in several relevant fields of research such as collaborative networks, supply networks, manufacturing networks, supply chain management, and business processes. Afterwards, it has been validated through its application to future virtual factories of three different industrial sectors: machinery, energy, and semiconductor.

Keywords: Virtual factory, collaborative business processes, small and medium enterprises (SMEs), reference model.

1 Introduction

The Virtual Factory is a temporary strategic alliance of factories from multiple companies that work together towards developing and bringing to the market innovative products [1]. Its coordinator, the Virtual Factory Broker, has to align processes among partners and ensure that every partner is working towards the same strategic objectives [3]. Although various forms of business networks exist among the manufacturing community nowadays, methodologies to form and execute such virtual networks are still scarce. A need for strong methodological support and processes for modelling, structuring and control of the virtual manufacturing system is recognized. The present paper addresses this research gap by offering the necessary guideline for companies to start up their virtual factory collaboration.

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The conceptual virtual factory reference model proposed in this research is a process framework to structure how work is accomplished and monitored among partners and is therefore a very useful tool for the individual enterprises to set up and operate a virtual factory of a dynamic and inter-enterprise network for complex product manufacturing. The presented model highlights a framework for collaborative design and operations of network manufacturing systems. It consists of business processes for virtual factories and is organized in the four phases needed to run a virtual factory – Join, Plug, Play and Dissolve. This model is used to formulate the business processes harmoniously with each other. The fact is that it supports distributed value chain mapping among collaborative companies.

2 Virtual Factory: A Way Out for Collaborative Business

Several frameworks for Virtual collaborations among SMEs were developed in order to address network collaboration and to support companies, mostly SMEs in the successful formation and operation of Virtual Factories. In 2007, Camarinha-Matos and Afsarmanesh developed the ARCON (A Reference model for Collaborative Networks) modeling framework to provide a model that can be instantiated to capture the definitions of all potential Collaborative Networked Organizations (CNOs) [2]. This framework also supports the co-working and co-development among the stakeholders and provides the high level base for design and building of the architectural specifications of modular CNO components. In 2009, Romero and Molina developed an Integral Business Process Management (I-BPM) framework with the view to explain a set of process models that depict what happens during each VBE (Virtual Organization Breeding Environment) and VO management processes [3].

Romero and Molina [7] presented a model-based VBE reference model that focuses on providing a comprehensive overview of the key elements/components of a breeding environment and the main requirements to create and manage VO during its entire lifecycle. Shamsuzzoha et al. [8] (2010) provided an implementation framework for business collaboration within a non-hierarchical business network that supports the logical approaches of the formation and operation of a business network. In 2010, Boukadi et al. [9] proposed a framework for meeting the flexibility and agility of requirements for collaborative business using a multi-layer approach. Chituc et al. [10] proposed a conceptual framework towards seamless interoperability in a collaborative networked environment following a service-oriented approach.

This literature shows that several conceptual frameworks have been already developed to support collaborative networked organizations; however these lack on completeness and fail to provide empirical evidence for their functioning. In this research, we were able to create a comprehensive reference model taking into account industrial's requirements and by reviewing various streams of literature: collaborative networks, supply networks, manufacturing networks, supply chain management, and business processes. Furthermore, empirical validation was gathered for this holistic approach in three different industrial sectors namely, machinery, energy and semi-conductor.

3 Research Methodology

In order to identify a comprehensive list of business processes needed for the creation, execution and dissolution of virtual factories, several fields of research were considered: collaborative networks, supply networks, manufacturing networks; supply chain management, and business processes. Table 1 summarizes the results of the literature review and provides an overview of the high-level processes of the virtual factory reference model.

The reference model was validated and refined by means of hands-on workshops with managers, who used the virtual factory reference model as the supporting management tool for the design of their future virtual factories. The workshops were the simulation of a kick-off meeting for the virtual factory creation and were based on a real situation and need currently experienced by the companies. The workshops contributed to refine the reference model. Table 2 summarizes some characteristics of these virtual factories.

Table 1. Virtual factory business processes (CN: Collaborative Networks; SN: Supply Networks; MN: Manufacturing Networks; SCM: Supply Chain Management; BP: Business Processes)

	CN			SN	MN	SCM			BP	
Process	[2]	[3, 11]	[12, 13]	[14]	[15]	[16]	[4]	[6]	[17]	[5]
Join										
To understand Business Opportunities	X	X	X							
Set-up the virtual factory (ICT) framework	X	X	X	X				X		X
Analyse market trends	X	X	X							
Select and invite partners to join the network	X	X	X							
Collect information about partners' products, services, competencies and capacities	X	X	X		X					
Plug										
Search and assign partners in the network	X	X	X	X						
Define contractual and NDA conditions	X	X	X		X	X				
Define the virtual factory business model	X	X	X		X			X		X
Define network's governance model	X	X	X		X	X	X	X	X	X
Make operational plan and processes	X	X	X		X	X				
Manage risks	X	X	X	X			X			X

Table 1. (*Continued*)

	CN			SN	MN	SCM			BP	
Process	[2]	[3, 11]	[12, 13]	[14]	[15]	[16]	[4]	[6]	[17]	[5]
Play										
Design and develop expected product			X			X			X	X
Manufacture product			X			X	X	X	X	X
Fulfill customer order	X	X	X		X	X	X	X	X	X
Define process plan and schedule operational activities	X	X	X							
Monitor operational processes on real-time environment	X	X	X	X	X	X	X	X	X	
Adapt processes according to the needs	X	X	X	X	X	X	X	X	X	
Dissolve										
Evaluate virtual factory partners	X	X	X							
Share benefits among partners	X		X	X		X				X
Assign liabilities among partners	X		X							
Virtual factory performance feedback	X	X	X							
Store the valuable knowledge and expertize	X	X	X							
Maintain intellectual proprietary right										

Table 2. Characteristics of the validation cases

Case	Industry	Virtual factory goal	Partners' profile
A	Machinery	Design, build and deliver a new machine	- Machine Manufacturer - Producer of mechanical equipment - Company specialized in surface treatment - Software company
B	Energy	Design, build and promote new technologies in the energy technology sector	- Technology centre - R&D provider - Energy producer and distributor - Technology provider
C	Semiconductor	Industrialize a new technology and launch it	- Semiconductor manufacturer - R&D Partner - Key raw material supplier - Foundry

4 Virtual Factory Conceptual Reference Model

The virtual factory (VF) conceptual reference model is developed as part of work accomplished within the ADVENTURE project under the funding from European Commission (Ref. 285220) [18]. This model basically provides the necessary guidelines to form a plug-and-play virtual factory to be used for achieving the identified business opportunity.

The developed reference model consists of three levels. In the first level it describes the main phases of the VF lifecycle [1], whereas, the second level highlights the business processes for each of these VF life cycle phases. The third level contains the activities of each sub-process.

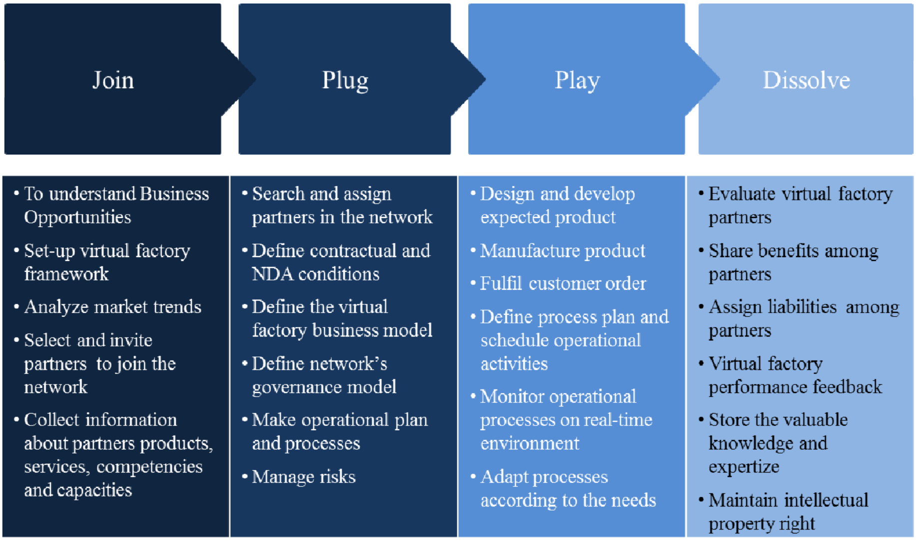

Fig. 1. Virtual factory conceptual reference model

From the reference model as highlighted in Figure 1, it is noticed that in the **Join** phase participating partners first of all need to join the ICT framework and to understand the identified business opportunities after analyzing the current market trends clearly in order to enthusiastically and actively join the VF network. At this phase, the VF broker also collects the necessary information of the participating partners with respect to their products portfolios, services, competencies and capacities. Potential partners are searched and assigned with specific tasks or processes in the **Plug** phased of the reference model. Essential contractual agreement within the network partners are defined a non-disclosure agreement (NDA) conditions are signed to protect intellectual property rights. Both the business model [19] and governance model [20] are defined to execute the VF during this phase. Finally, processes and operational planning of the VF network are also done at this plug phase along with the response plan of potential risks.

During the **Play** phase of the reference model the VF broker begins necessary steps to design and develop the target product. At this phase, essential design and drawing of the expected product is performed in a collaborative manner among partners [21]. Since the production process can be monitored through the ICT platform, the reference model also considers the monitoring of operational processes on real-time environment with the objective to find abnormality if there is any and to initiate required solution after consulting with the predefined response plan. At this phase, there is an option to adapt any processes in case of need. When the identified business opportunity is over the **Dissolve** stage of the reference model is evoked. At this phase, overall performances of the VF partners are evaluated based on agreed criterions. The expected benefits and liabilities are shared between the partners along with maintaining intellectual property rights. The expert knowledge and valuable information are stored for future use before dissolving the virtual factory.

Each of the main processes and its accompanied sub-processes can be defined in detail using BPMN (Business Process Model and Notation) diagram as has been proposed for example by Romero and Molina [3]. In our research we took a more operations management perspective and used the input-transformation-output model to describe each process [22]. Figure 2 highlights a sample input-transformation-output model of a process named as 'Define Virtual Factory Business Model'.

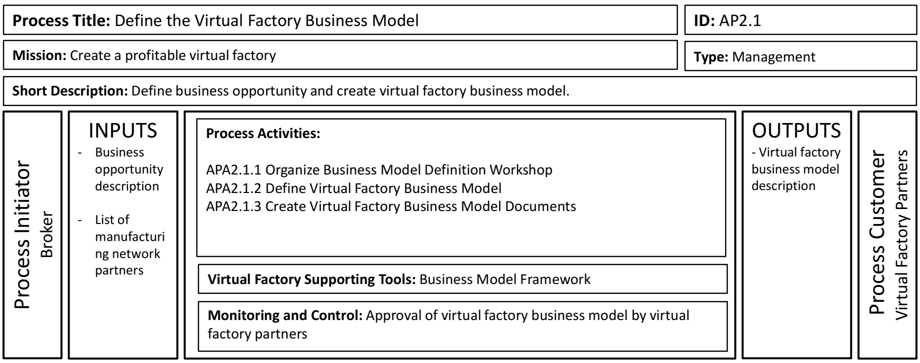

Fig. 2. Sample Input-Transformation-Output model for 'Define the Virtual Factory Business Model'

5 Discussion and Conclusions

The virtual factory reference model is a management tool used to design and manage a temporary strategic alliance among companies formed to exploit a new business opportunity. From the validation workshops we conclude that it is useful for managers operating a virtual factory because it:

- provides a structured guideline to help with the implementation of a virtual factory, so that managers to not have to start from scratch,

- provides a comprehensive list of processes giving managers an overview of the implementation scope, i.e., of what has to be done to implement a virtual factory,
- provides generic definitions of concepts that assist partners to create a common understanding among them,

The presented conceptual reference model is tested within three business networks, where it approves most the associated business processes and practices. Some processes and practices are not presented within these case networks but can be applicable in other networks too. In future research, this framework will be tested and validated within several virtual networks working in various business domains with the objective to offer a generic framework to be used in future virtual factory business networks.

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Collaboration Platforms

Methodology for Conceptualization of Customizable Virtual Workspaces

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Abstract. The improvement on evolution of quality of communications based on Internet technology is the base of the trend of development of free Virtual Workspaces. As an emerging family of applications to be developed, needs tools for conceptualizing process as input of design processes. This paper introduces a conceptualization process of virtual workspaces oriented to strictly cover specific interaction needs, and proposes a set of techniques where each of these techniques is associated to development of each conceptualization task of presented process.

Keywords: Virtual workspace, conceptualization process, formalisms for modeling human interactions, techniques to develop formalisms.

1 Introduction

Virtual spaces dedicated to collaborative work (VSCW) are intended to facilitate mediation inside teams whose members are not physically contiguous, and have to develop a conceptual object (for example: research, project development, software, technical articles, reports, documentation of building design, business plans, corporative investment plans, among others). The VSCW must satisfy the requirement of keeping and documenting the different versions of the conceptual object that is being developed by the collaborative working team; leaving a record of the evolution from the agreement among the members of the working group since initial specifications of the conceptual object until its final stage of development.

There are some proposals for conceptual modelling notations of aspects of group work [1-2]. Recently, there has been proposed [3] a set of interaction modeling formalisms among group members within a virtual collaborative work space that may be briefly describe as follows: [a] *Table Concept-Category-Definition*: Its function is to represent the factual knowledge of the conceptual model of group dynamics; [b] *Cases of Interaction*: are used to modelize the interactions between two actors, [c] *Diagrams of Group Interaction*: are used to modelize, in an integrated way, interactions among all actors considered in the modeling process; [d] *Interaction Procedures*: are used to describe the composition of interactions among the actors made for the development of an object; [e] *Sequence Diagram of Group Dynamics*: are used to express the group dynamics among the actors in the timeline imposed by

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 417–425, 2014.

the procedures of interaction; [e] *Diagram of Conceptual Object Development*: are digraphs with two types of nodes: the "conceptual objects" and the "transformations" which represent the action that must to be performed to make evolve the "conceptual object" from a level of development into another.

This paper is structured as follows, in section 2 is defined the problem of conceptualization of virtual workspaces, in section 3 is proposed a conceptualization methodology (the process, the tasks and the conceptualization techniques for each task of the process), in section 4 is presented a concept proof, and in section 5 is summarized preliminary conclusions and future research.

2 Definition of the Problem

Several authors [4-8] from a wide range of fields (users and developers) have pointed out in different ways that state of conceptual modeling of virtual work group is characterized by the following limitations: [a] lack of techniques to derive conceptual models (and absence of corresponding formalisms) of interaction among group members and among them and objects; from the description of the workspace and developed tasks within it; and [b] lack of processes that allow deriving the architecture of the virtual space designed for the particular needs of a workgroup, from conceptual models which describe the interactions among its members and objects. Regarding these limitations, we introduce a conceptualization process of virtual workspaces, and propose a set of techniques where each of these techniques is associated to development of each conceptualization task of presented process.

3 Proposed Conceptualization Methodology

The conceptualization methodology of virtual space oriented to collaborative work (VSCW) proposed in this paper is structured by a process with three phases: Phase of Static Conceptualization of VSCW, whose objective is focused on the characterization of the concepts related to Virtual Workspace and its categorization in: Actors, Objects and Interactions; Phase of Dynamic Conceptualization of VSCW, whose objective is focused on the characterization of the interactions between actors and between actors and objects, giving a comprehensive view of the interactions streaming along timeline; Phase of Modeling of VSCW, whose objective is to identify the features that should have the virtual workspace to support the interactions among actors, and among actors and objects, identifying which components should give support to each type of interaction. Each phase consists of tasks with an associated technique to develop each one; and a set of products that can act as elements of input and / or output of a given task [9]. Each task defines a set of products as insumes, and generates a set of products as output of its development. The products are partial conceptualizations of the description of workspace and interactions among persons in it. The partial conceptualizations are based on formalisms introduced in [3]. Figure 1 presents the interaction among phases, tasks and products, and shows the flow of products supplied to tasks and the products that are the result of the different accomplished tasks. A summary of tasks, the techniques that develop them, and products used as input or output for each task (technique) is shown in Table 1.

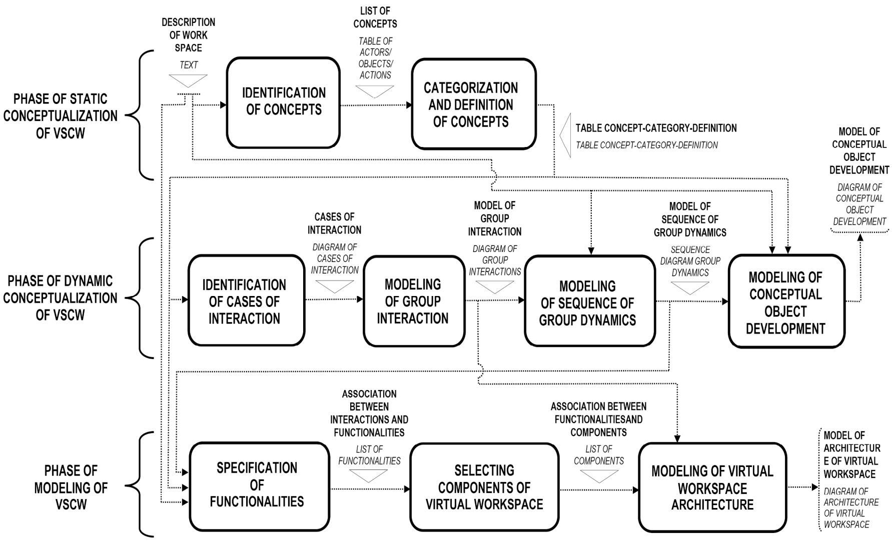

Fig. 1. Interaction among phases, tasks and products

Table 1. Summary Table of Tasks, Techniques and Products (Input or Output)

	FASE	TASK	TECHNIQUE	MODELING FORMALISM(S) FOR INPUT PRODUCT(S)	MODELING FORMALISM FOR OUTPUT PRODUCT
PHASES OF PROPOSED PROCESS	STATIC CONCEPTUAL-IZATION OF VSCW	Identification of Concepts	Technique for Identification of Concepts in Text (see Table 2)	Description of Work Space	List of Concepts
		Categorization and Definition of Concepts	Technique to Build Table Concept-Category-Definition (see Table 3)	List of Concepts	Table Concept-Category-Definition
	DYNAMIC CONCEPTUALIZATION OF VSCW	Identification of Cases of Interaction	Technique to Build Diagram of Cases of Interaction (see Table 4)	Table Concept-Category-Definition	Diagram of Cases of Interaction
		Modeling of Group Interaction	Technique to Build Diagram of Group Interactions (see Table 5)	Diagrams of Cases of Interaction	Diagram of Group Interactions
		Modeling of Sequence of Group Dynamics	Technique to Build Sequence Diagram Group Dynamics (see Table 6)	Description of Work Space Diagram of Group Interaction	Sequence Diagram Group Dynamics
		Modeling of Conceptual Object Development	Technique to Build Diagram of Conceptual Object Development (see Table 7)	Description of Work Space Table Concept-Category-Definition Sequence Diagram Group Dynamics	Diagram of Conceptual Object Development
	MODELING OF VSCW	Specification of Functionalities	Technique for Association between Interactions and Functionalities (see Table 8)	Description of Work Space Table Concept-Category-Definition Diagram of Group Interaction	Table of Association between Interactions and Functionalities
		Selecting Components of Virtual Workspace	Technique for Association between Functionalities and Components (see Table 9)	Table of Association between Interactions and Functionalities	Table of Association between Functionalities and Components
		Modeling of Virtual Workspace Architecture	Technique to build Diagram of Architecture of Virtual Workspace (see Table 10)	Table of Association between Functionalities and Components	Diagram of Architecture of Virtual Workspace

Table 2. Technique for Identification of Concepts in Text

Input:	Description of Work Space (DWS)
Output:	List of Concepts
Step 1.	Identify persons in DWS
Step 2.	Identify objects in DWS
Step 3.	Identify actions in DWS
Step 4.	Build a discriminated list of concepts classifying them in: actors, objects and actions

Table 4. Technique to Build Diagram of Cases of Interaction

Input:	Table Concept-Category-Definition
Output:	Diagram of Cases of Interaction
Step 1.	Identify pairs of actors interacting
Step 2.	For each pair of actors: generate a list of objects and interactions
Step 3.	For each pair of actors: Build the Case of Interaction
Step 4.	For each Case of Interaction: Give a graphic description in terms of Actors, Interactions and Objects

Table 6. Technique to Build Sequence Diagram Group Dynamics

Input:	Description of Work Space (DWS) Diagram of Group Interaction
Output:	Diagram of Group Interactions
Step 1.	Deploy the timeline of each Actor present in Diagram of Group Interactions
Step 2.	Identify in the DWS, the sequence of interactions present in the Diagram of Group Interactions.
Step 3.	For each Interaction in the Sequence of Interactions constructed in Step 2, identify in the DWS: Object present in the interaction, Actor who starts Interaction and Actor who completes Interaction
Step 4.	In the Sequence order of Interactions constructed in Step 2, deploy interact-tions with mention to associated objects identified in Step 3, between timelines of Actors constructed in Step 1.
Step 5.	Identify in the DWS, cycles of group of interactions and note them on the constructed diagram.

Table 3. Technique to Build Table Concept-Category-Definition

Input:	Description of Work Space
Output:	List of Concepts
Step 1.	Categorize Concepts in Actors(persons), Objects and Interactions (Actions)
Step 2.	Define each Concept
Step 3.	Integrate results on a Table

Table 5. Technique to Build Diagram of Group Interactions

Input:	Diagram of Cases of Interaction
Output:	Diagram of Group Interactions
Step 1.	Identify the same Actor (if exists) in different Cases of Interaction
Step 2.	Initialize Diagram of Group Interactions with one of Cases of Interaction identified in 1
Step 3.	For each Cases of Interaction not integrated into the Diagram of Group Interactions with an Actor in common with this: integrate the Case of Interaction with the common Actor to the Diagram of Group Interaction
Step 4.	IF: Still Exists Cases of Interaction with a common Actor but not integrable to the Diagram of Group Interactions: Initialize a new Diagram of Group Interactions with one of the Cases of Interaction identified. Go to Step 3. OTHERWISE: Finish technique execution.
Step 5.	For each Diagram of Group Interactions: Give a graphic description in terms of Actors, Interactions and Objects

Table 8. Technique for Association between Interactions and Functionalities

Input:	Description of Work Space Table Concept-Category-Definition Diagram of Group Interaction
Output:	Table of Association between Interactions and Functionalities
Step 1.	Build a table of Interactions present in the Sequence Diagram of Group Dynamics, distinguishing the type of interaction.
Step 2.	From the Description of Work Space extend the table developed in Step 1, mentioning the functionality which has to be satisfied by componente that will support the associated Interaction.
Step 3.	Build a table of Interaction and Component Functionality that will support the Interaction

Table 7. Technique to Build Diagram of Conceptual Object Development

Input:	Description of Work Space Table Concept-Category-Definition Sequence Diagram Group Dynamics
Output:	Diagram of Conceptual Object Development
Step 1.	From Table Concept-Category-Defining, build a table of Interactions and Objects presents in Diagram of Group Interaction
Step 2.	From the Description of Work Space and table generated in Step 1: build a table in which Objects and Derived Objects are distinguished. It has to be mentioned the object from which the derived object derives, the Interaction which generates the derived object and the vinculation of derivation.
Step 3.	From the Description of Work Space, Table Concept-Category-Definition, Sequence Diagram Group Dynamics and the table generated in Step 1: build a table following the order that describes the Sequence Diagram of Group Dynamics, identify: interactions, transformations associated with the interactions which object or objects are inputs of transformation, objects generated by each transformation, and cycles of transformation associated cycles of interaction.
Step 4.	From tuples (ASSOCIATED TRANSFORMATION / INPUT OBJECT / GENERATED OBJECT) described in table generated in Step 3: deploy the Elemental Components of Diagram of Object Conceptual Development.
Step 5.	Build Diagram of Conceptual Object Development by coupling Elemental Components built in 4.

Table 9. Technique for Association between Functionalities and Components

Input:	Table of Association between Interactions and Functionalities
Output:	Table of Association between Functionalities and Components
Step 1.	Build a table of Interactions present in the Sequence Diagram of Group Dynamics, distinguishing the type of interaction.
Step 2.	From the Description of Work Space extend the table developed in Step 1, mentioning the functionality which has to be satisfied by componente that will support the associated Interaction.
Step 3.	Build a table of Interaction and Component Functionality that will support the Interaction

Table 10. Technique to build Diagram of Architecture of Virtual Workspace

Input:	Table of Association between Functionalities and Components Diagram of Group Interactions
Output:	Diagram of Architecture of Virtual Workspace
Step 1.	Deploy Actors present in the Diagram of Group Interactions
Step 2.	Deploy Components present in the Table of Association between Functionalities and Components
Step 3.	Link the Actors and Components through the Components Integration System

4 Concept Proof

To illustrate the proposed techniques applied to the development of each task is provided a proof of concept based on a case brought in [3]. The descriptions of the interactions among persons in virtual space that will be designed are presented in the following paragraph:

> *"...Master's degree student sends the PhD degree student, his master's thesis plan developed previously. PhD degree student reviews the plan and made the corrections and comments that he considers relevant and then send them to master´s degree student. He appropriates the corrections and comments to continue working on his master's thesis plan. Once the PhD degree student believes that the version of the master's thesis plan has not problems, forward it to senior researcher asking for his overseeing of the final version of master´s thesis plan. Senior researcher oversees the corrections made by the PhD degree student. As a result of overseeing, he can send comments which may include observations about the correction made and/or to make further corrections to be introduced in master´s thesis plan. Upon receiving these comments, the PhD degree student appropriates these and forwards them to master's degree student for his appropriating also, allowing in this way the generation of new versions of the document ...".*

The Technique for Identification of Concepts in Text is applied to develop the task of Identification of Concepts, which produces partial conceptualization model (hereinafter PCM) shown in Table 11. The Technique to Build Table Concept-Category-Definition is applied to develop the task of Categorization and Definition of Concepts, which produces PCM shown in Table 12. The Technique to Build Diagram of Cases of Interaction is applied to develop the task of Identification of Cases of Interaction, which produces PCM shown in Figure 2. The Technique to Build Diagram of Group Interactions is applied to develop the task of Modelling of Group Interaction, which produces PCM shown in Figure 3. The Technique to Build Sequence Diagram Group Dynamics is applied to develop the task of Modelling of Sequence of Group Dynamics, which produces PCM shown in Figure 4.

Table 11. List of Concepts of case "Review of Master's Thesis Plan"

Concept	Category
INCORPORATE	ACTION
PhD STUDENT	PERSON
SEND	ACTION
SEND COMMENTS	ACTION
SEND CORRECTION	ACTION
SENIOR RESEARCHER	PERSON
MASTER STUDENT	PERSON
THESIS PLAN	OBJECT
REVIEW	ACTION
REVIEW AND CORRECT	ACTION
REQUEST OVERSEE	ACTION
OVERSEE	ACTION

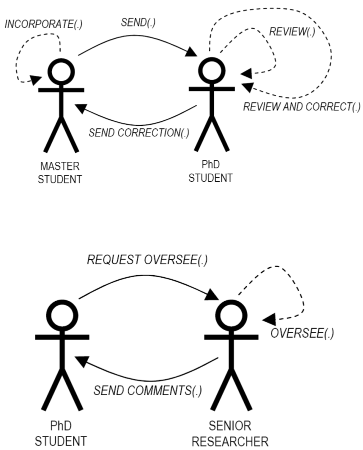

Fig. 2. Interaction cases of concept proof case

Table 12. Table Concept-Category-Definition of case "Review of Master's Thesis Plan"

Concept	Category	Definition
INCORPORATE	INTERACTION	Actor "A" incorporates the received information in the document and / or comments in it.
PhD STUDENT	ACTOR	Professional who has a master degree or academic equivalent and is making a career of doctoral degree
SEND	INTERACTION	Actor "A" sends to actor "B" a document or information.
SEND COMMENTS	INTERACTION	Actor "A" sends Actor "B" the comments on the results of overseeing carried out, this may include observations about the correction made and/or further corrections to make.
SEND CORRECTION	INTERACTION	Actor" A" sends to actor "B" the result of the review and correction of the document with its observations.
SENIOR RESEARCHER	ACTOR	Professional with a PhD degree or academic equivalent, with background in human resources training at the doctoral level and master degree.
MASTER STUDENT	ACTOR	Professional with grade title and who is making a master degree
THESIS PLAN	OBJECT	Document referred to student´s research project who is carrying out to earn a PhD, master's, specialty or grade degree.
REVIEW	INTERACTION	The actor reviews the document and states his comments (in case needed) but without doing any correction.
REVIEW AND CORRECT	INTERACTION	The actor revises and corrects the document with indication of his comments and corrections
REQUEST OVERSEE	INTERACTION	Actor "A" asks oversee of review / corrections on a document generated by a third actor. Overseeing will be made by actor "B”.
OVERSEE	INTERACTION	Actor "A" oversees the reviews or corrections made by an actor "B" on a document that has been sent previously to him by a third actor.

The Technique to Build Diagram of Conceptual Object Development is applied to develop the task of Modeling of Conceptual Object Development, which produces PCM shown in Figure 5.

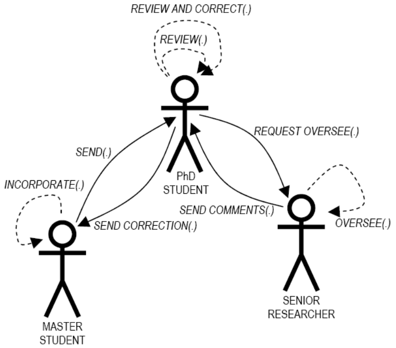

Fig. 3. Group interaction diagram among Actors

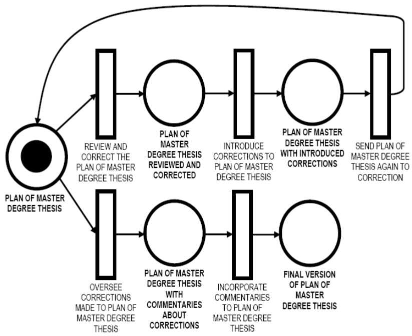

Fig. 5. Diagram of Conceptual Object Development for case "Review of Master's Thesis Plan

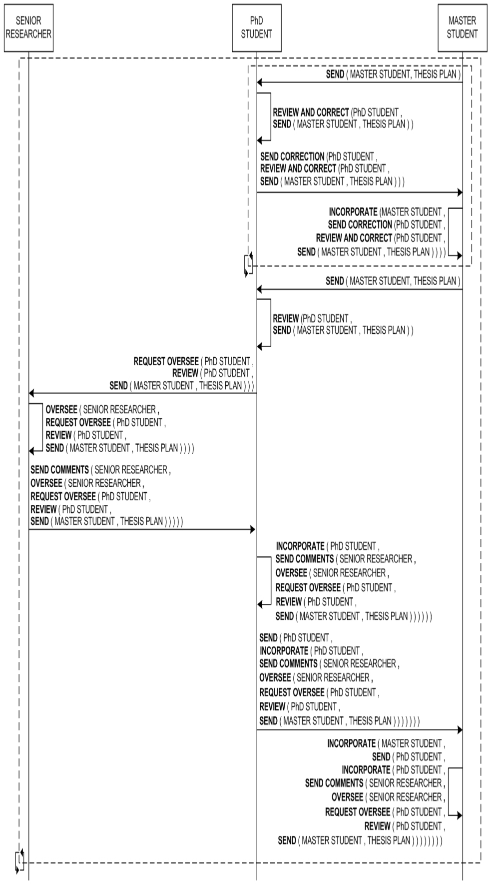

Fig. 4. Sequence Diagram of Group Dynamics of case "Review of Master's Thesis Plan

The Technique for Association between Interactions and Functionalities is applied to develop the task of Specification of Functionalities which produces PCM shown in Table 13. The Technique for Association between Functionalities and Components is applied to develop the task of Selecting Components of Virtual Workspace which produces PCM shown in Table 14. The Technique to build Diagram of Architecture of Virtual Workspace is applied to develop the task of Modelling of Virtual Workspace Architecture which produces PCM shown in Figure 6.

Table 13. Table of Association between Interactions and Functionalities

INTERACTION	FUNCTION-ALITY
INCORPORATE	No component required
REVIEW AND CORRECT	
REVIEW	
SEND	Ability to transmit documents in real time
SEND COMMENTS	
SEND CORRECTION	
REQUEST OVERSEE	Carry video conferences 1-1
OVERSEE	

Table 14. Table of Association between Functionalities and Components

COMPONENT FUNCTION-ALITY	COMPONENT
Ability to transmit documents in real time	EMAIL MODULE
Carry video conferences 1-1	WEB-CONFERENCE MODULE PERSON TO PERSON

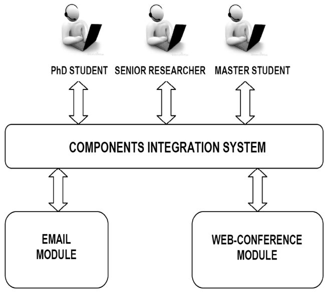

Fig. 6. Diagram of Architecture of Virtual Workspace

5 Conclusions

Work in groups is one of the usual labour strategies that may be mediated by Internet technology. Virtual workspaces arise as a possibility to establish working groups in which persons are not physically contiguous or have difficulty to share the same real space. Our work focuses on conceptualization process for customizable virtual working spaces that require to be strictly adjusted to the needs defined by the nature of task developed by the work group. The proposed process is a step towards formal design of the virtual space architecture in which the virtual work will take place.

To consolidate the results presented in this paper, the following research works have been started up: [a] the development of a prototype configuration of VSCW component-based and a prototype tool to support the process of formalizing interactions, and [b] explore the validity of the proposed conceptualization process in the following cases: (i) VSCW for Architects team working in building design, and (ii) VSCW for Software Engineers team working in software development.

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Collaboration in Virtual Enterprises through the Smart Vortex Suite

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Abstract. Collaboration is a key issue in modern virtual enterprises adopting service-oriented business models and functional engineering in the offering of their tangible and intangible assets, as in software oriented IT, CAM/CAD, manufacturing industries. In this paper, we aim at introducing the main components of a Collaboration and Decision Making Suite developed for such scenarios, in particular *(i)* Elgar, a collaborative workspace supporting the elastic collaboration concept, and a standard interface to realize the integration of groupware tools, and *(ii)* RegalMiner, capable of capturing, monitoring, processing and visualizing collaboration data streams generated from users of Elgar participating a collaborative process that exploits the elastic collaboration approach in order to evaluate individual and group performances by analyzing the generated activities and the produced text contributions.

1 Introduction

The last years have witnessed the emergence of a trend in the industry that fosters the offer of intangible assets within vendor-customer relations even if tangible assets still represent a high volume and a very precious part of the delivery. These underlying business models are called "service-oriented models", where the product offer is no longer the equipment itself, but the contractual agreement to specific performances of intangible features like transportation volume, reliability, physical parameters like torque, power, cutting speed or other measurable parameters, which are taken as contractual basis between vendors and customers. This new business model, already used in the software oriented IT and in the CAM/CAD industries, has now found strong interest from the manufacturing companies as well. To ensure that these industries would come into a similar business model, it is required exact knowledge about the behavior of the goods, equipment or the systems, their usage conditions, early detection of upcoming failure modes or maintenance requirements and dependencies with the delivered systems. Additionally, it is required a new way of engineering and design, called "functional engineering", in which a large quantity of data stream is used for validation, behavior prediction, simulation and more in general, will be produced in all phases of the product life cycle. These should be properly analyzed and intelligently managed.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 426–434, 2014.

Most important it will be the collaboration support, for improving the product and design life cycle and achieving better decision-making. As systems and products become more complex, and often offered by aggregation of companies (virtual enterprise), experts and engineers of the extended enterprise need to collaborate to manage integration and communication of the subsystems they design and develop. Parallel to this, users, clients and stakeholders are becoming increasingly often included in various phases of a product life cycle, including design, user feedback, innovation and improvement cycles. Collaboration in the product's life cycle can be supported by suitable technologies.

The SmartVortex project (cf. `www.smartvortex.eu`) addresses these topics providing a technological infrastructure consisting of a comprehensive suite of interoperable tools, services, and methods for intelligent management and analysis of massive data streams to achieve better collaboration and decision making in large-scale collaborative projects concerning industrial innovation engineering. It consists of a number of software components for capturing, processing and visually query high volume of data streams, together with collaboration and decision making support tools. In particular the infrastructure includes a *(i)* Data Stream Management System (DSMS), responsible of the access to the data streams and their processing, a *(ii)* Social Network, that basically realize a cross-organizational middleware which automatically connect organizations seamlessly while still protecting the intellectual property of the partners and minding the different company policies and the *(iii)* Collaboration and Decision Making Suite, playing a key role in helping the users in the collaborative work regarding data monitoring, data analysis and visualization.

In the following of this paper, we aim at introducing the main components of the Collaboration and Decision Making Suite, in particular *(i)* Elgar (cf. Section 2), a collaborative workspace supporting the elastic collaboration concept, and a standard interface to realize the integration of groupware tools, and *(ii)* RegalMiner (cf. Section 3), capable of capturing, monitoring, processing and visualizing collaboration data streams generated from users participating a collaborative process that exploits the elastic collaboration approach in order to evaluate individual and group performances by analyzing the generated activities and the produced text contributions.

2 Elgar

In complex design and engineering phases, different tools and techniques are useful at different point in the design. However, groups of engineers often do not have the knowledge to choose or select effective tools and techniques for specific situations. Elgar (ELastic GroupwARe) [8] addresses these problems implementing different coordination mechanism to support groups in collaborative tasks; it provides structured and unstructured coordination.

The major goal of implementing coordination mechanisms in groupware systems is to support users to coordinate task dependencies to accomplish a shared task. On the one side (*structured*), coordination mechanisms that are highly specified and routinized processes are needed; this allows experts in a certain domain to define processes and structures to support and guide group participants. For example, a software release control system follows a pre-defined process of activities to release new versions of a software product, e.g., bug repair, application testing and final release compilation activities [6]. On the other side (*unstructured*), coordination mechanisms that are highly unspecified and dynamic processes, are needed in order not use rigid structures or processes to guide group participants in their tasks. Instead, they relies on awareness mechanisms that allow for an informal understanding of the activities of others group participants [4]. For example, a spatial visualization of programmers' activities in their development environment and within a project's source code repository system can improve the sense of awareness in a team [3].

Some groupware systems address more than one part of the coordination spectrum and provide mechanisms from both extremes. In such systems, the decision on a specific coordination mechanism is delegated directly to groups of participants, according to the situation they handle [2]. For supply chains, Bernstein proposes a system that implements different coordination mechanisms to enable collaboration between users [2]. The system implements four mechanisms: guidance through scripts, planning based on constraints, monitoring constraints and context provision. Each mechanism supports users to overcome natural unexpected obstacles from the disruption of a computer supply chain, from pre-defined supply chain processes to exploration of context information.

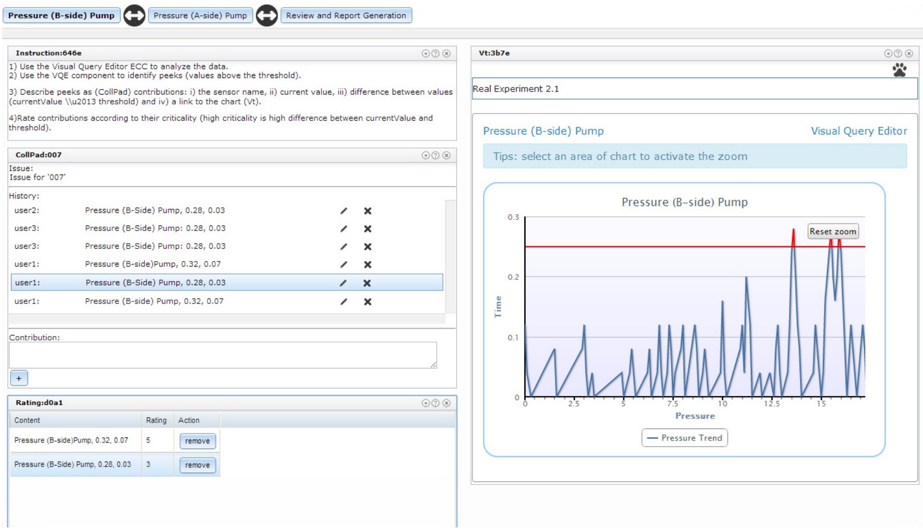


Fig. 1. The visualization of Elgar running the prescribed coordination mechanism

Elgar was implemented as an extensible web-based groupware that provides a modular infrastructure to integrate software components. In Elgar, such components are called *Elastic Collaboration Components* (ECCs). They represent web-based components, inspired on portlets. Developers need to implement ECCs according to the architecture described in [8] to use them as part of Elgar.

Currently four ECCs have been realized: V2QT, CollPad, Rating and CollPad Categorizer. The Visual Query and Visualization Tool (V2QT) [9] is an ECC that enables users to visually pose continuous queries (CQs) over machine sensor measurements. V2QT handles query requests and responses and displays results in a time-oriented graph. Users gain insights, through the V2QT, over possible anomalous equipment behaviors, e.g. the main hydraulic pressure is above a threshold.

Collaborative Notepad (CollPad) is a multi-role ECC that allows its users to share their ideas and create text structures, based on lists, collaboratively. The component supports engineers in documenting ideas of possible problems, solutions for given problems, description of consequences for both problems and solutions, and to sketch action plans for a machine's diagnosis process. Such component is important to create collaborative documentation during a diagnosis scenario. The component allows users to define the topic of a certain discussion and provide contributions focusing on the topic. A contribution can either be a category or ideas. Users may combine the CollPad with the V2QT to annotate results of a graph at a particular moment.

Rating is an ECC that allows a user to rate a set of pre-selected contributions from CollPads. Users of Elgar drag contributions from CollPad and drop them in the Rating, creating a dynamic list of contributions collaboratively that will be compared by users through rates. In this component, users can rate the elements of a list according to a scale of five points. The idea is that the highest rated element should be considered for further attention of the group. The rate of contributions is calculated as the average of all rates provided by all participants.

CollPad Categorizer is an ECC that summarizes all discussions in a collaboration session. This component organizes discussions in a list. Each list entry represents a discussion topic, called category, and is automatically associated to a CollPad ECC. Users can contribute to a category by opening the associated CollPad adding, removing or editing content. In addition to the list of categories, users can classify the list of categories with a topic, called issue, which describes the goal of the CollPad Categorizer.

Currently Elgar supports two coordination mechanisms: ad-hoc and prescribed coordination mechanisms.

- **Ad-Hoc Coordination Mechanism.** The ad-hoc coordination mechanism implements a possible type of unstructured coordination, in which computer-mediated collaboration within a group naturally emerges and is not guided by prescription. It supports groups that do not need guidance or prescribed coordination during collaboration. The ad-hoc coordination mechanism relies on the use of workspace awareness information to divide and synchronize tasks among group participants. In this mechanism, such information represents all group participants connected in a collaboration session and the ECCs in which participants work. Through such information, participants may create an understanding about activities of others, facilitating their coordination to achieve a common goal, such as in [3]. In addition, this mechanism enables participants to share ECCs with each other to collaborate for content production. Participants can connect to ECCs opened by other participants, provided by workspace awareness information, sharing its content automatically.

- **Prescribed Coordination Mechanism.** The prescribed coordination mechanism implements a possible type of structured coordination in which professional facilitators plan the sequence of phases and activities. This coordination mechanism guides group participants on the usage of elastic collaboration components. Guidance is described as a collaboration process, which represents a sequence of collaborative phases, each associated with a set of ECCs, and explicit instructions for the phase. In the prescribed coordination mechanism, the collaboration process is described at design time and coordinates the collaborative activities, executed by a group. It is based on process-aware systems [5], in which processes are described to coordinate users in accomplishing established goals. The emphasis of the prescribed coordination mechanism is to provide guidance to users in collaborative activities through components, and not to require a facilitator to enable and disable components at specific moments [6].

3 Regal Miner

RegalMiner is a collaboration support software tool that is capable of capturing, monitoring, processing and visualizing collaboration data streams generated from users participating a collaborative process, in order to evaluate individual and group performances by analyzing the generated activities and the submitted text contributions, to provide automatic notifications to a third-party facilitator or expert users in case typical meeting problems are detected and to supervise the meeting events to enhance the effectiveness of the current meeting session. The analysis and processing of activities and user contributions is demanded to text mining techniques [1]. RegalMiner adopts a modular approach that mainly consists of five components:

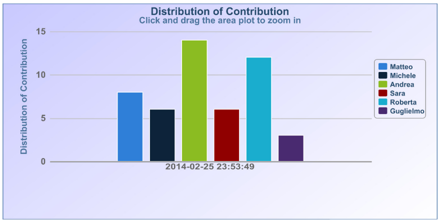
- The Fetcher module is responsible for the communication layer between the groupware platform that outputs the collaboration data streams (i.e., Elgar) and for the storage of all the retrieved information.
- The Reasoner module coordinates the Sentiment Analysis and the Keyword Extraction modules along with the execution of several subtasks:
  - sampling the events extracted from the collaboration data stream, according to some predefined intervals that a user, in the role of meeting coordinator, can configure according to the expected time length of the ongoing collaborative process;
  - processing of sampled events in order to obtain some basic meeting indicators as Group Participation Rate, Individual Participation Rate, Distribution of Contributions, Number of Contributions, Number of Interactions that provide support for the detection of the levels of attention, interest, discussion and negotiation. The mentioned meeting indicators help diagnose typical meeting problems such as the Dominant Spaces syndrome that occurs when the formation of independent subgroups prevailing on other participants increases the levels of frustration and insulation. Another meeting problem that can be detected by the monitoring of these meeting

indicators is the Sleeping Meeting syndrome that is caused by the lack of mental and physical energy thus decreasing the effectiveness of the overall collaborative process;

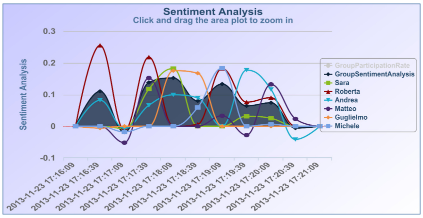
  - cycling the execution of the Sentiment Analysis module that processes the sampled events and returns scores for some high-level meeting indicators as Group Sentiment Analysis Score and Individual Sentiment Analysis Score. These meeting indicators relates to the level of interpersonal agreement or disagreement and individual positioning of participants involved in the collaborative session. Low levels of Sentiment Analysis indicators help to diagnose the Multi-Headed Beast syndrome, that occurs when there is no agreement on the agenda and confusion about the problem-solving strategies and participants interrupt or attack each other. Another typical meeting problem that can be detected by monitoring the mentioned scores is the Feuding Factions syndrome caused by internal power struggles that push participants against each other assuming an aggressive body language;
  - starting the execution of the Keyword Extraction module whenever the current meeting session has finished or having a break, thus returning the set of Extracted Topics for each participant. The extracted keywords can be associated with the topics and ideas argued during the meeting discussion, especially in brainstorming stages. The results of this process analysis provides insights about the levels of convergence/divergence towards a common solution, idea discussion and idea distinction that can help the early detection of several meeting problems such as Multi-Headed Beast, Dominant Spaces, Sleeping Meeting as already been discussed and Recycling syndrome caused by misunderstandings about the problem-solving processes thus resulting in a lack of consensus among participants that on the consequence start repeating the same arguments and reuse older solutions instead of generating alternative ones;

- The Sentiment Analysis module is in charge of processing the contributions that participants submitted during a meeting session. In particular, it returns the Group Sentiment Analysis Score and Individual Sentiment Analysis Score. It implements a dictionary-based approach built on SentiWordNet [10,7] that has proven to be efficient in terms of computational effort, especially in the case of repeated executions that are the requirement for a online analysis. The Sentiment Analysis module retrieves the collection of contributions for each participant and pre-processes the terms from extracted sentences, then detects terms that imply sense inversion as “no”, “not”, “don’t”, etc. and finally looks up into the dictionary to obtain scores for single terms, that are subsequently combined with other scores of terms in the sample of the collaboration data stream. A negative user score near -1 implies that the participant feels uncomfortable, isolated, in disagreement or in contrast with the rest of the participants, which can be one of the symptoms of the Multi-Headed Beast, Feuding Factions or Dominant Spaces syndromes. On the other hand, a positive user score near +1 indicates a user that feels positive, in agreement and an active subject of the group participating the collaborative process. It also reveals a high level of acceptance of group ideas, with a numeric majority of pros in contrast with a numeric minority of cons. Careful attention has to be provided to neutral user scores near 0 that may imply hidden issues that may arise in future phases of the meeting session, since participants that fear changes or are under the influence of a subgroup may not express their real opinions. A facilitator or an expert user is required to thoroughly analyze and understand individual behaviors that happened in the previous stages of the collaborative process and subgroups compositions that may have affected the direction of the decision-making process in order to avoid future meeting problems.

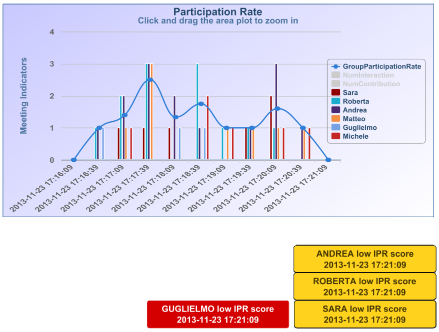
- The Keyword Extraction module is responsible for the automatic discovery of topics from submitted contributions, producing a set of keywords with their corresponding relevance score for each participant. The resulting sets represent the Extracted Keywords (or Topics) indicator that can be analyzed to identify subgroups compositions or isolated participants that may be the symptoms of the Feuding Factions or the Dominant Spaces syndromes that would decrease the effectiveness of the collaborative process. Furthermore the Extracted Keywords indicator reveals the level of idea generation, discussion, the level of similarity between proposed solutions or the level of convergence/divergence towards a common problem-solving model, as discussed in the previous chapters of this document. The Keyword Extraction module is coordinated by the Reasoner module that starts its execution once the coordinator selects the option to stop the fetching phase in case the meeting session has finished or having a break, since partial or none contributions would produce unreliable relevance scores. In fact, ideas can be developed during all the stages of the collaborative problem-solving process, either during the first phases or right in the middle of it. Extracting topics from single samples of the collaboration data stream would not consider concepts and notions that can be discussed in the subsequent stages of the meeting session. The natural approach is to examine the linear evolution of the collaborative process and not only the collections of fragments that represent the discrete samples generated from the Reasoner module. The implemented supervised approach used by the module takes advantage of a large training set constituted by almost 300 scientific articles from various disciplines, including Computer Science, Mechanical Engineering, and Electrical Engineering.
- The Web Visualization module provides a computer-supported, interactive, visual representation of the data collected, managed, analyzed and processed by RegalMiner in order to amplify the end-user cognition of the ongoing collaborative process. All the visualization are characterized by some common features such as interactive live updates, zoomable area chart, animations, pop up tooltips for detailed information and different colors to distinguish different series.



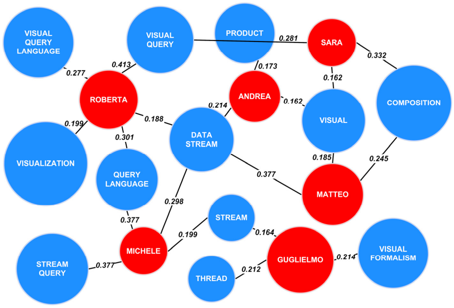
(a) distribution of contribution visualization



(b) Spline chart sentiment analysis visualization



(c) Participation rate visualization



(d) Keyword extraction visualization

Fig. 2. Examples of RegalMiner visualizations

4 Concluding Remarks

In this paper, we have outlined the main components of a Collaboration and Decision Making Suite specifically tailored to virtual enterprises adopting service-oriented business models and functional engineering, in which the ability to collaboratively manage huge data streams is a key factor. The platform is currently being validated in the context of an EU project by real users in the manufacturing industries, and preliminary feedbacks show the usefulness of the proposed tools, in particular the possibility to manage ad-hoc collaborations and to monitor and mine the collaborations themselves.

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A Novel Framework for Virtual Organization Creation on Cloud

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Abstract. Nowadays, virtual organizations (VOs) need to utilize new technologies in order to respond rapidly to collaboration opportunities. Cloud computing is a new paradigm that could leverage VO efficiency and flexibility whilst it could decrease VO expenditures and response time. Also, VO breeding environment (VBE) is an approach to create efficient VOs. Thus, combination of VBE and cloud computing may facilitate VOs creation and reactions to upcoming opportunities. This paper has proposed a framework to create VO on cloud environment, including three phases: creating and managing VBE on cloud, moving VBE on cloud and finally creating VO on cloud. The proposed framework may be considered as a solution to cope with VO requirements.

Keywords: Virtual Organization, Cloud Computing, Virtual Breeding Environment, Virtual Organization Creation.

1 Introduction

Virtual organization (VO) is an example of collaborative networks and refers to temporary or permanent cooperation of autonomous, independent and geographically dispersed entities. However, these entities act as a unique organization and provide customers product or service[1, 2]. During the recent years, VO concept is more and less combined with technology to facilitate partner's cooperation and to respond to business opportunities effectively. The first step of VO life cycle is VO creation[3] and more researchers attempt to create an efficient VO. But an important issue in VO creation is preparedness of potential partners which is neglected in most of the studies[3]. While ECOLEAD project introduces Virtual Breeding Environment (VBE) to address this issue and prevent self-interested partner's behavior[3, 4]. It integrates organizations with common principles and infrastructures to increase partner selection speed and respond rapidly to opportunities as VOs[3, 4]. This project suggested a process to create VOs from VBE with three main steps[3]: preparatory planning phase, consortia formation phase and VO launching phase. Another research[5] integrates structure of VO in VBE with service oriented architecture

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(SOA) and TOGAF methodology to generate Virtual Organization Breeding Methodology (VOBM). The VOBM tailors TOGAF's Architecture Development Method (ADM) to characteristics of VO and introduces ADM4VO. One early example can be found in [6] that it analyzed problems of multi-agent systems (MAS) and designed THOMAS architecture for VOs by integrating of the MAS paradigm and the service-oriented paradigm. The main problem of MAS is impracticability[3, 6] and THOMAS attempts to solve this. But ignoring of subjective facets like trust and successful cooperation history[3] is still remaining at it.

The emergence of grid and cloud computing brought a new approach for VOs and its creation, which could improve service quality. In this context, three researches can be referred: Agora[7] is a layered VO architecture for grid which it provides shared resources to grid users, CloudVO[8] and CVOE[9] that both compose a VO from cloud partners to use cloud services for resource allocation. Agora and CloudVO are special-purpose method and are employed for shared recourses whereas we intended to design a general-purpose framework. CVOE runs a business process by cloud services and assumes to provide all activities of the process by cloud services.

Among the above studies, the VO process of ECOLEAD Project has enough attention to preparedness of VO partners and subjective facets. Besides the process is a practical and generic process for VO creation. The process could be mixed with new technologies to increase efficiency and flexibility of VO and to decrease its expenditures. So we integrate VBE and cloud computing to exploit advantages of both and present a distinct approach for VO creation on cloud. The rest of this paper is structured as follows. Section 2 illustrates integration of VBE and cloud computing. Section 3 introduces proposed framework and their phases. Section 4 presents an example to evaluate proposed framework and finally section 5 gives conclusions.

2 Integration of VBE and Cloud Computing

Most of the cloud-based VO creation methods employ cloud partners alone, but the clouds only provide services and don't know VO business processes. In this paper, a VO is formed the organizations and the clouds. So that, organizations utilize cloud services to respond business opportunities and to provide customer with product or service in an effective manner. To realize this idea, firstly VBE put two different scenarios on cloud: one scenario occurs when the VBE doesn't already exist and the aim is the creation of new VBE on cloud (branch1 in Fig. 1) and other scenario moves exiting VBE on cloud (branch 2 in Fig. 1). Hence, VBE prepares organizations and clouds to collaborate each other and to create a VO on cloud when a business opportunity arises (branch 3 in Fig. 1).

This paper proposes an extended framework to achieve the objectives and facilitate VO creation on cloud by running its phases based on an existing framework[3]. It is necessary to redefine VBE and modify it with required changes. The modified definition considers the clouds as VBE partners, but they cannot undertake decision-making roles such as VO planner and VO coordinator. Thereafter, VBE is *a long-term cooperation agreement of organizations, clouds and their related supporting* *institutions, where partners adopt its rules and operating principles.* Unlike previous definition, there is no need to adopt organization's infrastructure, because it is provided by cloud services according to SOA standards. The modified VBE could prepare its partners for VOs, familiarize organizations with cloud services, build trust among them and create VOs on cloud.

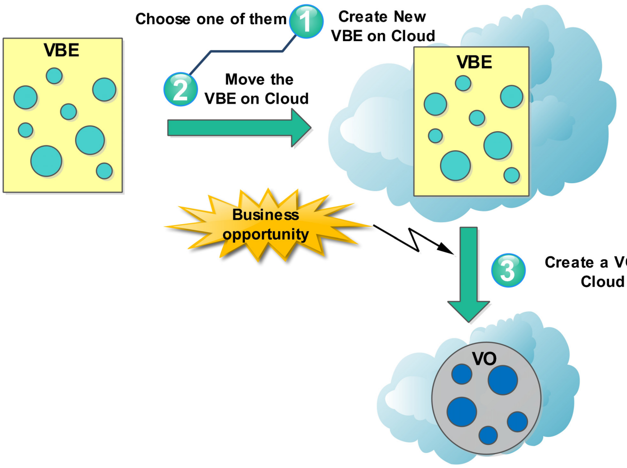

Fig. 1. Integration of VBE and cloud computing

3 Proposed Framework

The proposed framework is based on ECOLEAD project that is improved by three layers: business layer, service layer and component layer. Business and service layers emerge to cover two key elements, which the former is VBE organizations and the latter is cloud services. Component layer is defined to identify components of each service according to user's requirements and to provide access permissions at the component level. In fact the VBE; participating organizations and VOs use cloud services and expect to receive specific components from each service. Besides a cloud provides services in form of three models[10]: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Granulating of the services is coarse and unsuitable to define access permissions. Thus, we define and assign permissions based on components of service.

We also define three phases, is explained in the following, to cover three branches in Fig. 1. The phases employ proposed layers to classify its activities and operations.

3.1 Phase 1: Creating and Managing VBE on Cloud

This phase intends to create a new VBE on cloud and manage it to support building VOs on cloud. The phase is realized at first by analyzing processes, working principles[11] and functionality of VBE[1]; then classifying them according to proposed layers and defining activities to manage clouds and their services in order to deal with the cloud computing concept; finally introducing the following process to cover concepts of ECOLEAD project[1, 4, 11] and providing a new classification according to cloud computing as:

- *Business layer:* the layer focuses on VBE concept, collaboration process, rules, organizations and communication. They are detailed in [1, 11] and are arranged in four categories now:
- – *Foundational concepts and rules:* to declare the definition of concepts, processes, policies, working principles, ethical code and selection of supporting institutions depending on the VBE domain.
- – *VOs management:* refers to creation and registration of VOs at the VBE and management of VO performance and VO inheritance information.
- – *Organizations management:* refers to search, selecting and registering of new organizations as well as assigning roles and responsibilities when a VBE creates. During VBE operation, it refers to trust, competency and performance's management that may lead to rewarding or punishing organizations.
- – *Interactions:* a VBE on cloud interacts not only with VOs but also their clouds to provide services, which are matched with user demands and have reasonable cost. The VBE interacts other VBEs to utilize their information, practices and common services stored on clouds. The VBE manages interaction between organizations and clouds to facilitate their cooperation. For example, VBE can guarantee to offer cloud services with less cost or free to organizations.
- *Service layer:* handles clouds and their services through the following activities:
- – *Clouds management:* the clouds are VBE partners and should be managed, like organizations. When a VBE creates, administrator searches and selects clouds according to business layer subjects. Then selected clouds register in VBE and sign a Service Level Agreement (SLA). During the VBE operating, VBE evaluates cloud's performance, manages trust among organizations and clouds and if necessary provides incentive or penalties for them.
- – *Cloud services management:* this activity intends to provide easy and fast cloud services. So issues to consider: identify needed services for user (VBE, its organizations and upcoming VOs) that is a prerequisite for searching clouds to guarantee proper selection; register services and update them to search services at VO creation quickly; composition of services and registering them to rapidly respond to opportunities; extract services; service orchestration according to VBE processes and finally activation of services for users.
- – *Information services management:* the clouds maintain VBE information and provide them as services, including: VBE ontology that should be adopted with its domain at the VBE operation stage[1]; knowledge refers to initial knowledge of organizations and generated knowledge which both should be protected from unauthorized access; and other information such as competencies, services, bag of assets, VO inheritance, etc. is gathered in VBE lifecycle. The information should be inserted, updated and processed by cloud providers.

– *Other services management:* cloud partners provide all of hardware and software of VBE, its organizations and ICT Infrastructure (ICT-I) by services which should be synchronized and activated at VBE startup. So the VBE supports its organization's movement toward cloud infrastructure.
- *Component layer:* manages components of cloud service offered to VBE user.
– *Components management:* in this framework, although clouds are responsible for provision, maintenance, damage and error of components, the VBE should identify expected components of each service; defines access permissions at component level and assigns the permissions to intended roles.

3.2 Phase 2: Moving VBE on Cloud

This phase occurs when exiting VBE would be moved on cloud. Generally, exiting VBE comprises information, systems and activities[1, 11], which each of them moves on cloud as follows:

- *Information:* VBE information is stored in VBE repositories and actual movement of the information is nearly impossible, because it is more expensive and may cause losing or damaging information. So it offers another solution that is, making a cloud of VBE information and repositories to convert VBE into a cloud.
- *Systems:* VBE systems include hardware, software, ICT-I and tools are tailored with the VBE. VBE administrator could provide ICT-I, hardware and possible software of VBE and its organizations by cloud services. But, the VBE has special software and tools e.g. legacy systems, which may not be found in any clouds. They are moved like as information and are offered as services to utilize other VBEs. The solution can be used for VO creation support tools and ICT-I services[1] are developed in ECOLEAD project to save time and cost.
- Activities: VBE activities should be coordinated with the cloud computing concept. So we can use activities of prior phase and propose a process to move exiting VBE. In contrast to previous phase, the VBE exists now and have some of the activities, thus the process will create by editing previous process in the future.

3.3 Phase 3: Creating VO on Cloud

This phase creates VOs on cloud inside of VBE sitting on cloud now. This is done by matching VO creation process in ECOLEAD project[3] with cloud computing concept and adding new activities to it. Next the activities are classified in business, service and component layer (Fig 2.) and introduces a modern sequential process for VO creation on cloud with the same ECOLEAD steps as:

- *Collaboration Opportunity(CO) identification:* this step extracts CO characteristics to fit one of the collaboration models: collaborative business process, collaborative project, problem solving and ad-hoc collaboration model[1].
- *Rough VO planning:* this step employs business, service and component layer to design VO planning and respond to CO. Business layer defines VO business structure and identifies competencies. Service layer characterizes service plan and needed services and finally, component layer specifies components of each service.

- *Partners search and selection:* in general, VO planner searches VBE to select proper organizations and clouds according to rough VO planning. If VO planner doesn't find desired partners in VBE, he will explore out of VBE. This step may be repeated during VO operation to cover new needs or inefficiency of partners[3].
- *Negotiation:* this step is applied in most VO creation steps. In fact, it completes searching and selecting step and triggers contracting step[3]. VO planner negotiates with organizations, clouds and customer to reach agreement.

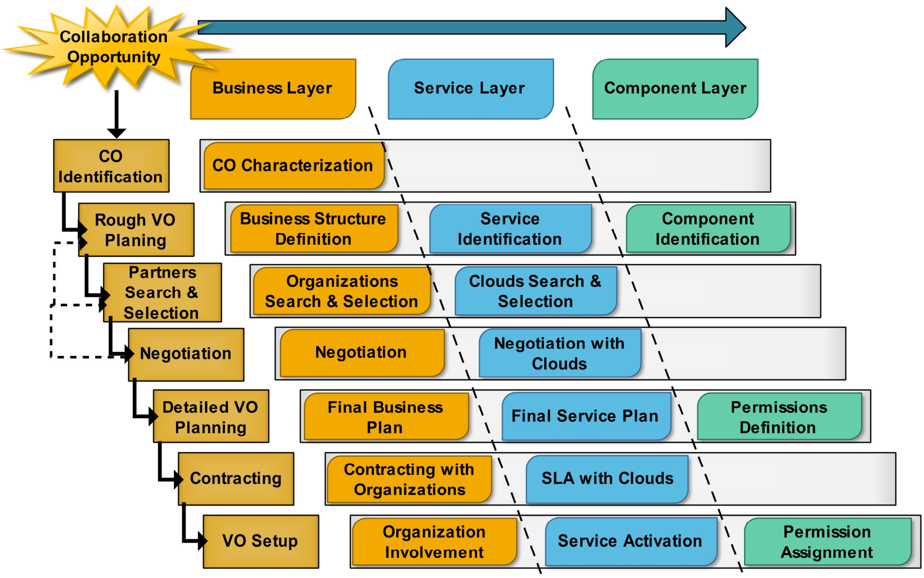

Fig. 2. Process of VO creation on cloud

- *Detailed VO planning:* in business layer, VO planner reviews VO business structure; forms collaboration process based on the selected collaboration model; assigns organization's role based on the process and specifies policies, working principles and VO scheduling[3]. In service layer, he improves the service plan; changes services if necessary and consequently adds or removes associated clouds. In component layer, he defines access permissions according to organization's role and collaboration process. Note access permissions can be changed or inserted during VO operation and they expire after VO dissolution.
- *Contracting:* addresses contracting with selected partners or in other words final organizations and clouds. Organization's contract contains responsibilities, liabilities, rights and role of organization[3]. Cloud's SLA specifies service characteristic, quality of service, accessibility, reliability and cost of service.
- *VO setup:* finally, VO coordinator informs organizations about VO startup time in business layer; notifies clouds to activate its services in service layer and assigns permissions to related organizations in component layer. After this step, VO enters operation phase and starts operating activities[3].

4 Example

Proposed framework is a generic framework and should be tailored with VBE domain and its VOs. This section gives an example to illustrate how to create a new VBE on cloud in order to built VO on cloud when an opportunity arises.

Hence, software development domain is selected to create a new VBE on cloud. The VBE's mission is integrating organizations competencies and cloud services to develop high quality software according to customer requests in reasonable time and cost. It executes analyzing, designing, implementing and testing processes to develop desired software. To pursue software license rights and software development's standards are its rules. The VBE employs organizations working on software development and registers their name, address, competencies, previous experiences, certificates, annual revenue and etc., then it identifies needed component and services to select cloud partners. Some VBE's components provided by IaaS e.g. data storage, processing, network and bandwidth. The VOs require various platforms and application for analysis, design, programming and testing to develop software. Other components consist of customer management application and project management application, collaboration applications, partners search and selection tools. This step specifies carefully the number of user; volume of data processing; type of operating system; database and programming language in order to identify services that may be composed of one or more components. Now VBE selects proper clouds, adjusts their SLA and registers their information including: name, type and components of service(s), accessibility, reliability, compatibility, security and cost of service(s). At this point, VBE executes activities of other service management to go operating phases and performs the rest of activities proposed to manage VBE in first phase.

A business opportunity, that is a software development's order, triggers the VO creation process on cloud. Software development is a team working project and so its collaboration model is the collaborative project. VO planner designs rough VO planning and specifies needed competencies, services and components according to the order. For example, these are different in Windows based application or UNIX based application. Next he searches and selects appropriate partners and negotiates with them to achieve a suitable configuration. Planner defines VO process and improves the service plan, assigns roles and responsibilities of organizations and defines access permission for them. Then, detailed plan is checked with customer and if he confirmed it, a contract adjusts between customer and all of VO partners. Now, VO startup is reported to all of partners; activated services; assigned permissions and registered the VO in VBE.

5 Conclusions

The idea of VBE and cloud computing integration is proposed in this paper to create VO on cloud and to improve ECOLEAD project. The VBE prepares their organizations and clouds to collaborate upcoming VOs and so responds rapidly to business opportunities. The clouds control the components of VO to save cost and time of VO. The VBE constantly evaluates its partners (organizations and clouds) to select efficient VO partners. Also the VBE monitors partners and builds trust among them through partners management to raise VO efficiency. Cloud services of VBE and VO could easily be integrated by SOA standards. Furthermore the idea enhances flexibility of VO for easily replace VO partners when the customer demands changes. The cloud infrastructure allows VBE organizations to collaborate independently for time and place. Proposed framework considers subjective facets and employs the clouds beside organizations. So it could be more realistic and more common than other approaches. It employs three layers to classify activities of VBE or VO thus simplifies their management. The framework includes three phases that can be customized with different domains as shown in section 4. The second phase of the proposed framework adopts previous studies. The cloud computing concept realizes VBE movement on cloud. We are going to accomplish this phase to offer VBE movement process in future. We also intend to develop a methodology, which is compatible with the proposed framework to describe its operation in details and to generate corresponding cloud services. Because it considers the clouds as super-provider that can provide any kind of services. Other future works include: establishing common ontology for VBEs on cloud and management of VO on cloud.

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Towards Automated Business Process Deduction through a Social and Collaborative Platform

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Abstract. The French project OpenPaaS aims at providing a social and collaborative platform that supports inter-organizational collaborations. This platform is a social network in which subscribing organizations are defined by their profiles (i.e. their capabilities). In response to a collaboration opportunity suggested by an organization, the IT system intends to automatically deduce a corresponding inter-organizational process, meaning that it enables simultaneously (i) the discovery of the collaborative partners and (ii) the building of a collective business process model. This paper aims at describing the interactions that take place first, between the system and the users and second, within the system between the IT components. It also provides an overview of two specific reconciliations in the context of such a design of emerging networks: (i) functional versus non-functional and (ii) business versus technical.

Keywords: Inter-organizational collaboration, interoperability, business process deduction, ontology.

1 Introduction

Inter-organizational collaborations have dramatically increased these last years in various fields. The Virtual Organization (VO) concept has emerged as an IT solution for supporting inter-organizational collaborations. Two main dimensions gave rise to the *virtual networks of organizations*. On the one hand, Camarinha-Matos et al. [1] explain the concept of *virtual networks of organizations* by faster demands from customers and more complexity concerning products and services. On the other hand, Byrne [2] considers the VO as a crucial factor for a company to increase its competitiveness by quickly adapting to new business contexts and also promptly responding to new tenders. He describes the virtual corporation as a temporary alliance dedicated to fulfill a market opportunity. In this context the ability of the IT system to support efficient interactions between the organizations has become the main key factor for success.

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The OpenPaaS[1] project aims at providing a platform to support fast business interactions between subscribing organizations. This platform provides a *design time* on which the inter-organizational collaborative process is deduced and transformed into a technical and orchestrable process (i.e. the automation of the two first steps of the lifecycle) and a *run time* that provides a support to the third step by orchestrating the process. The design time often turns out to be a *manual* and *time-consuming* task. Moreover it deals with competitive contexts in which the broker wants to find the best partners corresponding to its non-functional expectations (e.g. price, delivery time, geographical location…). This paper focuses on the design time that can be divided as follows: (i) *knowledge gathering* regarding the objective of the collaboration, (ii) *exploration of the potential partners* and, simultaneously, (iii) *selection of the "best" partners* and (iv) *building* of the corresponding "best" inter-organizational *process*.

This paper mainly aims at giving a state of the research concerning the knowledge gathering and the automated building of a process. From these two steps, it gives research directions to simultaneously reconcile process building and the selection of the partners. Section 2 focuses on a state of the art about the support of business process through a collaborative platform, then business process deduction and partners selection. Then Section 3 provides a functional solution for the business process deduction. Finally Section 4 aims at providing a discussion and further research works to extend the latter solution on a two axis reconciliation: functional/non-functional and business/technical.

2 State of the Art

2.1 Business Process Support on Collaborative Platforms

Facilitating business process modeling is a major priority that has been widely exploited these last years. A lot of products have been implemented in order to answer efficiency issues within a company (e.g. Bonitasoft). Closer to the inter-organizational collaborations problematic, some products like Kahua [3], ARIS [4] or SAP Netweaver [5] propose industrial platforms that enable organizations to share processes, workflows and also to exchange data.

With the XaaS (Everything as a Service) technologies emergence, BPaaS (Business Process as a Service) softwares have been created. According to Accorsi [6] BPaaS enables several organizations to work together on a process from design time to run time. Han et al. [7] consider the BPaaS as a scalable solution in that sense that companies pay regarding their use of the software. Moreover it increases the interoperability and the collaborations of the user companies by enabling them to share their own processes.

However these solutions come more as a way for supporting the coordination of the inter-organizational collaborations: the user companies have to design the concerned collaborative process before any orchestration and the partners know they are

[1] `https://research.linagora.com/display/openpaas/Open+PAAS+Overview`

going to work together on a specified collaborative project. Thus the business process modeling takes a lot of time and relies on accurate knowledge about the collaboration (i.e. partners, sequence of activities…). In order to improve the flexibility of collaborative platform and to offer the users more efficiency, the deduction of the inter-organizational business processes becomes a necessity.

2.2 Business Process Deduction

Various frameworks have been established towards process deduction. Enterprise-Reference Architecture and Methodology: GERAM [8] proposes a framework to support enterprise engineering and maintaining. It is specifically process oriented when detailing the lifecycle of enterprises. The difficulty for reusing this work in OpenPaaS relies on the fact that the concepts are too abstract. In [9], Mu proposes a framework based on two types of knowledge: (i) about the partner and (ii) about the collaboration to be set up. The goal is to help organizations that wish to work together to automatically design a business process that responds to the collaborative objectives. First, the partners describe their capabilities; second they propose a new collaboration objective. Thanks to the framework that has been established, from these two kinds of models, the IT system is able to deduce a process cartography that uses the capabilities of the partners. The further research works are mainly based on this framework, however it does not fully respond to the OpenPaaS needs since the partners of the collaboration are not already known. This is why an additional layer should be added to this framework to provide the discovery of the potential partners and then their final selection.

2.3 Partners Selection

In [10], Kulvatunyou et al. describe the use of a semantic-based framework which aims at deducing a distributed process plan that fulfills a specific collaborative goal. Nevertheless, this framework relies on a resource independent model initially given by the broker of the collaboration. The system focuses essentially on the discovery and filtering of the partners. Each partner is described through its profile that lists its capabilities. The selection of the final partners of the collaboration is based on the simulation and the evaluation of each potential manufacturers dependent process plan. Sha and Che [11] describe a genetic algorithm to select the partners of a complex supply chain. The algorithm seems very efficient but is also based on the fact that the main steps of the supply chain are already known.

3 Process Deduction

The deduction of an inter-organizational process is entirely based on semantic links provided by two ontologies: a Collaborative Ontology (CO) that provides generic objectives of collaboration and the capabilities to set up in order to reach the corresponding objective; and a Business Field Ontology (BFO) that specifies the domain of the collaboration. These ontologies allow the system to understand the information given by the users of the platform.

1. *Modeler level* (cf. Fig. 2 left side): first, organizations have to describe themselves in their profiles. These profiles contain all the *capabilities* (i.e. business services) that an organization can provide. These capabilities are linked with *near by/same as* relationships to the CO. *Inputs* and *outputs* should also be described and linked with *hasBusinessDomain* relationships to the BFO. Then, an objective of collaboration can be proposed in the same way, the broker should link it to the two ontologies.
2. *Process deduction level* (cf. Fig. 2 right side): two filters finally provide all the capabilities of the subscribing organizations to invoke in the final collaborative process: FI (cf. Fig. 2) allows keeping the capabilities that meet the objective of collaboration (via CO), and then FII determines the capabilities that also respect the right business domain. Thus, this latter set of capabilities can be ordered into a collaborative process by working on the inputs and outputs equivalence between the capabilities.

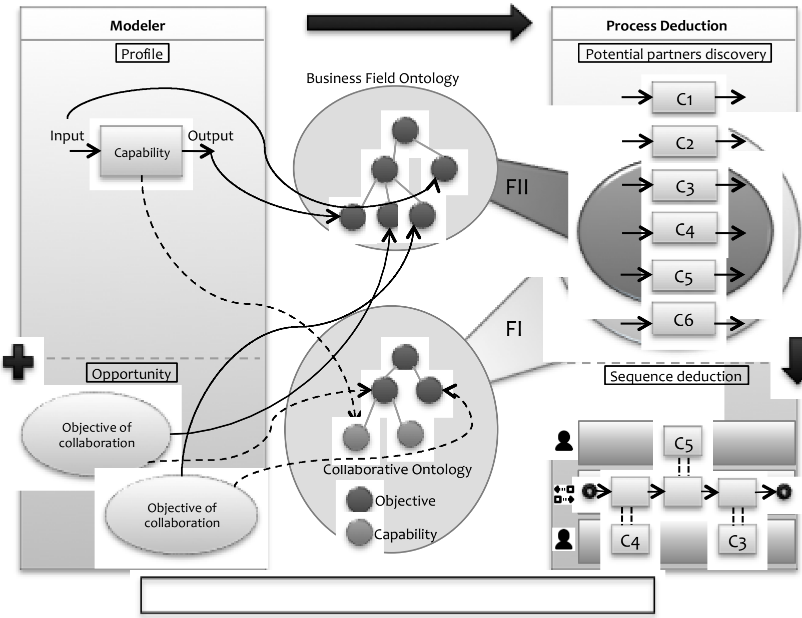

Fig. 1. Functional overview of the OpenPaaS process deduction service

4 Research Direction towards Functional/Non-functional and Business/Technical Reconciliations

In [12], [13] and [14], Mu, Boissel-Dallier and then Zribi have written complementary PhD thesis in the context of the MISE (Mediation Information System Engineering) project [15] (cf. Fig. 3). First Mu provides a method to obtain business process cartography from objectives of collaboration and the capabilities of the partners. Then Boissel-Dallier deduces "technical processes" through business/technical reconciliation and obtains potential technical services and their order of execution. Finally, Zribi provides a way to rank and find the best technical services according to non-functional criteria.

However in the OpenPaaS context, two observations appear:

1. *Non-functional assessment of the collaborative process*: OpenPaaS is a "competitive" platform: several partners could offer the same capabilities but with different conveniences (location, cost…). This is a major contribution that should be added to Mu's approach. Moreover, Zribi's works focus essentially on the non-functional assessment of inter-organizational process, however they are situated in the "downstream" phase, which is the assessment of technical services. These works should be adapted to the business process deduction phase.
2. *Technical reconciliation*: OpenPaaS aims at orchestrating inter-organizational processes. That is why the business processes should be transformed into "technical processes" that can be executed. Boissel-Dallier proposes an approach to achieve this reconciliation: how to switch from *1 to n* business services to *1 to n* matching technical services. Zribi's PhD thesis comes as a continuation of Boissel-Dallier's works, with non-functionnal reconciliation. However the OpenPaaS context leads to reconsider these separate steps as a unique technical and non-functional reconciliation.

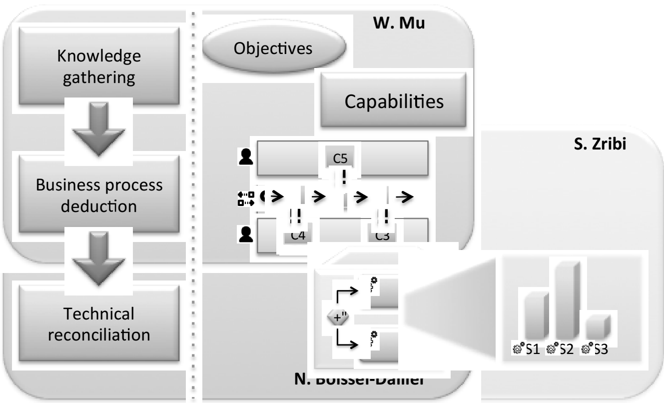

Fig. 2. Contributions in MISE project

4.1 Functional Versus Non-functional

As evoked in the previous part, a non-functional assessment of the process should be added to Mu's works. In this regard, a literature review on non-functional factors for the assessment of collaborative networks has already been written [16]. As a result of this study, a list of 33 criteria has emerged, which goal is to assess capabilities the most exhaustively possible. However, choosing the best capabilities one per one do not automatically lead the best process. This is why *the whole process should be assessed*. Since a large amount of potential partners are expected on the OpenPaaS platform, the assessment of all the potential process would be laborious and time-consiuming. An answer to this issue is based on the simultaneous building, assessment of the business processes and consequently selection of the partners.

4.2 Business Versus Technical

The business process model would be of no use if it were not for a further orchestration. During the orchestration, the system invokes the technical services corresponding to the business services that have been lately chosen. The difference between business and technical services arises because two different types of users are concerned: (i) some have managerial responsibilities and have often a global view of their company, that is why most of the time they will be led to describe business services; (ii) others have technical responsibilities that give them expert view on technical services. Because of these multiple potential points of view, the assumption is made that at least an organization provides all of the business capabilities that can be shared for inter-organizational collaborations. However zero, one or several technical services can respond to a business capability. It leads to two statements: (i) technical services should be non-functionally annotated as well, (ii) final process could by hybrid, with technical services that can be called during the orchestration and business capabilities if no corresponding technical services have been described.

Along with the functional/non-functional reconciliation, technical services should be selected when building the process.

4.3 Towards an Ant Colony Optimization (ACO) Algorithm

In complementary of the method described in Section 3, an algorithm has to be set up to deal with the functional constraints of the process deduction but also the two latter reconciliations. Since a lot of potential solutions are expected, the goal of this algorithm is to find an optimal technical (or hybrid) process.

Moreover, the current approach is based on paths selection: from collaborative objectives to required capabilities in the CO, then from required capabilities to partners' capabilities and finally from partners' capabilities to technical services if they exist.

Although metaheuristic approaches have been widely used in logistics for partner selection for example, they are often based on the assumption that the main steps of the process are already known. In OpenPaaS case, the complexity of the problem comes from the facts that (i) a collaborative objective could be reached by different sets of capabilities and (ii) these capabilities could be provided by different competitive organizations.

It has intuitively led the research towards metaheuristic and more precisely Ant Colony Optimization (ACO). This ACO should indeed allow at efficiently browsing a lot of potential paths, in order to find an optimum. The ACO is based on cycles. On each cycle a certain amount of ants browses the paths and assesses the built solution by setting more or less pheromone according to the non-functional annotations of the collaborative objectives. At the end of each cycle, the pheromone evaporates. Finally the optimum path (i.e. the optimum process) is the path that contains the largest quantity of pheromone.

The Fig. 3 brings a global overview of the application of an ACO algorithm in the OpenPaaS context. It introduces the constraints to be respected by the ants when browsing the paths and the behavior they should follow:

- **From collaborative objective to required capabilities:** the ants browse the CO. They have to discover the capabilities that *contributesTo* the collaborative objective and should duplicate themselves at each node (since the structure of the ontology states that all the capalibities that *contributesTo* the objective are complemantary).
- **From required capabilities to partners' capabilities:** the ants are constrained by the fact that the partners' capabilities should be *sameAs*/*nearBy* the require capabilities. At this step, the paths are competing with each other, that is why the ants have to follow random paths.
- **From partners' capabilities to technical services:** similarly to the previous step, if the technical services exist and have been decently described by the organization, the ants have to browse the technical services that *answer* to the business capabilities.

Finally the path that still contains most of the pheromone at the end of the cycles represents the optimal process that can be proposed to the broker organization.

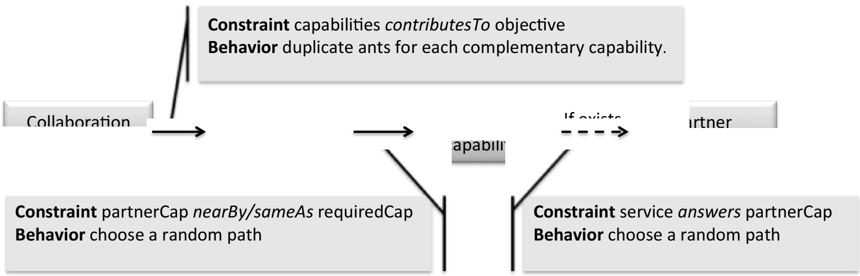

Fig. 3. Overview of the ant colony behavior

5 Conclusion and Perspectives

This paper presents a method to automatically design inter-organizational business process. From the objectives of the collaboration, we propose a method that (i) establish the list of every required capability to fulfill the objectives, (ii) then discover the corresponding partners and finally (iii) link the partners capabilities with each other to obtain the business process. The main contributions of this article lies on two levels: (i) a semantic-based method to functionally deduce a collaborative business process and (ii) a discussion and new investigations on the simultaneous establishment and assessment of a process with business/technical and functional/non-functional reconciliations through an ACO algorithm. Future works have now to be led on these areas of research.

However, the collaborative platform that has been described in this paper suffers from some lacks. First, the question of security and of dissemination of information should be deeply studied: which information organizations would like to share with which others organizations, during design or run time? Moreover this system entirely relies on IT technologies. This means that if the system encounters some technical problems, the supported inter-organizational collaborations could face severe consequences. Some studies oriented towards continuity of service or the data security especially on cloud platforms could be led to enhance the system robustness.

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Virtual Reality and Simulation

Virtual Learning Factory on VR-Supported Factory Planning

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Abstract. Learning Factories are becoming popular as tangible measures to teach engineering methods while making use of them in an industrial-like environment. Their core component is usually a factory demonstrator, users are physically working with. For factory planning such approaches can hardly be adapted, due to long lasting realization phases.

To overcome this obstacle a virtual learning factory has been developed whose core component is not a real factory but a digital factory model. Based on an exemplary product and production model participants learn how to use factory planning methods for a clearly defined use-case. They apply software tools coming from the digital factory and learn how to use VR-systems for validation purposes. The comprehensive digital planning facilitates the collaboration between multiple planning participants. Further extension of the approach towards distance collaboration and use-cases covering the whole product engineering process are proposed.

Keywords: Learning Factory, Factory Planning, Digital Factory, Virtual Reality.

1 Introduction

Learning factories became a relevant measure for companies and research institutions. Several advantages for the industry and also for the research institutions can be united in learning factories.

Every company has to face different challenges on a daily basis. These challenges can result from external factors like governmental requirements or technological innovations but also from internal factors like qualification of employees [1]. For instance, increasingly shorter product life cycles and shorter innovation times for technologies require a more changeable production and a wider knowledge base of employees [2]. Especially establishing, applying and communicating of consolidated knowledge of employees in regard to changing production conditions is a challenging task for companies. Another challenge is the collaboration between employees. Empirical studies on the extent and relevance of communication in projects revealed, that the majority of project managers stated that communication is the key factor for the success of a project [3]. The success of a project depends significantly on the

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collaboration between the participated employees. Several projects will take place where participants are located in the same team or location. But, production networks and spatially dislocated teams complicate the information exchange.

On the other side, also research institutions have to face new challenges. It is expected and required for example by national growth strategies and European programs, that research institutions provide a higher number of graduates with an excellent knowledge based on sophisticated methods and tools [4]. This is challenging due to demographical changes and shorter study periods. In order to meet those expectations and objectives while maintaining the excellence and quality of teaching, new didactical methods with innovative structures need to be applied and communicated.

Learning factories can bridge those challenges from both sides and unite several advantages. They close the gap between real challenges provided by industry and sophisticated methods and tools offered by research institutions. In general, learning factories can be defined as teaching and learning environments in which participants are given the option to consolidate theoretical taught knowledge under real conditions in a supervised environment [5]. Beside the teaching and learning environment a didactical concept is provided. This didactical concept is needed to reassure the success of the learning process. This broad definition of a learning factory is not finalized and leaves the option by which terms the definition will be specified. For example, in the general definition participants can be specified by using the term undergraduate students as well as advanced students or even industrial representatives. Different morphologies are providing helpful lists of attributes to describe and define learning factories [6].

The biggest advantage can be stated in the fact that learning factories consolidate and assure theoretical knowledge by directly applying learned methods and tools to real use cases and conditions. The required theoretical knowledge is communicated by traditional teaching means for example through face to face classes or comparable teaching methods like e-learning. With this theoretical background participants enter the teaching and learning environment. These environments can be part of real systems and processes but usually they are just authentic models that represent real systems and processes. Within these environments, participants can apply their theoretical knowledge and get their hands-on experience by physically interact with the components of a learning factory. Since effects and interrelations of actions can be observed, learning effects can be provided faster and the knowledge is consolidated.

Several organizations, research institutions as well as industrial organizations, recognized this potential and established learning factories at their facilities. However, many learning factories regarding manufacturing systems are dealing with changeability, energy efficiency and lean management methods [7, 8, 9].

Especially within these subjects, real environments or authentic parts of systems can be implemented easily. But, for factory planning such physical learning environments cannot be implemented. The factory planning process is very complex. It consists of several sequent planning phases [10]. Results of the different planning phases cannot be implemented and evaluated directly. The establishment of a comprehensive real model that covers all elements of a factory planning process within a learning factory is not realized, yet. Not only because of the extent of such projects, but also because of the temporal aspects. Traditionally, preparation and conduction of different work packages of each individual planning phase cover a long period of time. A workshop within a learning factory should not exceed ten workshop sessions [6]. In addition, several people from different domains are involved in such a project. A large amount of data and information is generated. Every participant needs a different set of information depending on their personal objective and task. An authentic learning factory of the comprehensive factory planning process could not handle the amount of information.

2 Virtual Learning Factory Approach

To overcome the duration and realization dilemma within learning factories facing on factory planning, the sole virtual execution of a learning factory has been developed at the Institute of Manufacturing Technology and Production Systems (FBK). Its core component is not a real factory but a digital factory model. Here is one main difference to other established digital learning factories, which also use digital tools, but validate the planned factory with physical models. An example is the learning factory advanced Industrial Engineering (aIE) at the IFF at the University of Stuttgart [9]. The focus of this virtual learning factory is a virtual supported factory planning process. The participants will pass different milestones during such factory planning projects. For example, they apply software tools coming from the digital factory and learn how to use Virtual Reality (VR) systems for validation purposes. The participants will experience to interact and how to prepare information in order to collaborate in interdisciplinary teams.

The main objectives of this virtual learning factory are placed in the shortened time period to understand complex interrelations and processes in the field of factory planning, to analyze and to identify weaknesses, and to develop appropriate solutions. Thereby time consuming early and late stages of the factory planning process are substituted by beneficial alternative actions (Fig. 1). The collaboration between the different planning participants is concentrated on the central planning stages. This will focus the attention on the key planning and communication tasks during factory planning.

The early stages (1) objective planning and (2) establishment of the project basis are captured by specially prepared basic conditions. In contrary to most real industrial projects the overall objectives are predefined and the initial situation is summarized in a structured and clear way. This ensures that all required information is available for fast and easy access, inconsistent information from multiple sources will be prevented. The late stages (5) realization planning and (6) monitoring of realization will be captured by an immersive VR-evaluation of the planning results. Therefore the participants will directly create a digital layout model during the learning factory execution which will be the basis for a VR-model. This VR-model will be evaluated by all planning participants against the initial objectives at the FBK CAVE (Cave Automatic Virtual Environment). By providing these two substitutive actions, the implementation of the condensed planning activities within a real industrial project is simulated with limited complexity, while reducing time consuming activities.

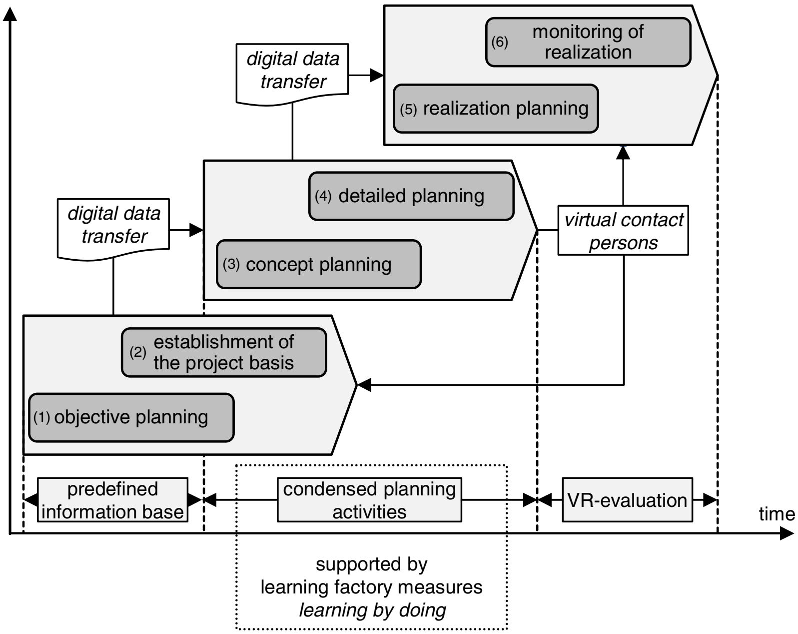

Fig. 1. Placement of the virtual learning factory activities regarding the factory planning process (based on [10])

Hence the major part of the learning factory activities are the (3) concept planning and the (4) detailed planning stages. They form the condensed planning activities in which the creative, collaborative planning activities are methodically supported. The planning participant will develop a factory design to capture the given objectives and to suit the prepared basic conditions. Thereby the objectives and basic conditions are covering the whole set of typically limitations at industrial level. This includes constraints from multiple domains such as product design, production planning, material flow, logistics, ergonomic and security, financial, and architectural. The given objectives from various domains affect each other which makes the development of an ultimate solution a complex challenge that cannot be solved from one single planning participant alone. To address this area of conflict the planning participants need to analyze and divide the overall problem into smaller parts by their own and develop part solutions. The part solutions will be assembled afterwards. This workflow requests a high level of commitment, effective communication, and ability to analyze problems from different points of view from all planning participants. These soft skills are a central ability that is taught by the learning factory.

To allow the sole virtual execution of the learning factory a continuous transition of digital information and planning data is established through the factory planning process. This includes the digital data transfer between the predefined information base and the condensed planning activities (e.g. digital product models) as well as the digital data transfer between the condensed planning activities and the VR-evaluation (e.g. digital layout plan) (Fig. 1). The data transfer is realized by a central server which represents a joint companywide storage systems for factory planning related information.

To allow collaboration not only between the planning participants, but even within the simulated company, virtual contact persons are established. They are described by an organization chart containing responsible persons for multiple domains. In case of discussion demand, planning participants can contact them via e-mail and request information or clarification for certain points. For instance logistic planners can be contacted to get information among used type and number of forklifts. Thereby the organization chart reflects the different source domains of objectives and their interrelationships as well as dependencies.

3 Virtual Learning Factory Design

The following section describes the course outline of the virtual learning factory. The workshop is organized in five phases as shown in figure 2. In those phases, the participants learn the basics of factory planning and apply the methods to a given factory planning project. At the end, the planning results are evaluated in the virtual environment.

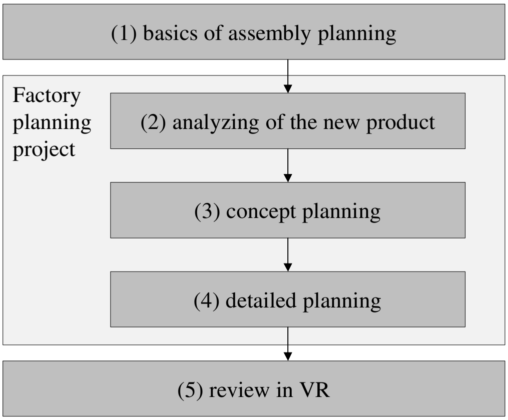

Fig. 2. Phases of the virtual learning factory

A line assembly for truck axles is defined as subject of the virtual learning factory and serves as the application scenario within the workshop. In the scenario, a new axle type will be introduced with complex sub-assemblies determining a wide range of variants. The amount of parts handled within this specific assembly line will increase. The current assembly line will not be capable anymore to carry out the required assembly operations and the reorganization of the current assembly line will be initiated. The major objective in this application scenario is to restructure the assembly line due to these changes in the production program.

The workshop is held and supervised by the Institute for Manufacturing Technology and Production Systems in Kaiserslautern, Germany. In addition to the physical supervision, a virtual contact person will be introduced in the first phase of the workshop which can be contacted for further information to the context of the scenario as well as providing specific data during the execution of the scenario.

(1) In the first phase participants receive the knowledge and tools which are needed to deal with the challenges of the virtual learning factory application scenario. These are the fundamental principles of factory planning. These principles include for example methods for analyzing and optimization of layout plans, material flow, storage concepts, scheduling, and budget planning. In addition to the theoretical foundations taught by the workshop supervisor, the participants are introduced to the application scenario with its initial situation, needs of adaption, and strategic vision. They obtain information among the initial situation and all necessary information in form of digital plans and data in order to start the restructuring task.

(2) In the second phase, the analysis of the product, in this case the new variation of the axles, and the production program are in focus. Different methods are used to generate for example the bill of material, required equipment, or capacity. At this point it is important that the participants learn how to deal with the provided information, how to extract required data out of a given data set and to work independently on a task but also in a team towards a given strategy.

(3) After they had a closer look at the product in the second phase, the participants deal with function structures of the production in the third phase of the application scenario. The concept planning of the assembly area is performed. Based on the product data, the best assembly order of the different parts and subassembly groups needs to be determined. Accordingly, the resources are specified, which are needed for the assembly task. Therefore the cycle time for the assembly process has to be taken into account as well as several different alternatives of tools and machines, for example electric or pneumatic screw drivers with different specifications. Those include for example differences in machining time, costs, required energy supply, noise level, size, safety, and operation complexity. The different specifications have to be weighed with regard to the constraints and restrictions at industrial level. The chosen resources have to be compared with the existing ones. For some assembly tasks, new machines and tools are needed due to the larger size and higher requirements of the new axle. In this phase the participants are learning how to extract and use information from the product data for the assembly program and resources. The third phase closes with a rough layout planning of the production hall.

(4) In the fourth phase the detailed design of the factory layout concludes the application scenarios. Within this phase, the concept planning gets detailed out. The exact arrangement of all the resources is defined. Also details regarding the subassembly groups are discussed as well as questions regarding the layout of the different working stations. First, the participants have to examine which assembly types are useful for the assembly of the new axle variation. Further they investigate what assembly type arrangements are possible and reasonable. For example, if there are any significant advantages of a specific assembly type or if there is no need to change the common line. After details regarding the assembly line, the detailing of

workstations is discussed in the next step. Here, the number of workstations and the allocation of assembly tasks to workstations is determined. At this point, it is important to meet the requirements of the program planning by designing the resources accordingly and adjust their capacities. Regarding the layout of different workstations, the participants apply the basics of layout planning. Boundary conditions of the given production hall must be considered. This includes the positions and orientations of the work places, tools, and machines. Also considerations concerning the dimensions of the axle, workstations' exposure to light, legally noise limitations, and occupational safety must be discussed. Storages and buffers have to be planned accordingly. Different methods and tools regarding the planning and visualization of assembly lines in 2D and 3D are focused and internalized. Altered arrangements of assembly stations can be visualized to see the effects and impacts of different formations. For instance, a net plan can be an effective tool to visualize the logical order and connections of the workstations and the subassembly and the assembly line. In this phase, the participants learn to plan workstations for the main assembly and the subassembly groups. This includes methods of capacity planning, schedule planning, and layout planning tools. The outcome of the detailed planning phase is the final layout and process plan of the new assembly area for the new truck axle with its subassembly groups and variants.

(5) In the fifth phase the final layout is evaluated which concludes the application scenario. The data is converted in a VRML-file, which can be read by the VR-System at the FBK. The 3D VR-System at the FBK consists of a 4-sided CAVE with Tracking Cameras. Here the participants of the virtual learning factory have the opportunity to analyze and evaluate their planning results together with the supervisors in a realistic way. They are given the option to walk through the new assembly scenario and identify critical sections. During that review, some obvious inaccuracies in the planning are determined, like tight walkways or neglected safety areas. The trainers will indicate more subtle problems in the layout and suggest solutions.

4 Outlook

Learning factories close the gap between theoretical taught knowledge and industrial hands-on experience. They unite the advantage of bringing together sophisticated methods and tools offered by research institutions and real challenges and problems stated by industrial organizations. This paper introduced a virtual learning factory that focuses on the condensed planning activities of a virtual reality supported factory planning process. It discussed why in cases of factory planning a virtual solution is needed. A special focus is set on the collaboration between the participants and how to handle and prepare a large amount of information.

In the future analysis are planned to compare the learning effectiveness of such hands-on experiences with established learning methods (e.g. through books, within real factories). Further the virtual learning didactic model will be improved, by purposeful usage and application of specified factory planning methods according to the participants' background.

The growing number of established learning factories mirrors the importance of the subject matter. In order to meet demand from industrial side and the offer on research side, learning factories must differentiate and complement each other. Therefore, a further extension of the approach towards distance collaboration and use-cases covering the whole product engineering process are aspired as well as the collaboration with other establishments in order to create a network of learning factories.

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Augmented-Reality Application for a Seru-type Manufacturing as Lean as Possible

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Abstract. The goal of this paper is to discuss the island-based organization of a manufacturing-assembly system, based on the Seru-Seisan approach, whose main goals are to decentralize the production line and to improve personnel qualification. The aim is to show that a Seru-type production island/cell can be really profitable in case the operator could be supported by augmented-reality tools, such to help him in any complex processing operation. The efficiency/effectiveness of a Seru-type organization will be proved by verifying that it satisfies the main principles of “lean manufacturing”, stated in terms of mathematical formulation of both the lean goals and the lean processing model. A practical validation of the Seru-type approach will be done by analyzing an assembly unit, now under development and testing in CNH Industrial, where the operator is supported by an augmented-reality system designed in cooperation with Regola S.r.l.

Keywords: Seru-type manufacturing, cell manufacturing, augmented reality.

1 Introduction

In the last years a deep revision of the organization of manufacturing processes is attracting increasing interest in managers of big and small industrial companies [1]. Two main lines are under discussion, to search a good compromise:

- on one side, the need of an organization of production systems as lean as possible, thus having simple manufacturing stages, continuous forward flows of items and backward flows of internal orders, needs of production management efforts and personnel "reduced to the bone";
- on the other side, the desire of more and more qualified personnel, so as to be secured against inefficiencies and reductions in product quality, but also to be able to decentralize some autonomy to the operators and reduce the management weight.

The first need seems to call for production lines with a "pulverization" of the processing steps, followed by a de-empowerment of operators: this is the situation that is felt in number of manufacturing companies in the automotive industry.

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The second desire seems to search for production islands with a “concentration” of the processing operations, with the need of a higher qualification of the staff: this situation is under consideration mainly in the electronic enterprises [2].

This contribution is focused on the second point above presented: the scope is to discuss the island-based organization of production according to the Seru-Seisan approach to decentralizing JIT through personnel qualification improvement.[3]

The goal is to present a seru-type assembling unit, now under development and testing in CNH Industrial, with the design of the augmented-reality support for the operator done by the SME Regola S.r.l.

Seru-seisan (“seru” means cell, and “seisan” means production) appeared to be an innovation of the production management made in Japan, recently [4]. It emerged from a very complicated environment of mixed factors both in and out of Japan: change of demand to high variety and low volumes; low flexibility of the conveyor lines; low employee morale resulting from work circumstance and enterprise culture; limits of the Toyota Production System, i.e. there is insufficient evidence at present to show that the Toyota Production System can achieve as great efficiency in other industries as in the auto industry.

Indeed, “cell production” (also denoted “cellular manufacturing” [5]) has been implemented in different business industries in the US and Europe for decades, based on Group Technology principles.

Cell manufacturing and Seru Seisan both have high flexibility, but the mechanisms behind the two systems are different. Seru Seisan production no longer treats each product separately as job shop does. Instead, it groups similar parts or products into a part/product family according to the characteristics of the parts/products, the similarity of process, and the manufacturing methods. All of the equipment are grouped by the similarities of products rather than the function of machines.

However, Seru Seisan is mainly applied in the electronic industry in Japan, and it seems that it could difficult to implement on heavy products with complex processes.

The aim of this paper is to show that a Seru-type island of production (in the considered case, assembly of a distribution center for the oil pressure driving a small excavator for road work) can be really profitable in case the operator could be supported by augmented-reality tools, such to help him in any complex processing operation.

2 From Cellular Manufacturing to Seru

In a production system, the origin of wastes can be ascribed to different sources: the excessive levels of stocks, the presence of unnecessary operations, the presence of long waiting in the process and the low quality level of manufactured products.

Important results on reduction of wastes and costs have been obtained with the born of the Cellular Manufacturing theory. Cellular Manufacturing is a product-oriented approach that introduce a reorganization of the plant into cells. Each cell is designed to contain all the necessary resources such as machines, workers, tools in order to produce a product or a family of products from the beginning to the end.

The adoption of the cellular manufacturing reorganization introduce significant quality improvements, moreover, thanks to the product-oriented approach, production systems so organized tend to be more customer focused and responsive to customer needs.

Important role in a cellular manufacturing environment is given to the training of the operators because they have to be able to do a great number of activities for a family of different products. The advantage is that an operator in one area can see how his actions change the product and how it impacts on the downstream activities. This usually generates improvement ideas, a higher efficiency and higher quality levels. This explains why the training of workers plays a crucial role in a cell manufacturing. In this paper an application of new technologies for the support of the operators activities is described.

Many companies, like Sony, Canon and other electronics industries, have reconfigured their conveyor assembly lines and adopted seru production; it is considered as the ideal of lean production systems [6]. This innovation in the plant organization consists in a human-centered production system where the long line is replaced by many short ones. Seru Seisan is suitable for processing light and small products, such as electric products, which are mainly manufactured manually, or with simple equipment. Seru Seisan is difficult to implement on heavy products with complex processes. Seru has many benefits. It can reduce lead time, setup time, WIP inventories, finished-product inventories, costs. Seru also influences profits, product quality, and workforce motivation in a positive way [7]. The main issues of implementing a Seru system is to decompose the process line into an opportune number of serus [8] and then to decide the number of workers to assign to each seru and compute the total training costs [9-10].

3 An Insight into Lean Principles

Let us briefly describe the principles of the lean manufacturing and to introduce some formulation in order to identify the theoretical framework that the collaborative system, based on an augmented reality technology and described in next section, wants to respect and with which wants to be compliant. The main concept of the lean thinking is “value”; value can only be decided by the final customer because only a small part of the production activities is recognized, by the customer, to introduce value on the final product. Costs are strictly related to the price, and then to the value, with the profit equation, so we can say that value is a function of costs. If the value increase with the cost, we can say that the operation is of value added, otherwise the operation represents a waste. In a formal description we can say that if

$$\partial V_i / \partial c_{ij} > 0 \ . \tag{1}$$

the operation *j* on product *i* adds value, otherwise the value doesn’t increase.

Once the real value (i.e. the price that a customer can spends for the product) for the final customer is identified, all the activities with a non-positive derivative must be targeted to be removed. The value stream is the sequence of activities j=1, …N, that add value on the product.

In order to reduce waste due to the levels of inventory, in a lean manufacturing the production system follows a "pull" approach where production is "dragged" from demand requirements and not on forecast or to produce products for the inventory. The pull system is quite easy and efficient, with few information it is possible to drag the production and satisfy the customer demand. If I is the inventory level, by applying this principle we can say that the inventory level is minimum and it does not change, in formula the two equations are true:

$$\partial I_i/\partial t = 0 \qquad \text{and} \qquad \partial^2 I_i/\partial t^2 > 0 \tag{2}$$

A characteristic of the lean manufacturing is the "one piece flow": it is a way to organize production with a continuous flow of pieces from a production phase to another. The advantages from this principle are the reduction of Work In Process, more flexibility and a more comfortable layout in the plant because machines can be allocated into a logical way following the pieces' flow. With the one-piece flow it's also possible to easily decompose the total cost into the unit cost for each product like the sum of the unit cost of each operation. If we consider a production system that is a line with N activities, the unit cost for each product i is:

$$c_i=\Sigma_j c_{ij} \quad j=1,\ldots,N\,. \tag{3}$$

The Takt time is the time when a productive unit must be obtained from the production process. The takt time is defined as

$$\text{Takt time} = \text{Available working time / demand}\,. \tag{4}$$

The Hejunka principle is to reduce production lots to the minimum size in order to have no variation on the inventory level. If there are no variation on inventory costs they can be considered constant, so every consideration and every effort on cost reduction doesn't involve the stocks.

An important prescription of the lean thinking is to stop the production as soon as a problem occurs avoiding the production of products affected by defects, in this way the defects detection is at each stage of the production line and before to go on with the next process the correction of the error is required. This principle has relevant consequences on the real cost computation of each product, in fact, the real cost of a particular activity depends from the output of the previous activity. If the output is not affected by defects, the cost of activity j is equal to the typical production cost of activity j, otherwise, if the output of the j-1 activity is affected by errors or defects, the real cost of activity j on the product i is equal to the effective cost of activity j plus the defects correction.

$$c_{ij}=f(c_{i,\,j-1})+p_{ij}\,. \tag{5}$$

where f is a Real non-negative function that relates the cost spent in the previous activity with the defect that must be detected and adjusted during the current activity and p_{ij} is the characteristic cost of the activity j for product i.

Another consequence of this principle is the importance of the presence of tools that can support the defect detection and the correction of errors in order to reduce the value of function f. The lean thinking allows and suggests the utilization of visual and automatic control in order to put in evidence every problem on the product.

An important suggestion of the lean thinking, that we will see implemented in the application described in next section, is the utilization of every tool that could help by supporting process. An example of support given to the workers is a real time training tool that can help the worker in order to identify the operation that he has to do in a specific process activity.

4 Application of an Augmented Reality Technology for a Lean Production Cell

The project, designed and developed by Regola S.r.l., consists in the study and implementation of a pilot software/hardware installation at the plant of New Holland Construction in San Mauro. The installation is a tool that must support the assembly operations of joint Mod 35-39 by showing the operator, the mounting sequences in augmented reality and by creating checks and controls in order to reduce or eliminate the possibility of human errors.

The goal of the project is to eliminate the human error in the assembly even when the operator does not have the specific experience. The solution found is so versatile that can be seen both as an important tool of training and a controller for the error detection and correction.

This is a pilot project to assess the use of technology choices and possible engineering solutions; it provides outputs useful for a possible application of the same instrument in other stages of production.

Regola S.r.l. noted, during its market research and by contacting various companies in the industrial sector, that there is a real need to provide instructions to the operator in real time and to verify the correctness of the operations performed during the assembly of complex components. Regola S.r.l. is developing an integrated tool that, using computer vision techniques, will verify the correct execution of the assembly or maintenance operations in terms of sequence of steps and correct positioning of parts and components to avoid mistakes and dangerous operations.

The application involves the combined use of augmented reality for the visualization of correct procedures and technologies with RFID tags applied to tools (i.e. torque wrenches) and mounting hardware for verification and operational control. The augmented reality is a variation of virtual environment in which the user is immerse inside a virtual environment. While immersed the user can see virtual objects superimposed upon or composited with the real objects around him. So the virtual reality doesn't replace the reality but introduce supplement objects that can give important information [11]. The acronym RFID stands for Radio-Frequency

IDentification; it is a wireless use of radio frequencies to transfer data with the objective to identify tags attached on objects.

The installation consists of two computers connected to each other via a network switch. The computers are equipped with a keyboard and mouse that are used exclusively for service needs (software updates).

To the network switch is also connected an RFID reader connected to the computers via a local network. The player is equipped with two antennas necessary to read the RFID tags. The two antennas are connected through coaxial cables, arranged so as to cover the two external mounting (mounting fittings and hose assembly). Each PC is equipped with a monitor (box 1 in Fig.1) connected via VGA cable, a functional keypad and a camera connected via a USB hub.

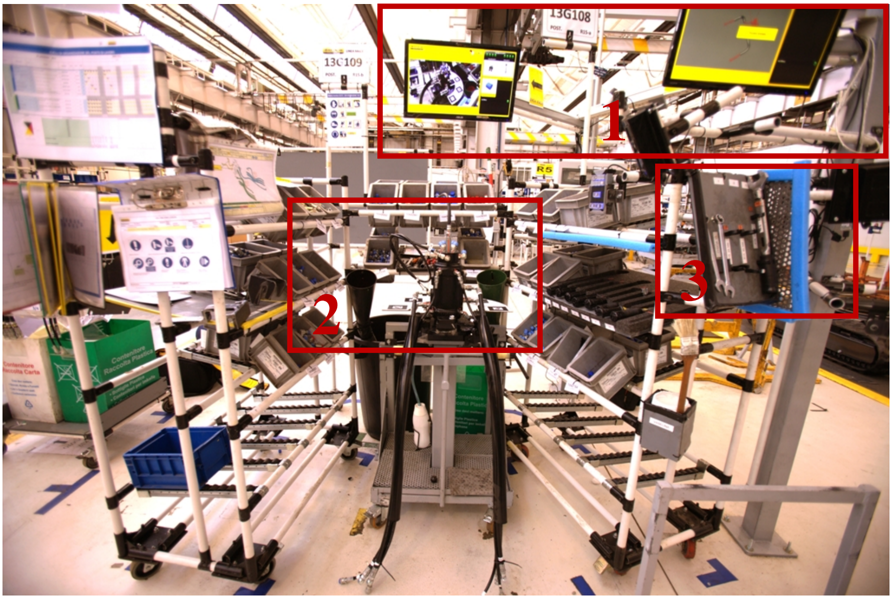

Fig. 1. Prototype of a Cell. Box 1: monitors connected with the computers; box 2: assembly station; box 3: control unit

The cameras are connected to the USB hub with a USB cable, shielded and amplified. The position of the piece to be worked is highlighted with box 2 in Fig. 1, in box 3 of the same figure the control unit, using by the operator to manage the application, is shown. During the assembly, for a correct positioning of the virtual objects on the monitor, a DIMA with MARKER is used. The system reads the position of the markers using the camera, and according to it, place the virtual objects in the scene. Incorrect positioning of the jig will lead to a misalignment of the virtual objects. This technique allows to follow all the stages of assembly of complex components, showing the operator the correct sequence of assembly, dropped on the real scene and establishing operational checks and controls. The torque wrenches, used during the assembly operations, are equipped with Tags. The tags are glued on the keys on both sides to ensure the reading by the antennas regardless of the position with which they are presented. Once the model of the coupling is selected, the first step of the procedure is shown on video together with several information that can be expressed in different forms: textual form, graphic form, in the form of 3D animation of augmented reality. The animation of augmented reality are superimposed on the video stream taken from the camera and the operator can manage the video if he wants to see again the procedure, to go back to the previous procedure in case of defects or to go on. Information available on video is shown in Fig. 2.

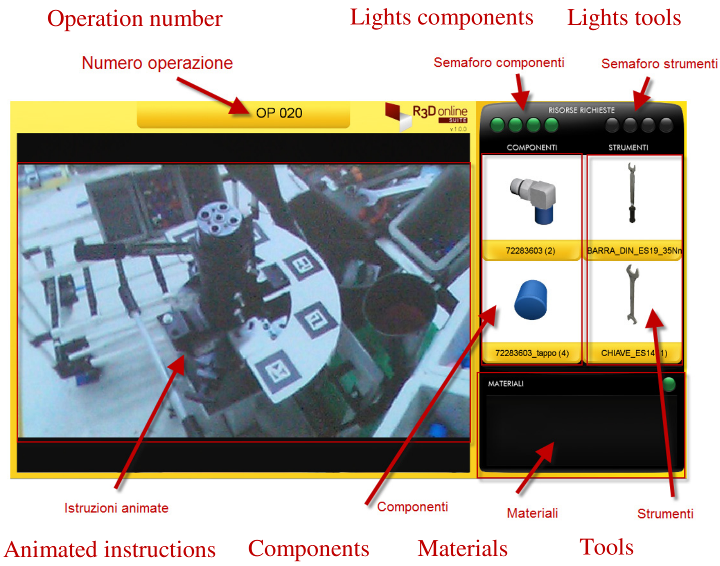

Fig. 2. An example of a video visualization

The numbers at the top correspond to the code of the operation (operation number) visualized on the display. In the main central part of the video are provided to the operator the instruction with the animation in augmented reality. Cameras positioned in the working cell can recognize the working step and the operation that must be done ant it is suggested to the operator with an animation that shows the correct operation. On the right of the video there is the list of components, materials and tools that must be used, both in graphic form and as codes. If necessary (transactions with torque wrenches) the system reads, through RFID antenna, the tag pasted on the torque wrenches, to determine if it is the correct one or not. The system is calibrated to detect the torque wrenches without the need to bring the instrument to the particular antenna. If it detects any incorrect torque wrenches it is displayed a visual signal with the ignition of the red traffic light in correspondence to the tools. At the same way a correct reading of the instrument will turn on the green lights in correspondence of instruments.

The described system is an integration of different technologies and software and it is connected with informative systems able to collect information coming from the productive cell that are used from other functions of the production system.

5 Conclusion

In this paper a formulation of the lean principle is proposed in order to underline the consequence of the application of lean principles in the computations of costs and value for the customer. The functions and the uncertainties for the costs computation can be controlled with tools, compliant with the lean prescriptions, that can support the production in a system reorganized according the cellular manufacturing approach. The application described is an innovative example of how new technologies, in this case based on the augmented reality and RFID, can support the workers during an assembly operation in order to reduce training times, to reduce requirements on the worker expertise and improve the quality level. The described tool has the double role to train the operator on the correct operation reducing the training time and improves quality by including a system of detection of errors providing also instrument for their correction. The presence and the action of the tool does not influence the production time, does not increase the production times and redesign the system in a way that is still compliant with the WCM methodology.

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Collaborative Web-Based Simulation Platform for Construction Project Planning

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Abstract. This paper presents a process-based simulation toolkit CST and collaboration platform ProSIM to support planning of construction projects using simulation methods based on Building Information Modelling (BIM) and multi-model data exchange approaches. CST uses reference process models for construction activities and addresses data interoperability problems caused by the diversity of available CAD/BIM and project-planning software. The online collaboration platform connects design, planning, construction, and simulation experts together and enables an efficient communication and information sharing. This paper focus mainly on the collaboration and data interoperability aspects of CST and ProSIM in order to enable a wide adopting of simulation methods for planning of construction projects.

Keywords: project planning, simulation, data interoperability, collaboration.

1 Introduction

Simulation methods have been used to optimize and improve the planning quality in many industry sectors like manufacturing and logistic since long time, and they are integrated as an essential part of the whole design and planning process. However, in the construction industry, the use of simulation methods for planning has not been widely adopted, it is limited to analyse and solve problems in an ad-hoc manner (simulation study or simulation-on-demand) at certain time point of the project life.

Simulation studies have been carried out in most cases through external simulation service providers on project basis and they are not a basic part of planning process. The application of simulation techniques for construction projects is a very promising but also a challenging field of research [1]. While great advances have been made in construction simulation over the past few decades, adoption by industry has lagged, for three potential reasons: simulation is not accessible, it cannot handle the complexity of modern construction projects, and the benefits are not immediately obvious [2]. Creating reliable and reusable simulation models is very complex, combined with high costs of software licenses and personal training for in-house simulation. Thus, providing convenient simulation tools and web-based collaborative platforms with low-cost entry is crucial to promote a wider adoption of simulation in construction industry.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 471–478, 2014.

This research work, which is partly developed in the project Mefisto "Management, Leadership, Information and Simulation in Construction" (http://www.mefisto-bau.de), aims to make a paradigm shifting of traditional simulation studies to be an integrated part of the planning process for construction projects. The main contributions in this research are: (1) Using formal reference process models based on BPMN to describe the construction and logistic activities, (2) Integration of a multi-model approach to exchange structured project data with the simulation environment to enhance data interoperability, (3) Implantation of a construction simulation toolkit CST and a collaboration platform ProSIM. CST is a process-based discrete event simulation toolkit for construction project planning [3]. It aims to accelerate the process of creating simulation models for production and logistic operations. Simulation models built with CST will help to verify the feasibility of a given schedule against a combination of different resource constraints or different building design alternatives. It aims to improve the quality of projects planning by reducing the total duration and cost of construction projects and improving the utilization rates of resources.

The target of this research is to promote a wide adoption of simulation methods to be an integrated part of the planning process for construction projects through the whole project life cycle. In this approach, simulation models will be created once during the early design phase and accompany the project progress from primary design and planning phases until the end of the construction work.

2 Process-Based and Multi-Model Data Exchange Simulation Approach

Construction is teamwork and successful team operations rely on collaboration. Because of the complexity of the construction industry, the multiple phases of the construction project lifecycle, the involvement of multidisciplinary teams (including owners, architects, consultants, engineers, contractors, sub-contractors, and suppliers), and the use of heterogeneous software and hardware systems/tools, systems integration becomes an important prerequisite to achieve efficient and effective collaboration [4].

The complexity of simulation models for construction projects and the increasing volume of information raise the need to adopt new collaboration and project data exchange methods. As the project size grows, the number and size of teams will increase. An interoperable and smooth data flow between planning and simulation experts and their tools is a key factor to reduce the time and efforts required to collect and update project data regularly. In our approach we use reference process models to manage the knowledge in the construction domain collaboratively and a new method to exchange project data based on multi-model method.

2.1 Reference Process Models

Reference models are generic conceptual models that formalise recommended practices for a certain domain [5]. As the knowledge in every domain is keep evolving, the reference models will go through the known approach "discover, model, evaluate, and optimize" so new models will be added or existing models will be improved and detailed with time (Fig.1). Therefore, a continuous collaboration between planning, construction management and simulation teams is very important to validate and integrate the feedbacks during the construction phase and embedded them correctly in the reference models. The reference process modelling method allows identifying, capturing, documenting, improving and sharing knowledge about the best practice of construction processes and their related information

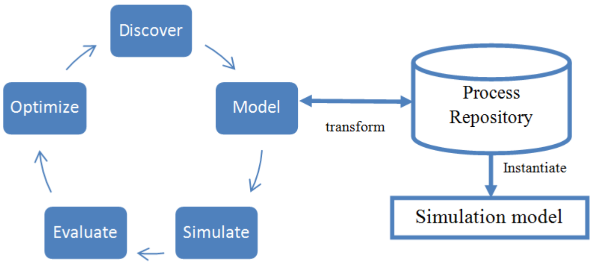

Fig. 1. Reference process models life cycle

In our approach, there is a clear separation between the core simulation engine and the process models for the application domains. Business Process Modelling and Notation (BPMN) models are used to capture and describe the logic of production and logistic operations and to transform them directly into simulation models.

Extension elements are introduced in order to define resource requirements and durations of tasks. Each activity or task inside the project schedule can be linked with a reference process model during simulation. In this way, the process models define the logic and level of details of simulation models. One needs to carefully examine every detail of the construction process and identify the major events and processes that will be presented in the simulation model in order to create a reliable simulation model [6]. The graphical representation of BPMN models makes models easy to understand and the formal specifications in XML allows transforming process models into simulation models automatically. The BPMN reference process models can be imported into a process repository in the simulation mode (Fig.2). The process repository includes reference process models for the best practices of various construction processes that are reusable across different construction projects and their data definitions of resources and productivity factors.

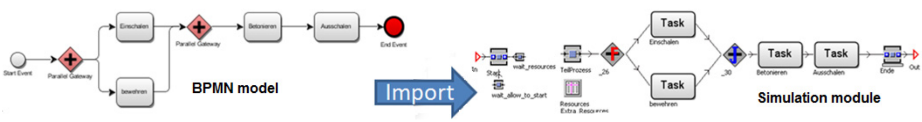

Fig. 2. Transformation of reference process models to simulation modules

2.2 Multi-Model Approach to Exchange Projects Data

Multi-model project planning is a paradigm shift from the building-centric approach, which tries to add and link all project data with building models toward an equivalent interlinked data models using special link models. The multi-model method offers solutions to structural problems of nD modelling in construction information processes [7]. A multi-model container comprises several data files and includes, besides the meta-information about the container content, several application models as well as link models [8]. It allows the combination of heterogeneous application models from different domains and various data formats. Inside multi-model containers link models bind the application models together. The link models specify the relationships between items from different data models. Multi-model containers can be used to exchange associated models among the project stakeholders by a common format. In their entirety the multi-models on a construction project open up a multi-dimensional information space of interdependent application models that can be independently processed by the project participants. Each participant has the opportunity to produce new application models on his/her own responsibility and interlink them with existing models. Depending on the situation these newly created multi-models can be maintained locally or published project-wide as a basis for further planning and controlling tasks. In comparison to the often pursued integration of project information in central project databases or product model servers, this approach distributed model-based collaboration represents a paradigm shift [9]. Multi-model approach is integrated with CST through providing import/export interfaces.

3 Collaboration Platform ProSIM

ProSIM is a web application designed and implemented especially for CST to work as a communication and collaboration layer between the simulation team and other design and planning teams. The main functions provided by ProSIM are:

- Share project data and keep them up-to-date: BIM models, project schedules, process templates, productivity factors can be updated at any time to reflect the actual state of the available information.
- Import and view the simulation inputs of various data models and multi-model containers directly inside the web browser.
- View and evaluate simulation results through online viewers to display results inside a web browser or download them using standard formats
- Manage construction process templates.
- Manage productivity factors, definition of resource requirements, and task duration of construction activities.
- Add, edit and run simulation experiments remotely.

Simulation models and their inputs and results will be available and re-runnable anywhere and responsive to any data update. The visibility of all input data and simulation parameters helps to identify errors and leads at the end to a better understanding among the planning and simulation teams and offers a high level of transparency and trust. Available API interfaces beside the simulation database connectivity make it possible to build integrated data management services around the simulation core components and offer it as Software as a service (SaaS).

Web-based simulation has many benefits over the classical desktop simulation systems, main advantages of using a web-based simulation tools are [10]:

(a) Collaboration: Communication and interaction are one of the essential factors to achieve a successful simulation project, (b) Cost reduction: traditionally the starting investment for a typical simulation environment or external simulation consultant are on a high level, the web-based interface allows new business models for the use of simulation services, which can be rented for an interval of time, this resulting in savings in terms of possible previous prohibitive factors of time and cost, (c) Wide availability: A Web-based simulation application can be used from anywhere in the world with an Internet connection, (d) Integration and interoperability: A Web-based tool can integrate and interoperate with both existing and future Web-based applications.

The main ProSIM collaboration features in the different project phases are:

Pre Planning phase

- Share and manage information about reference process models, productivity factors for workers and machines, and resource definitions of construction activities.
- Define the minimal requirements of information in BIM models and modelling guidelines based on the reference process models and scope of simulation study.

Design and planning phase:

- Provide import interfaces and online viewers for BIM and project schedules.
- Visualize and archive results for each simulation scenario.
- Change simulation parameters and run simulation scenarios remotely.

Construction phase:

- Collect real-time data from construction site and update the simulation model according to the real project progress and the changes in the construction site layout.
- Update estimated productivity factors and duration formulas based on actual duration of executed tasks.
- Improve reference process models continuously.

The real-time data collection aims to support project planning and simulation with accurate feedback during project execution phase. For this purpose, a developed solution based on RFID technology is envisioned [11]. This solution proposed a mechanism for semi-automation data acquisition on construction site throughout coupling the BIM/planning models and the physical construction using cheaper passive RFID tags. From collected and validated data the construction process progress can be derived and therefore as-built data extracted. This information can be send as inputs data to the ProSIM platform using an API interface leading to short-term simulation loops.

4 Prototype Implementation and Validation

This section describes briefly the system architecture and the prototype implementation of ProSIM.

4.1 Platform Architecture

The platform architecture consists of five main modules (Fig. 3): (1) Simulation engine (2) Web server (3) Simulation database (4) BIM data server (5) ProSIM web application.

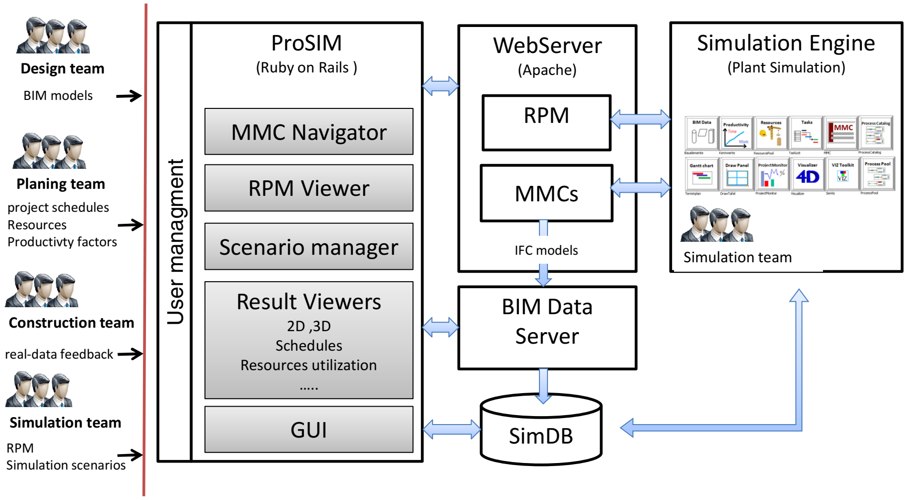

Fig. 3. System architecture and data flow

4.2 ProSIM; Technical Implementation

The ProSIM platform is designed as a Web-based system and implemented using the framework Ruby on Rails and the Web application is deployed via the Apache web server. The server-side data are stored in a SQLite database. The BIM and 4D simulation results models can be shown using a WebGL viewer based on the JavaScript 3D library "threejs" and Collada format. Ruby on Rails is suitable for rapid development; it emphasizes the use of well-known software engineering patterns and principles, such as active record pattern, and model–view–controller. The technical implementation has resulted in a rich web application with a REST API interface.

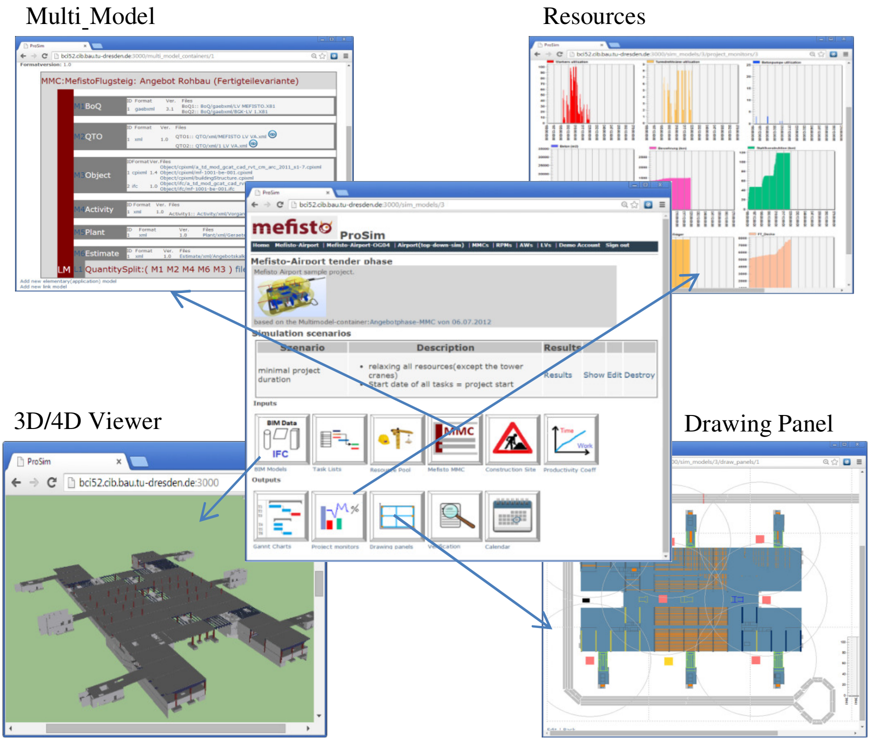

Fig. 4. A screenshots from a test case simulation model inside ProSIM

4.3 Validation and Test Cases

The CST simulation toolkit and the prototype of ProSIM platform were tested and validated based on two construction projects (multi-storey office building and an airport terminal). The easy access of projects data and simulation models through the online platform encouraged and enabled a collaborative work between different planning and simulation experts from different firms and helped to verify all input parameters and simulation results effectively. Some snapshots of a test case simulation model inside ProSIM are shown in Fig. 4. Simulation models of test cases can be accessed at: http://bci52.cib.bau.tu-dresden.de:3000

5 Conclusions

The target of this research is to promote a wide adoption of simulation methods to support construction project planning. Systems integration and collaboration are believed to be the key enabling technologies that drive the construction industry in improving productivity and efficiency [4]. This paper presented the integration between a process-based simulation toolkit and a collaborative platform. It discussed also the use of reference process models to capture and manage knowledge in construction domain and the use of multi-models improve data interoperability.

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Interoperability and Integration

Sharing through Collaborative Spaces: Enhancing Collaborative Networks Interoperability

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Abstract. Within collaborative networks, information sharing and knowledge creation are the main drives for value creation, wherever collaborative spaces (CS) has been used as the means to enable collaboration among the different social actors involved. Despite of technological availability, CS still a challenge in practice, mainly due to the lack of methods to support its development and to its tight coupling with the collaboration model adopted by the network. Thus, the main focus of this paper in on enhancing information sharing through the design of what we call agnostic collaborative spaces (ACS), supported by linked data approaches. Beyond this new perspective over CS, it is discussed a technological solution through which ACS are implemented.

Keywords: Collaborative spaces, semantic interoperability, Linked-data, Information sharing.

1 Introduction

Although the concept of collaborative networks (CN) are well defined [1], effective collaboration across organizations still a challenge, not so much technologically, but on how to manage information and share specific domain knowledge, between different social actors within dynamic and heterogeneous environments. Commonly, CN are driven by distributed activities requiring high levels of social interaction, wherein the processes of information management and knowledge sharing are of particular importance. The interest for knowledge management emerged, on one hand, driven by the need to be aware of all organization's stakeholders and their needs, and, on the other hand, to increase creativity and innovation by interrelating information towards the development of new techniques and technologies [2]. Nowadays, these demands (creativity and innovation) have gained a new dimension, and traditional approaches to information management, which merely collects and transmits items of static and un-contextual data, are no longer efficient. Beyond interlinking companies it is necessary to interlink data and people, mapping it all together. That is the way to effectively reach new levels of collaboration, fostering collaborative learning, innovation and creativity. This paradigm shift changes the view over the CN, whereas

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a network of organizations, to a wider view comprising a major network combining data, people and concepts. Collaborative spaces (CS) appear as the technological implementation of the different CN models, assuming different formats according to the model of collaboration and formality level. We share the view that the operationalization of CN in practice might be supported by the concept of CS, however without a commitment to a particular formalism, technology or collaboration model and capable to support network actors to share and retrieve information within and beyond CN boundaries. Hereupon, the main focus of this paper is on enhancing information sharing through the design of what we call agnostic collaborative spaces (ACS) supported by linked data approaches. ACS are virtual spaces in which all participants in dispersed locations are able to interact as if they were in the same local organization, but ensuring an independence of the collaboration model adopted by the CN. Furthermore, ACS intend to provide an environment giving support for participants to gather, search, retrieve and share information, assisted by semantic artifacts (ontologies), either individually or in group, and without the need to commit the participants to a specific workflow and without any social and cultural barriers. Our view is that linked data might play a crucial role to implement such an environment.

2 Background Knowledge

2.1 Collaborative Networks and Collaborative Spaces

The concept of CN encloses several formats, including: Virtual Enterprise (VE), Virtual Organization (VO), Dynamic Virtual Organization, Extended Enterprise and VO Breeding Environment (VBE). Each of these categories is very well defined in literature [3]. Some authors argue that CS might be used as mediators for information sharing in CN, supporting its basic operations [4]. Additionally, we consider that CS should encourage creative and critical thinking by means of clear and intuitive communication and information retrieval mechanisms, implemented as a service. The literature discusses around how different types of CS (e.g. community of practice [4], social networks [5] [6], community of interest [7], professional networks, etc.) support collaboration between organizations, or about what are the effects of inter organizational collaboration for the organizations [8]. From here, knowledge creation is evidenced as a key benefit. As mentioned earlier, technological solutions do exist to implement such collaborative environment. Yet, it is easier to talk about collaboration and CS than implementing it in practice. Despite of some authors argue about the lack of methodological support to develop such environments [9], some efforts have been developed to setup virtual spaces for individual and groups to discuss around domain knowledge within a CN, by means of dedicated methods and tools [10]. An additional challenge relates to the fact that a CN does not remain forever in time; it follows a life cycle, which might comprise five different states, from its creation to its dissolution [11]. In fact, it is possible for an organization to establish several partnerships (during its existence) through the formation of new CNs. This would imply a considerable effort for an organization since in each case, there may be the need to (re)adapt itself to: i) new collaboration and network model; ii) new information sharing workflows, supported by different CS and tools. This could be an unaffordable situation for many organizations. By analogy, if CS are the vehicle of collaboration, in order to ensure information transfer within and between organizations, it shouldn't be necessary to acquire a new drivers license, every time we change from vehicle. This research work provides a new perspective over CS as the means to share information in CN, performing a semantic shift by providing contextualized information retrieval mechanisms implemented as a service. By setting up ACS, domain experts are enable to search and share information, guided by specific domain ontologies, accessible through ACS. Additionally, it is intended that such a configuration could allow domain experts to choose the tool that will accommodate their own collaboration space. That means one individual could use a particular social network and another one a Wiki, but both contributing to the same CN.

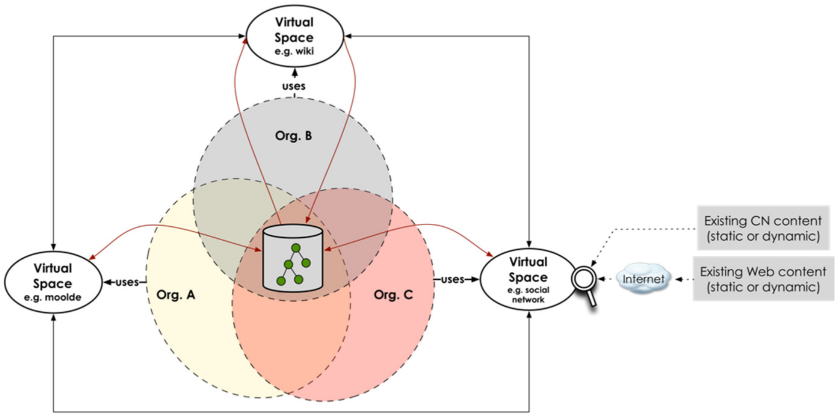

Fig. 1. ACS conceptual view

One of the main claims stated in this paper focuses on the need to interlink people, data and concepts, enriching CS in order to empower knowledge creation capabilities. This calls for semantic-based approaches for exchanging and retrieving large and heterogeneous amounts of information. In this context, semantic interoperability [12] plays an important role by providing technological frameworks capable of improving the intercommunication through Internet, addressing how to deal with a considerable variety of information sources, which implies producing information characterized to be sharable and reusable. Great part of these goals is feasible, thanks to the web semantic stack[1], allowing information to be accessible using a common architecture. By means of semantic web, information acquires a new dimension, being possible to relate information in a standard way. However, and according to W3C[1], for individuals, organizations and communities to benefit from this simplified way of

[1] `http://www.w3.org/`

sharing and reuse of information, it is necessary to keep large amounts of data available, accessible and manageable, which means that beyond describing resources and their relations (e.g. using RDF[2]), it is necessary that those resources could be made available in a shareable form - to this is called linked data. By following linked data principles [13], when setting up CS information is easily accessible from the CN. Furthermore, the effort employed to gather, treat and distribute data for avail of the network is much less, once it is provided access to contextualized information, this is, information semantically described, referenced properly and uniformly accessible.

3 Technical Architecture Proposal: Semantic Search Service

Advancing towards the definition of scientific artifacts that could address the problem posed by this article, an architecture was designed and used to support an experiment, further discussed in this document. This solution engineering was built considering the following assumptions: a) the CN is formed and its objectives defined, shared and understood by all participants; b) there is a data structured platform that works as the CN's knowledge base; and c) there is an ontology that defines the common domain vocabulary of the CN. These assumptions correspond to a part of the results obtained during the H-Know[4] Project. Current approach is based on those achievements, extending the resulting artifacts to cope with our view of ACS. Hereupon and in order to decouple the CS from the CN's format or platform, the design of the architecture followed a service-based approach developed upon virtuoso universal server[3] (the multi-model data server), which implements a high variety of linked data services.

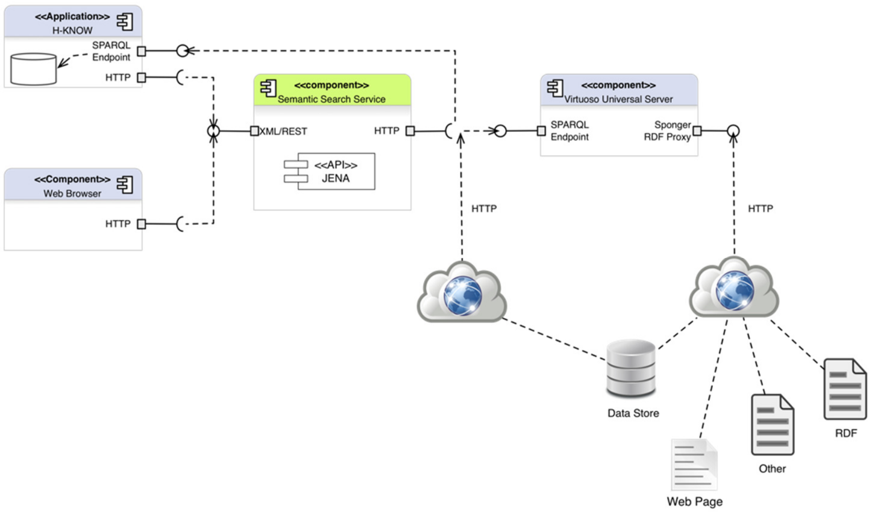

Fig. 2. Semantic search service architecture

[2] http://www.w3.org/RDF/ (RDF is a standard model for data interchange on the Web).
[3] http://virtuoso.openlinksw.com/

From the architecture depicted above (see figure. 2), the semantic search service component stands out, as the main instrument to promote a contextualized search by means of a concept-based approach (using domain ontologies), retrieving a more “ready-to-(re)use” information. Nevertheless, the architecture also allows ordinary searches, either internally or externally to the CN. The semantic search service accepts a couple of interaction scenarios, namely: a) using a web interface via a regular browser; or b) through the CN’s platform (e.g. H-KNOW[4]) or other organizational application integrated to semantic search service using XML/REST[5] API. With these two options, participating in a CN, won’t be such a burden for small enterprises, since the technological integration efforts and the commitment to specific platforms are much less. The semantic search service interacts with virtuoso server by means of SPARQL endpoints running over HTTP, through which it is possible to query and retrieve information from any source (recognized on the server) on the Internet (either a data store or a document), beyond all internally accessible data. Additionally, it is possible to use virtuoso local triple store, both to keep relevant metadata (obtained with the searches) that could be relevant for the CN, and to increase the search performance.

4 Solution Validation

4.1 Practical Experiment and Main Observations

This experiment was conducted based on the European project H-KNOW (Advanced Infrastructure for Knowledge Based Services for Buildings Restoring). H-KNOW was a project funded by the European commission (NMP-2007-214567) from 2009 to 2011, with 15 partners from 5 countries. H-KNOW project aimed at developing a system to provide the ability to share, to create and to reuse information and knowledge in an interactive fashion within a CN. To meet the needs of SMEs to network innovative knowledge-based, an electronic platform was built according to a perspective of collaboration enabled by a social network approach. The technological description of H-KNOW platform may be found in [14]. The semantic description of platform socio-collaborative activities and their connection with domain knowledge and the formalization of the platform domain knowledge may be consulted in [15].

The validation of the solution followed an experimental approach aiming at studying the research result artifact (the designed solution) in a controlled environment [16]. The objective was to assess the relevance of the description around our vision about collaborative spaces (the ACS) and to understand the facts behind the approach. For this experiment, the solution was executed with the existing data in the H-Know platform and conducted in order to illustrate and legitimize a possible scenario for the CS usage during the network operation. The described scenario was set up to be able to run into two different configurations (see figure 3). The experiment took into consideration (in a first iteration) two or more entities (organizations) that enroll themselves within a virtual environment wherein each

[4] `http://h-know.eu`

[5] Representational state transfer.
See: `http://docs.oracle.com/javaee/6/tutorial/doc/gijqy.html`

organization has a H-Know platform in-house (see figure 4). Thus, each organization may organize their information according to a common classification model, once the existing domain ontology was "shipped" within the platform. Additionally, users may use other semantic vocabularies, such as FOAF[6] and SIOC[7], to identify specific organizational structures and people. This configuration scenario of the first iteration, intended to demonstrate how the *semantic search service* allows interlinking several CS from several instances of a particular structured data platform, such as H-Know, since *semantic service* is accessible as a RESTful service via HTTP. With this configuration it is possible to ensure the interoperability between different platforms and, simultaneously, each organization guarantee the responsible for the degree of privacy of their own contents. The contents annotated as being "public" are transferred to a triple store, while the remaining contents are kept in private databases. Despite of providing an interesting level of semantic interoperability and decrease the coupling level of the CS involved, current configuration might not be interesting in all situations, special for smallest enterprises that could not afford for such a technological environment. However, their participation may be considered as a valuable asset due to their expertise in some aspect of the domain. In a second iteration, it was addressed two additional aspects to the scenario configuration (see figure 4): i) it was introduced a new component used by *semantic search service*, the Virtuoso Sponger. This component is used to manage a caching mechanism to enhance information retrieval from several data sources (not only from triple stores, but from any resource described in RDF or in other semantic formats); and ii) smallest enterprises are able to interact directly to *semantic search service* to gather domain relevant information, without the need to commit to any existing CN platform, just by using a web browser. The usage of this scenario configuration in a real business context can be an added value, as it allows interaction with a larger number of data sources. However, the administrator need to have a greater control over the data sources that are defined in Virtuoso Sponger[8], in order to not unreasonably extend the search domain. As expected for this second iteration, the number of obtained results from the *semantic search service* increases as more data sources are to be considered. Nevertheless, the navigation and retrieval of information from large amounts of data, might be mitigated by means of a concept-based search using the domain ontology. Although the increasing volume of data, its is possible to navigate in a accurate way across the obtained search results, streamlining the information retrieval tasks, which sustain the information sharing activity. Note that, in this particular scenario, the *semantic search service* deals with a more heterogeneous configuration. It is in the context of this scenario that the versatility of the work presented in this paper emerges, for the benefit of the CN operation. In this case, at any time, and in order to ensure the network operability, it is possible to include others organizations with particular interest to the network, notwithstanding of the adopted solution for information management. This can be easily accomplished, through minimum configuration.

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[6] `http://www.foaf-project.org/`

[7] `http://www.sioc-project.org/`

[8] `http://virtuoso.openlinksw.com/dataspace/doc/dav/wiki/Main/VirtSponger`

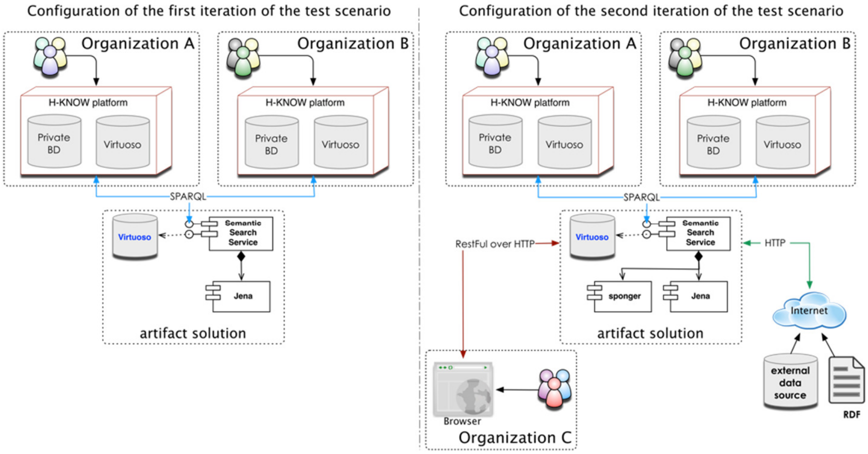

Fig. 3. Configurations for the test scenario

5 Conclusion and Future Perspectives

The discussed technological solution and the underlying vision over CS, showed to foster information sharing by focusing on content integration, through contextualized information retrieval mechanisms. The undertaken experiments allow observing that the implementation of ACS endows a CN of greater flexibility. The results, although obtained by means of controlled experiments with artificial data, prove to be significant and promising, which are motivating the authors to conduct larger studies around the subject, including other domains (using different classification models - ontologies). Nevertheless, it was evidenced that information sharing through CS assume a new dimension when supported by linked data principles, allowing broader searches, but sufficiently accurate, once they are supported by a domain ontology. Furthermore and benefiting from the fact that semantic search service are able to integrate several other semantic vocabularies (e.g. FOAF and SIOC), this technological solution also keeps a perspective of content integration between enterprise platforms. Hereafter, beyond the refinement of the designed solution, namely in what regards to the performance of the developed services (not considered by this experiment), is to be planned an extended exploratory research, aiming at evaluate, qualitatively, the use of different CS (e.g. social networks, wikis, etc.) by different organizations belonging to a virtual community, on performing their daily knowledge-based activities, such as information retrieval and information sharing. Through the execution of more case studies we intend to increase the number of organizations that recognize the need and advantages of content/information classification, showing that the classification improves the information and knowledge sharing and reuse, as well as the collaboration between several partners.

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Towards a Workflow Management Approach for Health Monitoring of Bridges

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Abstract. In brief, Structural Health Monitoring (SHM) refers to the storage and analysis of large amounts of sensor data associated to specific variables that indicate the condition of a civil structure, e.g. a bridge on a national highway. SHM analysis tasks typically involve the integration of different tools which may be highly heterogeneous, autonomous and physically distributed among different organizations. This paper introduces a scientific workflow management approach to model and execute strategic SHM queries that require proper integration of data generated by different software components.

Keywords: Structural health monitoring, bridges, workflow, data integration.

1 Introduction

Structural Health Monitoring (SHM) is a process consisting in the periodic recording of data generated by sensors associated to parameters that adequately reflect the performance and the condition of a civil structure [1]. This raw data is then processed to obtain valuable information for planning of maintenance activities, increase safety, verify hypothesis about the structure and, in general, to expand the knowledge about the behavior of the structure being monitored. Proper monitoring of civil structures such as bridges contributes to prevent the socio-economic consequences that may be caused by a damaged structured.

In the particular case of bridges, SHM systems should ideally support integrated decision-making processes through functionalities such as: user friendly web interfaces, GIS (Geographic Information System) services, distributed monitoring units, data management features, historic knowledge bases, expert systems, and integration of bridge inventory systems [2].

Although, there are some systems available in the market offering integrated solutions with many of these capabilities, in practice, individual institutions working on SHM have developed different systems and used a wide variety of tools depending on their specific objectives and approaches (see [3]). For an effective development of SHM policies, different institutions and professionals including civil engineers, university labs, transportation ministries, and local government units (municipalities),

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need to share and analyze large amounts of SHM-related information generated by heterogeneous and distributed systems and tools. This scenario lays out specific information integration requirements that can be met by Collaborative Networks (CNs) framework and in particular, by workflow management components.

This paper explores some SHM scenario requirements and introduces the application of scientific workflow management technologies for information integration in this field.

1.1 Related Work

There exist several studies regarding the state-of-the-art of SHM of bridges (see [4],[5]). These works summarize established and emerging technologies, practices and projects in the field. Other reports focus mostly on commercially available systems and their functionalities for SHM support, including specific systems such as BRIMOS and SHM Live [6], [7]. These systems offer a variety of services and functionalities for on-line monitoring that come “off-the-shelf” with a proprietary infrastructure. Other specific approaches for data management systems in SHM can be found in [8], [9], [10]. Most of these initiatives are based on a centralized relational database approach for gathering, storing and analyzing data.

On the other hand, the Collaborative Network (CN) paradigm has been successfully applied to similar complex domains (e.g. industrial manufacturing, tourism value-added service provision, virtual laboratories) in which different entities that are physically distributed, autonomous and heterogeneous, need to collaborate in order to achieve common goals based on computer networks [11]. In fact, an early conceptual paper on Virtual Enterprises (VEs) mentions how this manifestation of CNs can be applied in a “building a bridge scenario” during the preparation of the call-for-tenders for a construction project [12].

Nevertheless, the application of specific CN models and tools in SHM, such as distributed business processes or workflow management techniques in order to define, execute and coordinate tasks that must be achieved by network entities, remains an open issue. In [3], a ontology-based mediator system is proposed for semantic integration of different tools and systems in SHM; this mediator is seen as a “router” that suggests specific tools to the user following a general workflow (planning, monitoring, data preparation, evaluation). However, this approach uses this workflow as a reference and does not consider generic workflow management features.

In this paper, we present a novel approach for data integration based on generic definition, execution and monitoring of scientific workflows that support different data analysis scenarios in SHM. The proposed approach is being developed in the context of the e-Bridge 2.0 project as described in the following section.

2 The e-Bridge 2.0 General Approach

The main goal of the e-Bridge 2.0 Project - Integrated System for Performance Assessment of Bridge Structures, is to develop a prototype of a system for solving strategic queries regarding the performance of bridges. This project is carried out at the Costa Rica Institute of Technology (TEC) as part of an e-Science Program bringing together engineers from different schools including Construction Engineering, Electronics, Computer Science, Industrial Production Engineering and Forest Engineering. The main components to be developed or integrated within e-Bridge 2.0 include:

- Reliability model: a probabilistic model to predict structural behavior of bridges using variables that have an impact on potential structural failures.
- Technical information system: integration of data from on-going national inventory of bridges and their technical characteristics.
- Sensors systems: development of sensors networks for SHM of bridges to measure variables such as vibration, deflection and deformation.
- GIS: web-based geospatial information system to properly assess environmental aspects associated to national bridges.
- Information integration system: a single entry-point for users in order to access and analyze strategic information generated by other components.

The implementation approach followed in the project promotes the use of existing open-source technologies and tools from multidisciplinary domains based on a peer-to-peer communication architecture. This approach foresees integration of other e-science tools regarding for instance: simulation environments, 3D visualization tools and high-performance computing clusters. Please notice that in this "open environment", each component may use different data models and software tools. However, in order to solve strategic queries regarding high-level SHM scenarios, information from these heterogeneous sources needs to be seamlessly integrated from a single interface for end-users. The following section provides some examples of these requirements and scenarios.

3 Requirements Analysis for Information Integration

In order to identify general functional requirements for the e-Bridge platform, two main kinds of workshops were organized:

1. Internal workshops. A first workshop was organized with the university colleagues working on the project in order to achieve a common internal perspective on the main requirements for the project. This workshop allowed the identification of main personas (user roles) and system functionalities from an internal point of view.
2. External workshops. Several other workshops were organized with external potential users of the platform including collaborators from the Ministry of Transportation, Ministry of Agriculture, Ministry of Health, National Road Council, municipality councils, and civil engineers. These external workshops delivered new potential functionalities and allowed us to validate the results of the internal workshop.

Some of the strategic queries that were identified through these activities include:

- Real-time failure detection based on different types of sensors.
- Validation of structural models (real vs. theoretical bridge models).
- Generation of bridge reliability rankings.
- Analysis of remaining lifetime for given bridges.
- Identification of failure tendencies by structure types.
- Lists of bridges by maintenance priorities.
- Alternative traffic routes in case of bridge failures.
- Vulnerability (risk) analysis of bridges according to environmental factors.

This analysis allowed the identification of requirements for the general platform and more specifically for the Information Integration System. For this system, we concluded that there are two main types of strategic queries that need to be covered:

1. Predefined queries: solving specific strategic queries for high-level end users e.g. a minister who asks: which are the most important bridges that need urgent maintenance in the country?
2. Analysis queries: solving specific technical queries for experts and engineers that need to perform SHM tasks or queries of a more scientific / experimental nature, e.g. can this bridge support an 80-ton truck load at 60km/h speed?

The first type involves common important queries that are relatively fixed or well-defined but that need to be solved through configurable integration of different components. For instance, in the case of "real-time failure detection", the following interaction sequence among platform actors can be outlined:

1. Sensors System detects a strain measurement value out of the normal range for a given bridge beam and sends an alarm in real time to the Information Integration System.
2. Information Integration System sends an alert to the Geographic Information System so that the event is properly reflected in the GIS layers.
3. Information Integration System records the event in the bridge Technical Information System.
4. Information Integration System sends an alarm SMS/email message to operators responsible for bridge maintenance.
5. Bridge maintenance operators access the Information Integration System interface with a dashboard for global bridge monitoring, providing access to detailed information about the event.
6. Bridge maintenance operators enter the GIS from the Information Integration System and analyze possible actions depending on the bridge location.

Currently, the components involved in this scenario are managed by TEC, but in the near future, they may be managed by different organizations, for example: the bridge inventory may be managed by the Ministry of Transportation, the Geographic Information System may be hosted in the cloud by a GIS service provider, the bridge monitoring dashboard may be accessed by National Road Council, and the

Information Integration System and the Reliability Model may be hosted at TEC or other university.

The second type above involves queries that relate to a flexible "problem-solving environment" (e.g. similar to a virtual laboratory) in which construction engineers need to experiment, test hypothesis and answer questions in different ways. An example of this kind of queries will be given in the next section. In both cases, queries require the integration of data from different tools that may be located in different organizations.

Based on the analysis both kinds of strategic queries, a scientific workflow approach is suggested to properly model and support these requirements. This workflow approach is described next.

4 Scientific Workflow Management Scenarios

According to the Workflow Management Coalition, a workflow is "the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules"[13]. Workflows represent a prevailing approach for service-oriented integration since they provide the "glue for distributed services, which are owned and maintained by multiple organizations" [14]. When workflows are applied to support large-scale scientific applications, they are called scientific workflows. These scientific workflows set forward specific challenges in relation to traditional business-oriented workflow management, such as the need to handle large amount of data, intense computational tasks, and more data provenance and "interactive steering" features for scientists and engineers [15]. Furthermore, workflow management technologies have been extensively used to support Collaborative Networks scenarios involving distributed, heterogeneous and autonomous entities [11],[16],[17]. Certainly, other approaches for coordination of these entities are possible, including agent-based technologies, coordination languages, and GRID services. Nevertheless, the workflow-based architecture was chosen for e-Bridge since it represents a simple, common, flexible and user-friendly approach for service integration. In particular, scientific workflows tools allow the modeling and execution of SHM analysis tasks in a way that can be easily adopted by engineers and scientists from different disciplines with some technical training.

In this context, based on the requirements analysis presented in the previous section, a workflow management approach has been adopted for information integration in e-Bridge 2.0. To this end, several business process / workflow tools have been compared and evaluated including Bonita, Taverna, Bizagi, and jBPM among others. As a result of this evaluation, Taverna is being currently used to model and execute preliminary workflows in this project.

Taverna is a Java-based open-source workflow management system that offers a set of tools to define and execute scientific workflows [18]. Taverna provides a desktop application that allows scientists and engineers to easily define and execute workflows without the need of advanced software development skills. Taverna

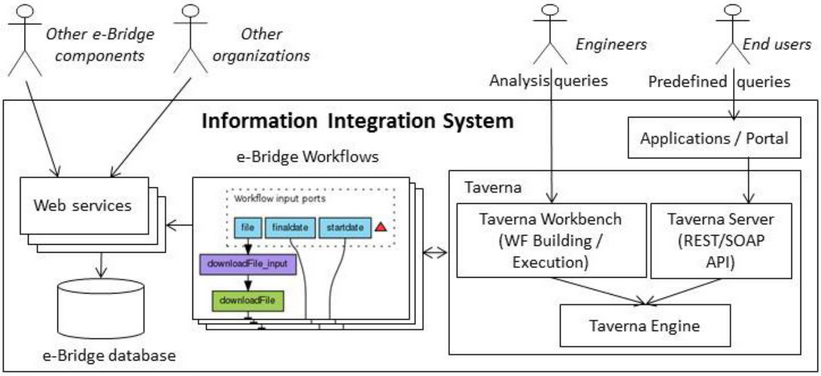

Fig. 1. General architecture of the Information Integration System

workflows can also be edited and executed on the web and invoked from the command line in batch mode. Workflows are represented as directed acyclic graphs using a dataflow language called SCUFL (Simple Conceptual Unified Flow Language). Nodes in these graphs are called processors which can be regarded as mathematical functions mapping a set of input data to a set of output data. Processors can be connected through data links to achieve function composition. Finally, Taverna allows the integration of many different software components through SOAP or REST web services.

The proposed general architecture for the Information Integration System of e-Bridge 2.0 is depicted on Fig. 1. This figure describes how the system architecture supports analysis queries for engineers as well as predefined queries for end-users, using Taverna workbench and server tools respectively. In this way, e-Bridge workflows can be created and executed orchestrating web services related to other e-Bridge components and potential organizations.

The current prototype of system includes basic Taverna workflows which allows construction engineers to seamlessly orchestrate distributed web services to carry on sensor data acquisition, database storage and data visualization (see Fig. 2). In brief, the sample workflow presented in this figure basically collects sensor data as a file from a remote data collection unit (e.g. FTP server) associated to a bridge, processes the file, stores the data in the local database, and finally formats and exports data sets that can be visualized on a web browser (see Fig. 3).

Workflows can be properly edited by engineers by using other existing web services and connecting them accordingly in a graphical environment. Workflows can also be executed from Java applications that will offer strategic queries for SHM. Currently available web services have been developed using SOAP with Java on Ubuntu Linux operating system and PostgreSQL as database engine.

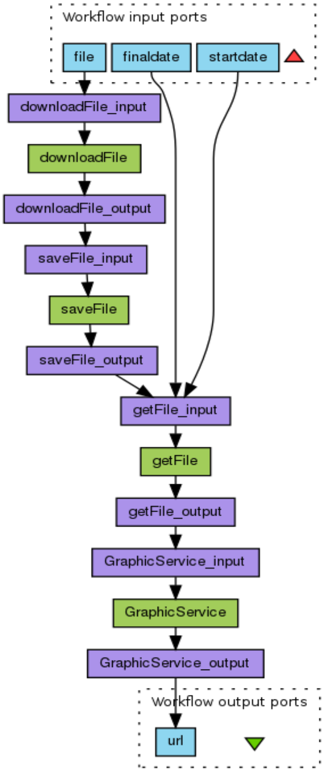

Fig. 2. Sample partial Taverna workflow for sensors data analysis

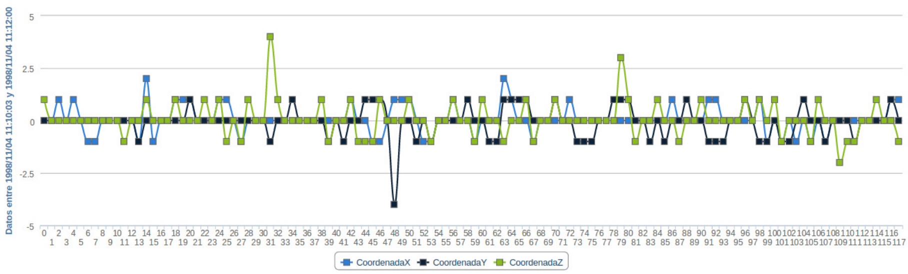

Fig. 3. Visualization of sensor data for bridge vibration variables

5 Conclusions and Future Work

This paper described how a scientific workflow management approach can be applied to support information integration scenarios in the specific domain of structural health monitoring of bridges. In summary, through the workflow-based information integration component, e-Bridge 2.0 end-users will be able to solve general strategic queries as well as tailored experimentation/analysis tasks regarding structural monitoring of bridge behavior. The proposed service-oriented workflow approach allows the seamless integration of sensors, GIS, reliability model and technical data, which may be physically distributed over different organizations.

Future work within the project includes the specification of more integration scenarios involving other components and organizations, development and integration of web-services according to these scenarios, and development of web applications.

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Capability Matrix for Open Data

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Abstract. With the rapid growth of data on the web, a significant number of businesses have embraced the idea of open data to enable innovation, generate revenue and develop new data products and services. However, many businesses are still reluctant due to paucity of information on requisite capabilities to successfully publish and reuse open data to support their business goals. However, scholarly efforts articulating the nature and types of capabilities required for open data processes and innovation are very limited. This could be partly attributed to the fact that most of the discussions on open data capabilities are predominantly in the practice community. We bridge this knowledge gap by mapping Open Data (OD) capabilities described in extant literature, organizing these capabilities into major capability areas and deconstructing these areas to build a capability matrix. The resulting capability matrix provides OD program managers in particular with a framework (or tool) to develop their detailed OD capability requirements. We also believe that the developed framework provides researchers with a foundation for further analysis of OD capabilities.

Keywords: Open data, value chain, open data value chain, Information Technology capabilities, open data capabilities, data-driven virtual organizations.

1 Introduction

During the last decade, businesses across the globe have struggled to comprehend and adapt to the changes brought on by the ubiquitous growth of Information Technology and the Internet [1], [2]. One of the changes is the emergence of OD, which resulted from opening up and sharing of non-sensitive information in machine-readable format with businesses and the general public [3],[4]. Drivers for opening up data include ensuring accountability, delivering quality services, reducing operating costs, and stimulating innovations [5], [6] [7], [8]. Data underpins businesses and the economy, and thus key in providing new insights into consumer needs and enabling new products and services to be developed [9].

Recently, attention of major stakeholders in the OD community, including policymakers have shifted to the economic value of the rapidly growing OD asset. For instance, the European Commission estimates that the direct economic gains from

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opening up Public Sector Information (PSI) or government data could amount to €40 billion a year. Similar believes across the world has spurned a growing number of OD small and medium enterprises seeking to tap into the shared resources or commons. As new entrants flood the marketplace, OD businesses are seeking to uniquely position themselves through specialization in the landscape to create and capture value for their stakeholders [10].

To creating and capturing value for OD stakeholders, OD business managers are required to employ emerging set of capabilities to catalyze positive change in the business [11]. Capabilities enable a business to achieve specific purpose or output [12].

However, there are no scholarly studies available that gather OD capabilities, map capabilities to OD value chain and provide sophisticated tool for businesses to describe, design, challenge, invent and pivot OD business capabilities. In addition, understanding, using, and representing a set of OD capabilities for OD businesses is challenging for many management teams. This research is the first effort to address these problems by providing OD businesses with an OD Capability Matrix as a tool to specify and develop OD capabilities for specific (virtual) organization needs.

2 Concepts

The concepts described in this research paper are OD, capability types and value chain frameworks. Figure 1, shows the relations between these concepts. Capabilities are required to exploit OD. Capabilities are required to build and implement value chain. With an adequate set of capabilities used to build value chain, value chain can then generate OD value. Each of these is elaborated below.

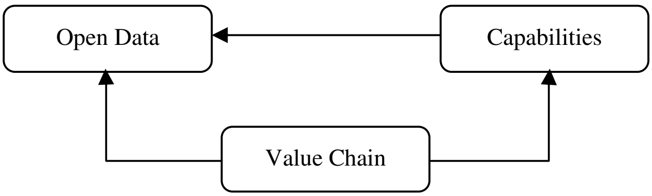

Fig. 1. Research concepts

2.1 Open data

Nowadays, surprising amount of data is generated and stored than at any other time in history [11], [13]. As a practice of good governance, governments globally started to open up their public information in various domains, such as transportation, education, mobility and meteorology [14], [11]. When data is freely accessible and re-usable by public, it could have a larger impact on citizens' ability to hold governments accountable and stimulate innovation [11].

The more technical view of OD is that it is machine-readable [8], [3]. OD is published in common standards, accessible through non-proprietary software, and subject to open licenses [15]. However, there are also limits to what can be released. For example, personal information and information related to national security [5].

OD can help uncover consumer preferences, allowing businesses to improve new products [8], increase revenue, and expand the supply and value chain [16]. However, to benefit and capture value from OD and build or expand the business value chain, businesses are required to identify and develop set of capabilities. Section below presents definition of capability and describes capability types.

2.2 Capability and Capability Types

According to Ulrich and Rosen [12], a "business capability" is a particular ability or capacity that a business may possess to achieve a specific purpose or outcome. In business study and community, this definition of capability has been in common use for the past several years.

Researchers argue that different types of capabilities are required in order to provide businesses a competitive advantage [17], [18]. However, in this research work, we focus on value capabilities of OD businesses. In table 1, business capability types and capabilities associated are shown.

Table 1. General business capabilities

Value capability	**Innovative/ Dynamic capability**	**Competitive capability**
-Individual/competences -Business process -Organization -IT infrastructure -Management/ governance -Technological	-Process innovation -Knowledge mgt. -Manufacturing performance -Supply chain integration	-IT (Strategic choices) -Manufacturing strategy -Business operational (Localization/ Internationalization)

Value Capability: Value capability is specific set of capabilities required for adding value to the product or output. This capability consists of the following elements:

Individual/competences: Jaques and Stamp [18] define it as the extent and complexity of the context within which an individual can operate.

Business process: is a collection of related, structured activities or tasks that produce a specific service or product for a particular customer or customers [19], [20].

Organization: refers to the way systems and people in the organization work together to get things done [21].

IT infrastructure: is the technological foundation of computer, communications, data and basic systems. It includes hardware, software, network resources and services [17], [22], [23], [24], [25].

Management/Governance: is a process of controlling things or people and action of governing an organization [21].

*Technological: t*echnology is a knowledge embedded in products and processes on doing practical things, especially producing things [26], [23], [27].

Each of the capabilities described above are valuable and necessary for a business and/or organization. These capabilities come together to form more holistic approach to build and manage value chain. Section below presents three value chain frameworks.

2.3 Value Chain Frameworks

Businesses must pay attention to how to use OD to create value for their business [28]. In OD context, value is not only money but, value can also be economic, social, transparency, democratic and etc. Thus, it is essential for a business to establish value chain that suits the purpose of the business [28]. From the literature, we extracted the three well grounded value chain frameworks. *Porter's Value Chain,* which is based on the concept of physical value chain of the firm [29], [30]; *Rayport and Sviokla's Value Chain,* which is based on the concept of virtual value chain of the firm [28] and the *Public Open Government Data Value Chain,* which is based on the concept of PSI value chain [31]. For analysis of OD capabilities in section 4, we use PSI value chain as it visibly put in place both Physical and Virtual value chains. Besides, PSI value chain also suits better to the context of OD.

Open Government Data Value Chain: Understanding value chain of open government data is necessary to establish knowledge on who are the actors and what are the main roles of actors in various data related activities.

The following PSI value chain is in the context of the European Commission PSI Directive. Value chain identified four main phases:
Data Generation, Data Collection, Aggregation and Processing, Data Distribution and Delivery and Final Data Use [31], [32].

3 Eliciting Open Data Value Capability Areas

List of OD value capabilities have been identified and extracted from OD literature. We studied each capability and were able to extract and use top-level capability as capability areas for classifying low-level capabilities. Table 2 shows OD capability areas and capabilities associated with each area.

Publishing solution: publishing OD requires methods and mechanisms. For example, publishing as Linked Data is one publishing solution.

Data generation: a business and an organization need to generate data out of data processed for further processing. Data generation design, technology and infrastructure are required to create and collect massive data from various sources.

Data retrieval: this includes extracting the wanted data from data storage. This process requires sophisticated querying and appropriate design for retrieval.

Table 2. OD value capabilities

OD capability areas and capabilities associated with each area	*References*
Publishing Solution	
Publishing as Linked Data	[15]
Sustainable publishing Solution	[33]
Publishing in different format; machine-readable data	[34], [15], [11], [31]
Publishing on web as API to be queried or data dump to be downloaded as a whole	[15]
Development of software tools to scrape, clean, format, visualize and create API services on the web	[15]
Data Generation	
Efficient design and features to collect massive data	[33]
Technology and Infrastructures	[9]
Reuse of PSI	[35], [9]
Linking information from different sources	[35]
Data Retrieval	
Sophisticated Querying	[34]
Efficient design and features to collect massive data	[33]
Data Processing	
Cleaned data to fill gaps, eliminate invalid records or duplicates, standardize attribute values	[15]
Harmonizing data in terms of format	[34]
Format transformations to allow effective machine reading	[15]
Create mash-up	[15], [33], [11]
Data reform and refine	[15], [33]
Data Analysis, Visualization and Visual analytics	[34], [15], [33], [11]
Data Validation	[34], [15], [33], [11], [31]
Data Quality	[34], [15]
Cataloguing data	[15]
Usage of platforms capable to convert datasets in data streams	[34]
Data geo-referencing	[33]
Provision of computing capacity	[33], [13]
Standardizing Linked Data to allow joining to other datasets	[15]
Data Release	
Proactively release data	[34]
Data structuring	[15], [33]
Data classification	[15], [33]
Support data with metadata	[34]
Data update and maintenance	[34], [15], [33]

Table 2. (*continued*)

Data Storage and Computing Facilities	
Data storage	[33]
Computing capacity	[33]
Providing Access to Data and APIs	
Guarantee on data availability	[34], [15]
Commoditization and democratization of data	[33]
Data distribution channel quality	[36], [15], [33]
Data exposure via GUI	[33]
Data exposure via APIs	[34], [33]
Freeing data	[15]
API development	[34]
Using APIs	[34]
Testing and Bug fixing	[34]
Data change feed	[34]
Data Usage	
Help and guideline on accessing, using and adding data, information or knowledge to the original data source	[34], [15], [11]
Available data on the Web to the public and in formats that citizens can reuse	[35]
Support data intermediaries	[11]
A general search engine helping to locate data	[15]
Dedicated service searching purely for datasets and providing useful categorization and tagging	[15]
Management/Governance	
Collaboration	[15]
Training programmes	[15]
Technical expertise of data holders and publishers	[15], [33]
Quick response accepting additional data for advanced features	[33]

Data processing: this includes manipulating and aggregating data to produce meaningful data and information that can be used by stakeholders. Data processing includes cleaning data, harmonizing, format transformation, mash-up, data reform and refine, analysis, visualization, validation, cataloguing and etc.

Data release: data processed and aggregated by an organization or a business must be released to enable data re-use. Before release, data need to be structured, classified and supported with metadata. Data released require data update and maintenance to ensure continuous data re-use.

Data storage and computing facilities: data is backed up in data storage, which is a device that retains data used for computing. It is essential for an organization to appropriately estimate data storage and computing capacity to ensure data quality.

Providing access to data and APIs: data processed should be freely available, accessible and exposed via GUI and APIs through qualified channel of distribution to be used by public. APIs can be developed by responsible entities and developers for data re-use.

Data users: data users are all stakeholders involved in the context of OD. This is to enable and support users mostly citizens with less technical expertise to effectively use OD.

Management/Governance: this includes all parties involved in an organization or a business with main responsibilities to control the process of generating, processing and make data available to public. In addition, training programs, collaboration and quick response to changes can effectively enhance the process of opening up of data. A major requirement for the capability is decision making.

4 Analysis of Open Data Capabilities

In section 4.1, we align OD capability areas to the four stages of PSI value chain. In section 4.2, we provide a deconstruction of OD capability areas.

4.1 Aligning Capability Areas to PSI Value Chain Phases

As OD has evolved, businesses have responded by quick adoption of OD. OD changed the way business performs and has changed the business for the better. However, this requires defining and implementing new set of capabilities, processes, resources and management across the business.

However, business managers are sometimes accused of not really understanding how value can be created and captured from OD. Value chain facilitates managers to know what stages they should follow to create and capture value however, knowledge of what capabilities are necessary to achieve each stage is essential. Previously in table 2, we identified OD capability areas and in figure 2, we align these capabilities to different phases of PSI value chain. This helps managers to establish knowledge on the capabilities require for different phases of value chain.

In figure 2, we showed this alignment.

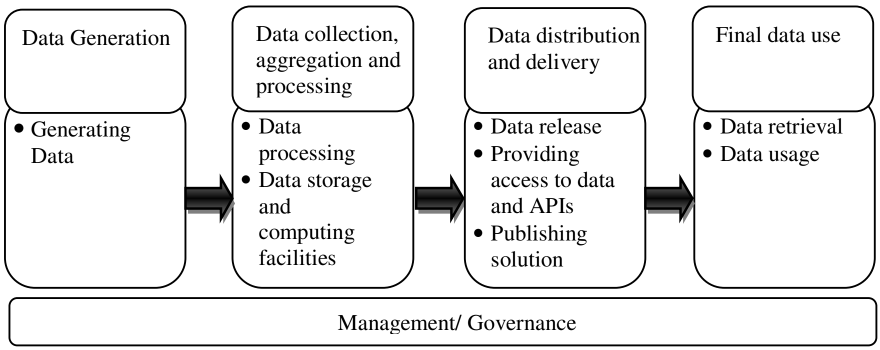

Fig. 2. Alignment of capability areas to PSI value chain

Phase 1: Generating data – according to OECD working paper [31], data generation phase covers all capabilities required for generating data by public sector entities. In our paper, we identified an OD capability area required to carry out this phase of value chain.

Phase 2: Data collection, aggregation and processing - Raw data may not have enough quality and meaning to be used by public, therefore; as it was reported in OECD working paper [31]; data need to be aggregated, linked, and or manipulated in order to add value before being open and freely distributed to public. Our study identified combination of OD capability areas required for data processing. Before data is open to public, it needs to be cleaned, analyzed, standardized, harmonized, transformed in the right format, catalogued and supported with metadata. Quality of data must be obtained and processed lawfully before publishing. Data storage and computing facilities are necessary to be pooled together for efficiency of data processing and aggregating.

Phase 3: Data distribution and delivery - according to OECD working paper [31], data processed need to be distributed to public to enable access and re-use. In our paper, we identified combination of OD capability areas. Public sector entities and businesses are obliged to define precise publishing solutions, providing access to data and APIs and ultimately releasing data.

Phase 4: Final data use - data previously distributed to public need to be re-used by different users to sustain public value creation [31]. Our paper identified the data retrieval and data usage capabilities are required.

Management/ governance is required throughout all phases of value chain to control people and tasks and to ensure data are processed and released according to the goal of the business.

4.2 Deconstructing OD Capabilities

The deconstruction of OD capabilities is a matrix of strategic management and value chain analysis for OD businesses, which aims at capturing all capabilities an OD business require – from generating data to final use and re-use of data - for creating and capturing value from OD.

The matrix is a strategic tool for OD businesses of any scale to exercise and exploit for their business. Capability matrix allows OD business managers to identify what capabilities are valuable to the business they are running. As different businesses have different business model, specific OD capabilities for OD businesses need to be specified.

OD capability matrix (Table 3) is based on the general business value capabilities (table 1), OD capability areas (table 2), and the PSI value chain phases.

Table 3. OD capabilities matrix

General Business Capabilities / Value Chain Phases	Data generation	Data collection, aggregation and processing		Data distribution and delivery			Final data use	
OD Capability Areas	Generating data	Data processing	Data storage and computing facilities	Data release	Providing access to data and APIs	Publishing solution	Data retrieval	Data usage
Individual/competences								
Business process								
Organization								
IT infrastructure								
Technological								
Management/ governance								

There is only one approach to utilize capability matrix in an OD business. Business managers need to identify specific individual, process, organization, IT infrastructure, technological, and management capabilities for all value chain phases. They need to start from the first phase of value chain and define these capabilities for each capability area separately. For example, the first value chain phase is *Data Generation* and this includes set of capabilities required for generating data. Managers should identify what are the individual, process, organization, IT infrastructure, technological, and management capabilities they need for generating data. OD business management/governance is necessary throughout the value chain.

5 Discussion

Both government and business data are rich sources of potentially valuable but currently relatively untapped resource as the data is frequently locked up by the data holders. According to existing literature, considerable OD efforts are largely technology driven. OD publishing process shows that OD publishing requires capabilities for collecting and generating of data, processing, securing privacy and the development of standards for publishing and use of data. Transformation requires the development of these capabilities and development of capabilities require business management team to understand them. Our work has revealed ten OD capabilities areas which have been structured based on the OD value chain. These capability areas contain a number of capabilities which we deconstruct based on the six classical and domain-agnostic capability types already identified in literature.

As a framework, the question about the validity of the framework naturally arises. Given that it was constructed by analyzing capabilities described in existing literature and initiatives, the coverage (or content validity) of the model linked to how exhaustive our review was or to the extent to which, the obtained capabilities cover the major OD value chain stages. We have shown in Section 4 that the ten capability areas adequately cover all the OD value chain stages.

Since there are no OD capability framework in literature, comparison of the developed framework with similar frameworks is not possible. However, detailed specification of the framework elements for pragmatic or tooling purpose is the next logical step.

In addition to serving as OD capability planning tool, the framework could also serve as tool for benchmarking or measuring OD capabilities in organizations.

6 Conclusion

A number of list of political, social and economic benefits have been associated with the use and impact of OD. The economic aspect of OD has naturally generated a lot of interest resulting in a number of OD business models. In this paper, we developed an OD capability matrix as a tool to support design of OD business capabilities. In addition, the OD Capability Matrix could help the implementation of OD business models. Matrix can assist OD business managers to understand and describe how capabilities should be utilize and extended throughout the OD value chain of the business. As there is no OD capability framework in literature, our OD Capability Matrix provides a significant starting point for OD businesses to plan and develop the requisite capabilities to support their business models. With time, concrete experience from practice will be useful in refining the capability framework.

Regarding future work, our main interest is to develop the framework into a concrete tool (similar to the Business Model Canvas) to support OD practitioners. In this regard, business modelers and managers are encouraged to utilize the Matrix.

From the research perspective, we intend to refine the capability matrix to reflect maturity levels of OD capabilities. To represent the matrix as a modeling technique, a potential future work would be to offer more specific guidelines for designing the matrix. Moreover, we are considering the possibility of generation of OD capability patterns from the OD capability matrix. Another potential future work would be to study how capability driven development approach can support evolving OD businesses and facilitates adjustment of capabilities according to changing context.

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Supporting Interoperability of Virtual Factories

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Abstract. The manufacturing industry is entering a new era. This emerging era starts with the integration of new ICT technologies and collaboration applications into traditional manufacturing practices and processes, such as manufacturing 2.0. Manufacturing 2.0 has been conceptualised as a system that goes beyond the factory floor, and paradigms of "manufacturing as an ecosystem" have emerged. The virtual factory is one of the important concepts and foundations central to the realization of future manufacturing. In this paper, we take a look into the current research on virtual factories and propose a new approach to improve interoperability through the integration of different proprietary, legacy and existing solutions. Interoperability as technical implementation finally supports collaboration among business partners for forming virtual factories.

Keywords: Collaboration, Interoperability, Virtual Factory, Virtual Manufacturing.

1 Introduction

One of the most important and visible trends in recent years for the manufacturing industry is towards the use of ICT to enable intelligent manufacturing [1] [5]. ICT enabled intelligent manufacturing has been identified as a key aspect in supporting the European manufacturing industry in the challenging transition from post-crisis recovery to European STEEP (Social, Technological, Economic, Environmental and Political) sustainability and regain competitive advantage in the global market competition [2]. ICT (and especially intelligent manufacturing) in this context is not only important for design, production, testing, distribution and recycling, but it is also crucial in supporting changing business trends. Intelligent manufacturing has seen massive adoption in large corporations, promising to close the gap between what companies or factories require and what IT is able to deliver. Many EU initiative programmes and projects, such as FI-PPP[1], FI-WARE[2], FInES[3], FITMAN[4], and

[1] FI-PPP: `https://www.fi-ppp.eu/`
[2] FI-WARE: `http://www.fi-ware.org/`

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 510–517, 2014.

MSEE[5], industrial advisory groups and research associations are investigating a more flexible IT infrastructure that is able to react to business changes more quickly than the classic monolithic IT manufacturing systems [3] [6].

New ICT technologies and collaboration applications are integrated into traditional manufacturing practices and processes. For example manufacturing 2.0. *Manufacturing 2.0* has been conceptualised as a system that goes beyond the factory floor; it allows paradigms such as "manufacturing as an ecosystem" to emerge. An extension of this paradigm, virtual factories, is one of the central concepts in providing the foundation of future manufacturing. A *virtual factory* allows the amalgamation of manufacturing resources to create timely, demand driven product lines. A virtual factory can also be seen as a specific virtual enterprise which focuses on manufacturing.

Surveys, previous research, and experience shows that traditional manufacturing, supply chain and business systems are primarily used for internal integration. Sometimes this integration is with a fixed number of external partners (for example traditional supply chain management systems). Only very few companies/factories can offer access to their (internal) services to a limited set of customers/suppliers. Even then these integrations are closed environments. It has been increasingly recognized that this is insufficient for the future.

Forming a virtual factory, collaborative partners need to communicate, cooperate, collaborate, or interoperate with others. These partners who can be located anywhere, with day to day collaboration coordinated over the Internet. Interoperability is essential to go beyond the small sets of limited interoperability to a dynamic environment with cost-effective, efficient and deep integration between multiple partners. This integration enables these partners to share information and services as well as to form collaborative processes.

In this paper, we look at how to use ICT to facilitate companies, organisations, and factories in interacting with each other to form supply chains and business ecosystems. More specifically, we look at the role of semantic discovery and interoperability in facilitating virtual factories, a key aspect of future of manufacturing.

The paper first looks at the technical challenges in manufacturing interoperability. Next, related issues to manufacturing interoperability are discussed. We provide the architecture of a manufacturing interoperability platform. Finally, the paper reviews related works and concludes with a future research direction.

2 Interoperability Issues and Enablement

The increased reusability of manufacturing systems leads towards globally interoperable factories. These are then able to provide services and develop products anytime and anywhere, independent of the technologies, culture or language in use at

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[3] FInES: `http://www.fines-cluster.eu/`
[4] FITMAN: `http://www.fitman-fi.eu/`
[5] MSEE: `http://www.msee-ip.eu/`

the different production sites [4]. Real-world virtual factories combine the resources of pre-existing organisations. Those resources are generally supported by existing legacy systems that cannot be changed for the purpose of the creation of a virtual factory. This means that an interoperability platform is a hard requirement for realising virtual factories. The interoperability platform further enables collaboration.

In the "factories of the future roadmap" [2] the European Commission sets out its strategy on the future of manufacturing. We have extracted a number of interoperability issues that have been identified in this document. These issues form the focus of this paper. The first issue is the need to realise a supporting infrastructure for manufacturing business Webs (MBW). Nowadays the Internet is a major driver in collaboration with very significantly reduced costs. The expectation is that collaborative supply processes are location independent, and work in cloud-like ways. The end users of the supply network perform end-to-end manufacturing services orchestration: covering activities of customer collaboration, collaborative service management, and collaborative manufacturing.

Second, to support rapidly evolving virtual factories it is needed to build commonly-used IT backend systems that form the backbone infrastructure for these factories. Such systems facilitate holistic representation, monitoring, and management of future (virtual) factories. A critical enabler of the implementation of a backend system of virtual factories is an integrated scalable and semantic model of manufacturing.

Third, enterprises are increasingly facing frequent design changes. It is essential for European manufacturing to have a high degree of reactivity in rapidly delivering new products and services based upon design changes. In this paper we look at how to increase this reactivity. This is in contrast to traditional research on supporting enterprise integration that focuses on supply chain aspects. To enable rapid change in the setup of virtual factories, potentially interrupting a long life cycle, a holistic approach is needed. A core aspect of the approach is an integrated vertical view on interoperation: not only the data level interoperation, but also service level or even process level interoperation.

To support the above mentioned requirements, a platform has to support interoperability on different inter-connected levels, namely a data/information level, a service level, and a process level.

- The *data/information interoperation level* is related to sharing and exchange of different data, documents, messages and content between different collaborating enterprises from different factory data resources. At this level, the data format, the semantics of contents and documents' structure are important for cross-enterprise collaboration.
- The *service interoperation level* is providing the capability to discover, aggregate, orchestrate and execute various services that have been independently designed and implemented. At service level, interoperability supports transparent composition and mediation among specified services in a cloud environment.
- The goal of the *process interoperation level* is to integrate internal processes of an organisation with the partners' processes to generate cross-organisational business processes.

Table 1 shows each level of interoperation and its enablement.

Table 1. Interoperation and Its Enablement

Interoperation Level	**Interoperation Enablement**	**Examples**
Data/information interoperation level	• Building an ontology or ontological models is a common solution to support interoperability.	MSE (Manufacturing System Engineering) ontology [14]; MASON (Manufacturing's Semantic Ontology) [15]
	• Building common virtual factory data model (VFDM) that consider as a shared meta-language providing a common definition of the content and intent of data within a virtual factory ecosystem.	Some existing work includes EU FP7 VFF (Virtual Factory Framework) project, a virtual factory data model is provided in [7] [18].

Service interoperation level	• Transforming manufacturing asset services
	• Specifying manufacturing asset services
	    ○ Manufacturing asset service specification language
	• Classifying manufacturing asset services
	    ○ Manufacturing asset services annotation
	    ○ Manufacturing asset services clustering
	• Marching and discovery manufacturing asset services
	• Manufacturing asset service composition
		Previous EU projects (e.g. SOA4All, FAST, ServFace, ATHENA, COIN, and COMMIUS) have provided frameworks for business service discovery relying on lightweight semantics; end-user dynamic service composition based semantic mediation and easy to use tools; and/or service composition or orchestration of annotated services to build interactive service-based applications. There are existing technologies and knowledge fragments that can function to inspire and inform our research.

Process interoperation level	Process level interoperation defines synchronisation steps and messages and defines coordination and collaboration mechanisms for collaborative processes.	The Process Specification Language (PSL) standard [13] specified a general ontology for manufacturing processes to exchange process information and knowledge. ANSI/ISA-95 [14] is another international standard, which provide a consistent terminology and information models as well as consistent operation models.

3 Architecture of Manufacturing Interoperable Platform

Figure 1 provides an architectural overview of the interoperability platform. The overall architecture can be structured in to four parts: the repository parts (the low three repositories), sematic supporting part (the middle part), interoperability parts (the top three blocks), and manufacturing standards (the right part).

The bottom part of the architecture provides related manufacturing resources. The *data repository/resources* represent manufacturing data resources, data from assets, machines, sensors, objectives, and workers. The *manufacturing asset service repository/resource* denotes manufacturing related assets and services resources. The *collaboration process repository* stores collaboration capabilities in a business process model format.

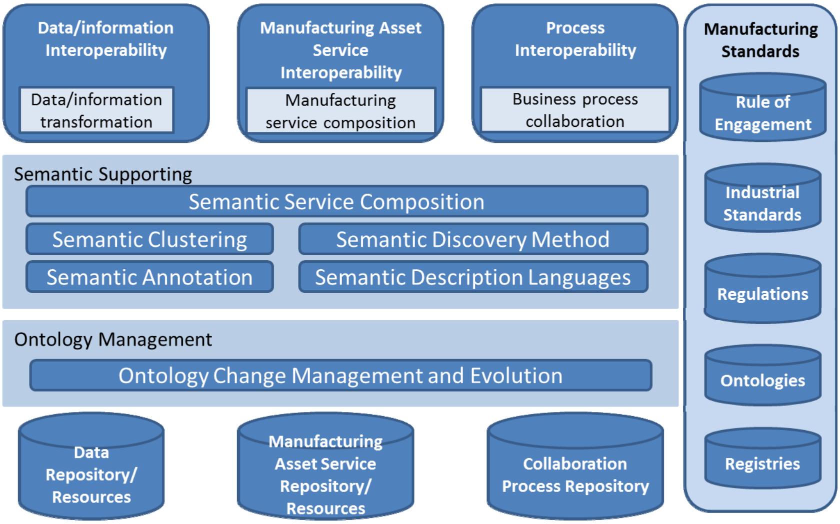

Fig. 1. Architecture of the Manufacturing Interoperability Platform

The middle part of the architecture provides semantic supports. All potential manufacturing related data, assets, services and collaboration processes need to be annotated using suitable methods. The *semantic annotation* provides a way to interpret the meaning of data, information or knowledge, which deals with data/information integration and consistency issues. Annotated data, information, or knowledge is foundation of supporting cooperation, collaboration and knowledge and information sharing around a virtual factory. The different *semantic description languages* describe both tangible and intangible assets of manufacturing services and manufacturing collaborative processes. The semantic description languages may comply with base upon existing languages, such as USDL (Unified Service Description Language). The *semantic discovery methods* contain a board collection of existing work on the dynamic discovery of semantically annotated manufacturing assets and services as well as collaborative processes.

The top part of the architecture supports interoperability. The *data/information interoperability* helps data/information transformation, which define the ability of sharing, aggregating or synchronising data or information across different partners within a virtual factory. The *manufacturing asset service interoperability* assists as service brokerage functionality to wrap service bundles or value-added services. The *process interoperability* brings collaboration capabilities within a virtual factory and deal with coordinating business processes.

The manufacturing standards part allows transforming textual rule of engagement, regulations of different countries, and industrial standards into computer understandable knowledge. This can then be used to ensure that new forming manufacturing processes or services comply with existing rules.

4 Related Work

Previous EU projects SOA4All, ATHENA, Super, and COMMIUS have discovered semantic interoperability which addresses standards based approaches, semantic technologies, architectures and frameworks, business vocabularies, modelling languages and methodologies. The above mentioned projects are not specific for manufacturing domain. Although the many design principles are adoptable, there are many specific issues for implementing interoperability in manufacturing domain. For example, service specification languages are not designed for manufacturing services. Manufacturing assets could be both tangible and intangible assets. To transfer different manufacturing assets into manufacturing services is certainly new for dealing with interoperability of virtual factory. Further manufacturing service clustering and discover methods are certainly different with general service clustering and discovery methods, a deep analysis is needed of characteristics of manufacturing services, which is critical for clustering services and optimising the service discovery process.

EU projects such as VFF, FITMan and MSEE are in the domain of virtual factories. There are still differences with our research perspectives though. None of these projects completely addresses end-user aspects, or setting up a useable BPaaS. Our work [16] on the area of interoperative end-user process modelling for process collaborative manufacturing and BPaaS (Business Process as a Service) [15] can certainly contribute to the new approach to support interoperability.

Paper [19] describes the development of a virtual factory application based on multi-touch interaction, high resolution projection technology and industry standards like X3D. Ding, *et al.* introduce how to using 3D technique to design and simulation of virtual factory layout [20]. Paper [21] presents a structure and architecture of an integrated simulation method (ISM) to meet the requirements of virtual factory engineering (VFE) which combine CAD, VR and discrete event simulation techniques. Above mentioned ontologies can be used for supporting our vertical interoperability of virtual factories.

5 Conclusion

In this paper we discussed what is needed to provide interoperability in virtual factories. We identifie three different levels of interoperability, i.e. data/information level, service level, and process level. For each level, the potential issues and applicable technologies were analyzed and specified. We also provided an overall architecture for implementing such interoperability in the domain of virtual factories. The interoperability of the three distinguishing levels is aligned with the concept of service-orientation. Core scientific challenges remain on the semantic level specification and integrating three-level interoperability as one.

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Performance Management Frameworks

Fundamentals for the Development of a Performance Analysis Approach in Collaborative Networks

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Abstract. This contribution focuses the challenge of analyzing the performances of enterprises which participate in modular Virtual Enterprises. Modular in that context means "consisting of independent participants". In order to be able to draw valuable conclusions a comprehensive performance analysis approach (PAA) is required. For the development of an approach for the value-added process-related performance analysis the fulfilment of some preconditions is necessary. A comprehensive approach for the analysis of performances within networked production structures is an indispensable component of the operative management to secure sustainable success. In the following the fundamentals are distinguished and some effects are discussed. Additionally some possibilities for the extension of the approach are introduced.

Keywords: Virtual Enterprise, Performance Analysis, Soft-Factors, Collaborative Network Model.

1 Motivation and Objective

The production of goods in collaborative networks has become a widespread form of economic added value. Nevertheless both for the theory and in practice, numerous starting points arise that require an improvement of the current situation. The present article focuses on a topic, which is very relevant from the practical perspective, however, but only has found little attention from the theoretical point of view. This refers to approaches for the value-added process-related performance analysis of economic units that operate in dynamic networked production structures i.e. collaborative networks.

The scope of the term performance analysis in this contribution is broader than the understanding of performance evaluation in common. Now an appropriate approach for a value-added process-related performance analysis is developed. For a comprehensive approach for performance analysis at first relevant perspectives need to be identified and then appropriate perspective combinations have to be developed. In that context perspectives mean the starting point for research activities. This procedure is followed by a classification of selected theoretical approaches for performance management by taking into account its relevant perspective combination.

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Finally the derivation of a framework for an approach to the performance analysis for the given situation is started. Considering the specific practical framework that approach can be completed. After validation and verification it is ready for practical application.

The main objective in that context is to model a framework for the development of approaches for performance analyses which are very flexible. That means these approaches are adaptable to a high degree according the scope of application. Therefore it is necessary to research fundamentals i.e. possible perspectives. The research methodology includes a literature research. Also already applied approaches for the analysis of performances in enterprises are considered. The suitability is checked and the necessary range of adaptation is determined.

2 Consideration of Different Perspectives

2.1 Classification of Perspectives

At first, reasonable prospects for a value-added process-related performance analysis are considered. This allows different possibilities concerning the focused perspectives and therefor the intended modelling. The commonest perspectives include a chronological and an organisational perspective. These perspectives are introduced and discussed in section 2.2 and 2.3 in this contribution. Further perspectives can be included in the already mentioned perspectives. For example the perspective of number of participants in included in the organisational perspective. A financial perspective could be considered as well, however finance is not focused here. Product quality and distribution channel represent sub-categories with minor impact.

2.2 Organizational Perspectives

The organizational perspective focuses the organizational alignment. The most common form of organization depicts the company (enterprise) itself, with large companies and corporations, medium-sized businesses (SME) or small enterprises can be distinguished. As a consequence of the increase in competition, enterprise collaborations gain growing popularity. Distinction can be made in two main categories: static networks and dynamic networks.

Static networks (also called resource pools) include all types of supply chains, which are a form of long-term business cooperation (exist value-added process-neutral) and dynamic networks, e.g. virtual enterprises that embody a short-term business cooperation (value-added process-related) form of cooperation. That means cooperation in a specific configuration is formed only to realize one value-added process. In an idealized form, consequently, companies, virtual enterprises and enterprise networks can be distinguished. As companies turn to be part of both of virtual enterprises and enterprise networks and virtual networks emerge from corporate networks, there are several different combinations which allow an assessment from an organisational perspective.

2.3 Chronological Perspectives

As a second dimension the chronological perspective is considered. It focuses on the time horizon of the analysis. Here, the strategic, tactical or operational performance analysis can be distinguished. This variety shows that generally only a retrospective analysis can be initiated. From the practical point of view, a subdivision into a value-added process-neutral and value-added process-related form of performance analysis is used for research.

The value-added process-neutral perspective is longer term in nature, i.e. it is a strategic performance analysis process including multiple value-added processes. This perspective is very wide-spread among the current approaches of performance measurement and management and related research works. In that case, appropriate data are determined, allowing a statement on the long-term competitiveness on the basis of services provided in the past performances. This perspective, however, can only identify locally occurring weaknesses in the provision of services to a limited degree as such weaknesses can be overlaid by strengths in the same range.

The analysis of the realized performance of a particular value-added process is focused on the value-added process-related perspective. It is to provide an operative, i.e. short-term analysis. Unlike the value-added process-neutral approach, it is possible to identify specific weaknesses that have occurred at a specific value-added process. That allows gaining a more detailed knowledge on the quality of a value-added process and its participating organizational units.

It is comprehensible that a performance analysis can be performed based solely on already existing data. Freedom of choice, however, exists on the number of value-added processes to be considered, and thus the orientation of the performance analysis. In the following, the introduced perspectives are combined to identify a relevant perspective combination for the performance analysis and to classify selected approaches presented in the scientific literature according to this spectrum.

2.4 Synthesis and Focus

Although further perspectives like product range, the number of participants or the distribution channel can be taken into account, the organizational and the chronological perspective are sufficient to create an appropriate index. Both perspectives and the resulting assignments can be best represented in a matrix.

As relevant organizational perspectives single enterprises, Virtual Enterprises (dynamic networks) and enterprise networks (static networks) were identified. Additionally, there exist enterprises that operate in virtual enterprises or enterprise networks. That means these enterprises are involved in a value-added process realized by intensive cooperation represented by a Virtual Enterprise or an enterprise network.

Also there are virtual enterprises (with several enterprises), which are integrated into enterprise networks. That means within a long-term network a short-term cooperation is evolved. After completing one value-added process that Virtual Enterprise splits up. Further characteristics are not relevant here and therefore are not considered.

From a chronological point of view, both the value-added process-related and the value-added process-neutral perspectives are distinguished. A further classification is not necessary.

By combining these two different perspectives the relevant perspective combinations for a performance analysis can be derived. However not every combination is of practical relevance here. In general virtual enterprises are constructs that are configured in order to perform a specific value-added process. Thus, a value-added process-neutral performance analysis in or with Virtual Enterprises as an organisational construct is generally not feasible and marked black.

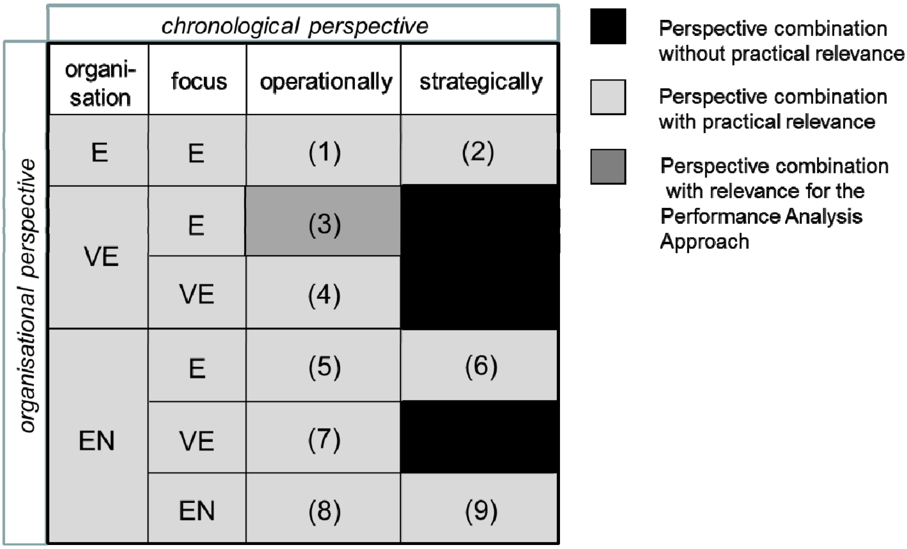

Fig. 1. Overview on Perspective Combinations

Figure 1 illustrates possible perspective combinations and its relevancies according to the practical situation of value-adding analysis. Here "E" stands for the classic "Enterprise", "VE" means "Virtual Enterprise" synonymously for a short-term cooperation and "EN" represents "Enterprise Network" standing for a long-term cooperation.

All feasible perspectives (1) to (9) including selected examples from the literature are discussed subsequently. In that context the matrix is to be read as follows: combination (3) means that the (performance) analysis focuses an enterprise which is part of a Virtual Enterprise (short-term cooperation). In that context a value-added process-related performance analysis is realized. In that way every combination is interpreted.

In general there is little novelty according to the identified perspectives and its combinations. However this approach allows a sophisticated (literature) research. So deficits in research can be identified and eliminated. Hence a comprehensive literature research is done. The major findings and its consequences are introduced in the next section.

2.5 Literature Review

The number of publications focusing on performance analysis in networked structures and related research areas is very difficult to overlook. It is almost impossible to mention all important publications in a brief literature review. For this reason, only those publications are referenced, which have a significant influence on the development of the performance analysis approach in collaborative networks.

According to figure 1 the variants (1) and (2) focus on enterprises which participate in the view of network theory to no cooperation. An performance analysis is possible both short-term (1) or long-term (2). While for option (1) hardly exist any approaches for performance analysis, case (2) includes all established approaches for performance measurement, such as the EFQM-model, the Performance Pyramid or the Balanced Scorecard.

With variant (3) the performance of enterprises is evaluated which operate within a virtual enterprise (dynamic network). This variant represents the focus of this contribution. This value-added process-specific form of performance analysis and evaluation is hardly considered yet. This deficit is to be eliminated. As an organisational unit both an enterprise and a part of an enterprise can be considered. There is no difference for the research methodology.

The evaluation of Virtual Enterprises as an independent organization form is considered with option (4). This may exclusively focus on a value-added process-related examination, since a long-term view because of the dynamic nature of this form of organization is not possible. A framework for the development of performance measurement systems for virtual enterprises can be found in [1].

The perspective combinations (5) to (9) are related to a cooperation which is realized in enterprise networks. An approach for the performance analysis of enterprises operating in enterprise networks related on a value-added basis (5) was not found. This variant is conceivable; however, has hardly any practical relevance. The value-added process-neutral evaluation of enterprises in long-term networks, however, represents some practical relevance. A few publications exist [2],[3]. This corresponds to option (6).

A further option is variant (7) where the performance of a virtual enterprise with respect to a particular value-added process in the context of a participation in an enterprise network, is evaluated [4].

Finally, there is the possibility to realize both a short-term (8), as well as a long-term (9) performance analysis of an entire enterprise network. Because enterprise networks exist value-added process-independent and thus have a high degree of practical relevance in the literature, numerous approaches, especially for the value-added process-neutral perspective [5],[6],[7],[8] exist. Also approaches for the value-added process-related, i.e. the dynamic perspective can be found, e.g. [9].

Based on the synthesis shown in Figure 1 and the associated research literature is to be concluded that the value-added process-related performance analysis of enterprises in dynamic networks is inadequately treated. A major reason is that for the majority of companies especially the long-term survival is the major objective. In order to evaluate the long-term situation of an enterprise especially established systems of Performance Measurement, such as the Balanced Scorecard, the EFQM-model or the Du Pont-System [7] are suitable.

The value-added process-related performance includes a target-actual comparison of parameters without the strategic direction of performance measurement. Thus, parameters such as warranty claims per month, error rate in the production, delivery rate, conversion times, downtime, the return on investment, employee satisfaction and corporate culture for assessment are less or not at all relevant.

3 Development of the Analysis Approach

3.1 Analysis of Requirements

Within the process of the development of an approach for the performance analysis initially an analysis of requirements is accomplished. From the gained findings the corresponding model is derived and structured.

Since the approach of performance analysis is integrated into a comprehensive model for the distribution of profits, including incentive and sanction mechanisms [10], it focuses primarily the task of determining sanctions in case of a poor performance or to calculate bonuses when an outstanding performance was delivered by an enterprise. This is realized by an appropriate implementation of calculation algorithms.

In that context, therefore, it is necessary to analyse the services provided by enterprises within the framework of a specific value-added process. At this point, it must be clarified with what conception such performance analysis can be conducted and the possible requirements in detail need to be identified. Figure 2 (right column) shows an exemplary sequence of the operative, i.e. value-added process-related phases of the intended performance analysis approach.

Conceived in three stages the value-added process-related performance analysis approach focuses on the following sequential steps in the form of modules:

- Performance Measurement (measurement phase),
- Performance Assessment (assessment phase) and
- Performance Evaluation (evaluation phase).

This modular structure enables the application-oriented exchange of individual components and individual related instruments of application.

As part of the measurement phase the corresponding figures from the considered performance parameters are recorded. By monitoring and workflow management, this can be realized computer-aided and automated to a large degree. The implementation takes place in the measurement phase. It is the premier step of the process-related performance analysis.

During the assessment phase as the core of the performance analysis approach for each performance parameter a comparison of the service provided with fixed set targets is realized. While the actual performance is determined value-added process-related, the target performance of the performance parameters is determined independently of value-added process as a comparison criterion. This is making these values the character of static variables. The determination of the reference values belongs to the value-added process-neutral part of the performance analysis. This is explained in detail later.

Finally, the evaluation phases complete the performance analysis approach. As a key challenge, the various results of the performance evaluation of the different performance parameters are summarized into an aggregated measure of performance based on relevant indicators. The choice of appropriate weights allows considering the different importance of the performance parameters.

Based on the aggregated measure of performance finally charged sanctions can be imposed and promulgated as a result of the performance evaluation. In order to realize the operational phases of the approach, strategic, i.e. basic preparatory work is required.

The key challenges in this context include defining the performance parameters, identifying the key figures, determining of the assessment function and the determination of the weights of the performance parameters. While the first three operations can be assigned to the basic stages, the determination of appropriate weights should be interpreted in preparation for the actual performance analysis, but also has a strategic character, since the weights of the parameters are not determined anew for each value-added process. Figure 2 (left column) shows an exemplary sequence of the value-added process-neutral i.e. strategic phases and its contents.

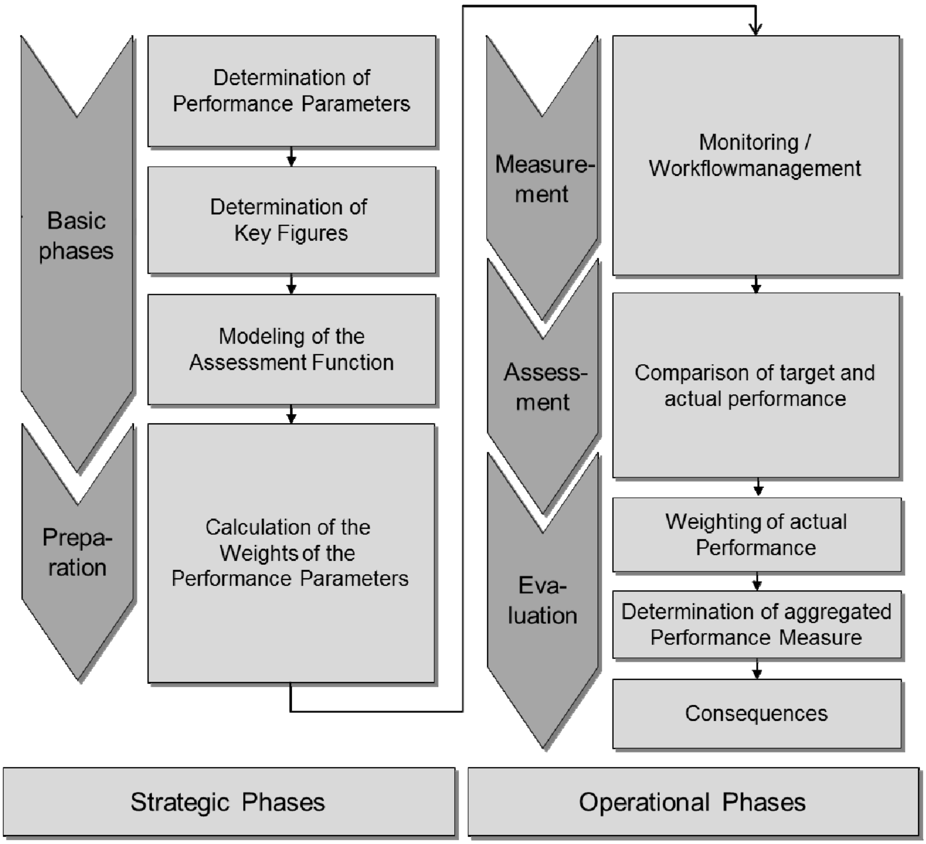

Fig. 2. Strategic and operational Phases of the Analysis Approach

Deriving the requirements both from a strategic, but mainly from an operative perspective the understanding of the performance analysis and the associated (strategic) processes in the context of production-economic networking is summarized as follows:

"Performance analysis in the environment of networked production structures is the determination of the degree of target achievement in terms of performance of an enterprise in a specific production processes."

The performance is determined at the end of a value-added process based on a general performance evaluation system using selected performance parameters for an enterprise which are combined to an aggregated performance figure. Based on that figure, profit share affecting sanctions (income cuts) or bonuses (additional payments) can be calculated. This allows new steering mechanisms for the collaborative network management.

3.2 Derivation of the Approach

In developing an approach for the performance analysis in collaborative networks focusing specific value-added processes, care was taken to ensure a high degree of flexibility in terms of applications. In that context individual aspects of established approaches are accessed in order to be integrated with equivalent qualifications in the model.

A comparison of established approaches of the performance management shows that particularly the balanced scorecard approach is suitable to determine the performance parameters to be considered in the performance analysis approach. However the actual function of the performance parameters for evaluating the performance of business enterprises and to define possible consequences is not an instrument of the Balanced Scorecard (BSC) [11], hence must be supported by other concepts and approaches.

The utility-benefit analysis [12] represents a potential concept, which is applied in a modified form. The "set of complex alternatives for acting" for the performance analysis is given by the number of different values for performance parameters of an enterprise. The "preferences of the decision maker" form in the given context of the performance analysis the general requirements, as introduced in the previous section. The "multidimensional target system" finally is equivalent to the requirements (target values), which are imposed on any enterprise. In conclusion, this means that in terms of the issue of this research work the utility-benefit analysis classifies the performance parameters characteristics of enterprises into the multicriteria objective system of performance analysis by considering the specific requirements of the network.

Thus a basis for judgment is created on which conclusively sanctions or bonuses can be defined as consequences. Based on these findings it should be noted that some aspects of the BSC and an adapted form of utility-benefit analysis can be incorporated as established approaches in the context of the value-added process-based performance analysis. The BSC is to serve as a basis for the proper identification of relevant performance parameters. That part represents one of the most challenging aspects of modelling.

The utility-benefit analysis is included in the performance evaluation and performance weighting in a modified form. Based on an aggregate measure of performance appropriate consequences in the form of sanctions for a poor performance or bonuses on exceptional performance should be quantified. The focus of this approach is the highest possible degree of automation in order to ensure a smooth implementation and application.

3.3 Structuring of the Approach

The following the requirements to be taken to a performance analysis approach described in section 3.1 are considered and merged with the previously derived coarse approach to performance analysis in Section 3.2. in order to form a comprehensive model.

The global approach for performance analysis in virtual enterprises is divided, as already shown in figure 2 in a strategic and an operational part. The strategic, i.e. value-added process-neutral phases including their processes are to be carried out at regular intervals, however of course not for each value-added process separately. At regular intervals hereby means, that a review should enforced after each modification of the basic conditions or periodically (e.g. annually). This is composed by decision-makers on all resource pool parties or enterprises. In contrast, there are a number of process steps, which are directly related to the performance analysis approach. These tasks are assigned to the dynamic or value-added process-related phases. All relevant steps are to be executed for every particular value-added process. The order always remains unchanged.

Among the value-added process-neutral steps are the basic phases and a preparation phase. The basic phases are represented by three steps that are directly related to each other. Primarily the relevant performance parameters to be considered in the performance analysis approach need to be identified. Under a performance parameter in this case an attribute is understood, which is of significant importance for the evaluation of a performance of an enterprise considering a value-added process. Among the most important performance parameters the price, delivery date or the quality are expected. However there are more parameters which can be included depending on the specific application field. Especially soft-factors play an important role in network management. This includes the quality of a cooperation or the cooperation climate.

After determination of relevant performance parameters by the help of the Balanced Scorecard approach, the corresponding key figures are determined. The key figure of a performance parameter enables the quantitative analysis of performance of an enterprise. Key figures are closely related with the considered performance parameters.

Based on the key figures of the performance parameters, in the following an appropriate assessment (evaluation) function needs to be derived. An assessment function can be understood as a mathematical function representing the dependence between degree of fulfilment of a performance considering the appropriate key figure and the credits granted. Credits represent the input for the utility-benefit analysis. In that context also the nominal performance of a performance parameter and its key figure is defined. In case the nominal performance is realised the full score is awarded. In case of a performance not reaching the nominal value less credits are granted. The range of credits must be defined in advance. Usually the maximum is 10 and the minimum is 0 credits.

To reflect the different importance of each performance parameter, they are integrated in the performance analysis in a weighted form. The determination of the weights is carried out by a suitable method of decision theory, for example, the trade-off method [13]. This process is represented by the step "determination of weights", which is the (only) part of the preparation phase. Consequently, the basic stages help to create proper conditions for performance analysis approach, while in the preparatory phase the requirements for the consideration of weights are met. Basically, a performance analysis can also be performed without any weighting of the performance parameters. Then all parameters are interpreted equally important.

By working on the aforementioned steps all preparation work is done, i.e. the value-added process-neutral phases are complete. Now the structure of the performance analysis approach is detailed in that way that it is applicable.

The value-added process-related phases include the measurement phase, the assessment phase and an evaluation phase.

Central component of the measurement phase is represented by the measurement of the performance provided by an enterprise (actual performance) by considering all relevant performance parameters. The measurement of the performance is realized on the basis of the already established key figures and is supported by monitoring functionalities or by the workflow management system used the information system.

Based on this performance measurement procedure consecutively the step of performance assessment can be carried out as part of the assessment phase. This is realized by a comparison of the target and the actual values. It therefore a target value must be given representing the desired target performance (which was determined within the framework of the evaluation function) and an actual value, which results from the performance assessment, i.e. in terms of the actual performance provided considering the performance parameters. Hereby the assessment system should not be constructed in a binary way, i.e. "met target or "target not met". It should enable a finer gradation in order to provide a meaningful assessment of the performance.

The assessment of individual performance parameters respectively their key figures is realized by using the prepared assessment functions for each performance parameter.

Subsequently, the services provided by an enterprise can be evaluated. This is done in the evaluation phases. By weighting the assessments the calculation of an aggregated performance measure is possible. This aggregated performance measure represents the realized performance of an enterprise in an aggregated form with respect to a specific value-added process under consideration of all relevant performance parameters. Hereby the assessment functions and the corresponding weights of the performance parameters are included.

The steps performance assessment, weighting of performances and calculation of the performance key figure are based on the fundamental ideas of the utility-benefit analysis and result in an adapted approach for application in the context of performance analysis in virtual enterprises. Finally, from the enterprise-specific performance key figures, appropriate consequences can be derived. As applicable consequences the aforementioned sanctions in the form of profit cuts or the payment of bonuses in case of an outstanding performance are conceivable. By combining the different phases the comprehensive approach for the value-added process-related performance analysis in virtual enterprises results.

3.4 Advancement of the Approach

For the practical implementation a further detailing of the individual phases is required. Future works on the performance analysis approach include a more detailed modelling on the interdependences between degree of fulfilment of a performance of an enterprise and granted profit share. It has to be clarified whether there is a linear or a non-linear coherency. That interrelation also needs to be modelled by a mathematical function. However, to ensure flexibility, different proposals for the application are made available.

A specific feature of the performance analysis-approach is the comprehensive consideration of soft-factors. The major problem when including soft-factors in a performance analysis approach is that there are no figures available originally. That means the performance of an enterprise regarding a soft-factor is expressed as a linguistic term, for example very well, well, average or bad. Now these terms need to be quantified. Social sciences offer different approaches for the quantification of soft-factors. One very promising approach in that context is the Repertory Grid-methodology [14]. The procedure for the quantification of soft-factors already has been explained in [15]. It serves as a solid base for future works.

3.5 Validation and Practical Relevancy

After completing the approach the validation is planned. That procedure can be realized by using real-world data. The results need to be discussed by experts. According to the specific situation the approach and its calculation schemes can be adapted until satisfactory results are available. There are not “right” or “wrong” but “realistic” and not “realistic” results. The high degree of adaptability allows applying the approach in almost every collaborative network.

The practical relevancy of the approach can be derived from the necessity of a retrospective analysis of a performance of an enterprise. In most cases the analysis of the performance of an enterprise represents the base for future cooperation.

4 Conclusions

The present paper primarily focused on the foundations of a value-added process-related performance analysis approach. Within the context of an analysis of various perspectives an appropriate framework for the topic was developed. Hereby the operational, i.e. the value-added process-related performance analysis of organizational units that operate in virtual enterprises is focused. In this case the order-specific production network represents the virtual enterprise. It could here be noted that for this combination of perspectives hardly relevant approaches for performance analysis have been developed and published.

Based on the corresponding previews and considering established performance measurement systems as a rough concept, a comprehensive approach has been derived. Hereby elements of the Balanced Scorecard are applied in order to determine the relevant performance parameters. The appropriate weights are calculated by approaches of decision theory. Finally a modified utility-benefit analysis supports the assessment and evaluation of the information collected. This combination of different approaches is novel and allows the processing of the topic with a high degree of adaptability. That means that the performance analysis approach can always be adapted to the circumstances given.

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Strategic Context, Organizational Features and Network Performances: A Survey on Collaborative Networked Organizations of Italian SMEs

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Abstract. In the growing body of business network literature the need of phenomenological perspective is increasingly perceived. In this paper the results of an empiric research on the Enterprise Network Agreement (ENA) is reported. ENA is an important form of collaboration among companies, born in Italy, whose diffusion is rapidly growing, because it is considered by policy-makers a promising mean for the entrepreneurial development and the re-industrialization of the Country. Based on a survey addressed to a significant sample of ENAs formalized in central Italy regions, the paper draws a phenomenological framework on the strategic context of network formation and its organizational features on one side, and the performances obtained on the other side. This empiric evidences may represent a first attempt to build a solid base for the development of a credible scientific literature on business networking. From a theoretical point of view, this study firstly provides interesting insights to the living discussion in the managerial literature about "engineered" and "emergent" networks. Secondly, a specific focus is devoted to analyze those types of network in which ICT sector is involved and that are distributed in at least at two provinces, that is the kind of networks which is candidate to became what in the literature can be included in 'second generation Virtual Breeding Environment'. In particular, the study aims to understand the characteristics of these different collaboration forms, and of how these characteristics influence their performances. At the same time, the research can serve as a useful indication for policy-makers to address supporting actions towards the most promising network collaborations.

Keywords: Strategic context, organizational features, performance, Enterprise network agreement (ENA), survey.

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1 Introduction

Network collaborations have become an important business management strategy to improve the competitiveness of companies, especially for SMEs operating in complex and turbulent environments. SMEs are characterized by tight resources, which puts them in particular difficulty to increase internationalization and rapid technological change. Collaborative networked organizations (CNO's) can improve the competitiveness of firms by providing access to external resources, synergies and by fostering rapid learning and change [1].

For several years, scholars have been developing a very rich literature on business collaboration, framing different perspectives [2-4] and demonstrating the usefulness of collaboration strategy, especially for SMEs [5]. Despite the enormous effort spent on theorizing collaborative strategies and processes, it is always difficult to study the real features of networks in a phenomenological perspective able to integrate theoretical development with empirical evidences.

The Italian context could nowadays represent a formidable opportunity to advance on this direction, providing a good economic and institutional framework to gain a specific knowledge based on a real-cases approach. Firstly, because of the Italian economy structure, where more than 99 per cent of companies are SMEs, wishing to keep their business autonomy but feeling the need to cooperate in search of competitive advantages [6]. Secondly, in the light of the recent legislative framework defined by Law 122/2010 that introduces the Enterprise Network Agreement, a very broad range of networks are now formalized in Italy according to standardized and disclosed procedure, thus increasing the visibility of network implementation processes [7]. Thirdly, the availability of official data indicating the main characteristics of real networks represents a good start to design a comparative study on their empirical features.

2 Strategic Context and Organizational Features of Collaborative Networks: Theoretical and Institutional Perspectives

Theoretical literature and empirical observation demonstrate that CNOs are complex entities, whose proper functionality and performance may strongly depend on their strategic context and their organizational features [8].

As far as the strategic context of formation is concerned, literature normally refers to the specific pre-conditions characterizing the environment in which the network has been developed [9]. Some drivers that can be considered as condition affecting the success of the network are represented in particular by: i) the pro-activity about developing and focusing the originating idea [10]; ii) the important role that an external entity can play to stimulate the network design and implementation, helping partners to evaluate new development opportunities, on one hand, and assessing the strengths and weaknesses of the partners themselves, on the other hand [11]; iii) the importance of a good climate of trust among the partners, which can be testified by the existence of previous collaborations [12]; iv) the importance of an objective condition of network economic benefits [13], which is perceived as an opportunity to develop markets and initiatives that would not otherwise be reached by individual firms, as often happens for the international competition.

In this analysis dimension an important debate has divided international literature regarding the strategic value of a prior planning of collaborative relationships among firms [14]. It is possible to distinguish two major process of network formation: "emergent" or "engineered" [15]. In the first case, the links between the various companies tend to form spontaneously and are influenced by cultural, social and economic context of the area in which such collaborations are formed. Alternatively, in “engineered” cooperation, these conditions are not sufficient in itself to develop inter-company synergies but represent essential elements for formulating the strategic planning of networking, which is then modulated with respect to the network design, partner selection and performance measurement and control. In this context a "trigger entity" is considered helpful to monitor the opportunities and threats from the external environment and capable of identifying possible synergies among potential partners.

Moving to consider the organizational characteristics, the literature gives much importance to the network model, defined as the set of elements characterizing the structure of the collaboration [16, 17]. Particularly, the analysis of the model can be carried out from three different perspectives: i) the strategic planning activities [18]; i) the organizational leadership, mainly related to the skills and the position that the person who leads the network project has to possess in order to achieve the strategic goals, coordinate the activities, managing the relationships among the partners and nurturing a climate of trust (so called "network manager" or “alliance manager”) [19]; iii) the operating model, based on the specific processes that companies are willing to share through collaboration, going to distinguish whether such synergies are mainly pursued on creating new business development opportunities and/or integrating core/support internal processes [20-22]. In this context, a very significant literature has emerged to deepen and illustrate the different models of innovative networking, exploring their impact on the organizational features and strategic perspectives. Particular attention should be devoted to the approach of VBE perspective [23], by focusing on the 2nd generation VBEs. This VBEs, which are not bound to geographical regions or specific activities and integrate their process through innovative ICT approaches, shall play an active role in the society/market as competitive entities [24].

Finally, the issue of network performances has to be considered in an innovative way, overcoming a traditional approach and integrating financial and non-financial dimensions. To this extent, the predominance of strategic activities and the high complexity of collaborative networks management tend to produce weak financial returns in the short run [25]. The exploitation of the partners’ synergies reflecting on higher revenues, lower costs, investment returns, requires a longer time perspective and should be built on higher level confidence among the partners with a strong perception of the network potential benefits. For this reason, as in the new ventures, it is necessary to emphasize the "intangibility" of subjective performance [26], paying attention to important signals in terms of: investment realized by the network, considered as an important output of the collaboration; financial support received by banks and public institutions; level of satisfaction of the coordinator of the network; confidence in achieving strategic results; willingness to participate in further collaboration experiences.

Framing all these concepts into an institutional perspective, the case of Italy provides an important opportunity to develop a phenomenological perspective to study the CNOs on empirical basis.

In 2009 the Italian government has defined a new legal framework to regulate and stimulate collaborative networks on contractual basis, introducing a new legal tool named “Enterprise Network Agreement” (ENA) . The contract can be implemented for a wide variety of collaborations, both in terms of vertical alliance, f.e. in the form of supply chain among companies that operate in the same sector at different stages of production, and horizontal alliance, f.e. among competitors sharing some special projects of innovation and strategic development. The contract has to be drawn according to a formal procedure with a notary, requiring an official registration with the competent Chamber of Commerce where the companies reside, and it must indicate (law n. 122/2010): i) references of partners; ii) strategic objectives; iii) performance measurement criteria to assess the progress toward strategic goals achievement; iv) network action plan; v) duration of the agreement; vi) specific endowment to manage cooperation activity.

By combining the above presented theoretical and institutional perspectives, the paper intends to fill a gap on network literature and policy making strategies, and to answer to the following research questions: which features the collaborative networked organizations present in terms of strategic context of formation, organizational characteristics and performances, and how these features are influenced by the network dimension (e.g. number of partners)? How the emergent/engineered process of network formation and implementation can affect network performances? What are the specific characteristics of collaborative networked organizations of SME’s involving ICT sector and geographically distributed and which level of differential performance they show?

3 Data and Methodology

In order to answer the above mentioned research questions a survey has been conducted to a sample of real cases of CNOs, by performing a telephone structured interview [27] with the person in charge for network management and coordination.

The population is represented by 1.213 ENAs recorded in the official Chamber of Commerce registers, involving 5.811 business entities, 103 provinces and all the Italian regions. The breakdown of legal forms allows to note that over 75 % of the total business entities are individual businesses, partnership and limited companies, i.e. the typical organizational structure of entrepreneurial and small-medium enterprises (SMEs). Basing on this database, the research focused on ENAs formalized on the regions of Central Italy (Tuscany, Lazio, Umbria, Marche and Abruzzo), mostly characterized by traditional SMEs system operating in an economic environment with a broad range of competitive and uncompetitive conditions.

The original list included 307 ENAs, involving more than two thousand business entities. Considering the network contract as the unit of analysis, the sampling has focused on the partners belonging to the ENA, with the final objective to individuate the network coordinator. The questionnaire has been completed with the method of telephone interview supported by detection system (CATI Id Monitor) where the script reference and the quota allocations have been transferred and computerized, implementing all the controls of logical consistency and flow control. A total of 1.800 companies were contacted to carry out 339 interviews in total, lasting on average 15 minutes, that allowed to complete the full questionnaire for 214 network contracts, reaching a coverage of 70%.

The data collected have been elaborate in a set of descriptive statistics detailed for dimension classes (2-5 partners, 6-10 partners, more than 10 partners). A specification of results related to those networks involving at least one ICT partners (registered with ISTAT code J) and geographically distributed in at least two provinces has been obtained. The analysis has been completed through a cluster identification based on selected features of “engineered” and “emergent” networks, represented by: 1. incubation promoted by one/more entrepreneur/s; 2. strategic objectives focused on creating new business opportunities, 3. appointment of a professional figure to manage the network; 4. presence of a business and action planning; 5. commitment to share the strategic process. The network have then been classified to be “engineered”, with the presence of at least three conditions, differentiating in “strong” (compliance with all the five points), “moderate” (points 2, 3, 4 and 5) and “medium” (points 2, 4 and 5). Other network have been considered “emergent”, with a “low” (less then three) or “weak” (less than one) presence of the above mentioned conditions. Focusing on descriptive incidence related to more innovative performance[1], the impact of different strategic contexts and models (“engineered” vs “emergent”; focus in ICT with more than 2 provinces) has been measured through a differential calculation between the specific clusters and the average results referred to the whole sample.

In the light of the research design and method adopted, the study performed is characterized by the following limitations and delimitations. The structured interviews may be biased by characteristics of interviewers, response sets, acquiescence, social desirability effect and problem of meaning [27]; the data collection is based on the complete survey to network coordinator/manager and has considered only qualitative and subjective issue; the network coordinator perception and involvement may have overestimated answers on subjective performances; this study only includes the ENAs formalized in Central Italy regions.

[1] Defined by: innovative investments (software, patents and other intangible assets), banking and institutional support (i.e. the network has received the support as required and benefitted from grants for R&D, innovation and internationalization), high level of coordinator satisfaction (incidence on answers referred to highest levels on the scale), perceived positive network benefits (affirmative answer to the specific question), confidence on strategic objectives fulfillment (high and moderate level indicated on replies), declared interest on improving internal communication and professionalization of network management (frequency of citation) and positive orientation for future partnership (affirmative answer to specific question).

4 Results and Discussion

Results are divided in three sections of analysis, represented by strategic context, organizational features and performances. The following tables show only the most significant responses collected through the structured questionnaire that presented in some cases one choice and in other cases multiple preferences.

Table 1. Strategic context of collaborative networks formation

	Total sample (#214)	Breakdown by dimension			Focus
		2-5 partners (#114)	6-10 partners (#58)	> 10 partners (#42)	ICT & > 2 provinces (#21)
Network originating idea					
- find new markets	59.8%	59.6%	62.1%	57.1%	28.6%
- realize new products	32.7%	37.7%	29.3%	23.8%	42.9%
- cost reduction	32.6%	28.9%	29.3%	47.6%	0.1%
Per-existing collaboration					
- yes, informal	42.1%	44.7%	44.8%	31.0%	33.3%
- no	41.1%	38.6%	44.8%	42.9%	42.8%
Network incubation					
- owner/s of one/more partners	62.6%	67.5%	55.2%	59.2%	47.6%
- business association	15.9%	10.5%	20.7%	23.8%	9.5%
- manager of one/more partners	11.2%	8.8%	15.5%	11.9%	19.0%
Internationalization					
- partners not internationalized	40.7%	40.4%	37.9%	45.2%	52.4%
- minority of partners internation,	26.2%	27.2%	27.6%	21.4%	19.0%
Main strategic objectives					
- New strategic segment	74.3%	78.1%	70.7%	69.0%	81.0%
- Core process integration	13.1%	12.3%	12.1%	16.7%	9.5%
- Support process integration	11.2%	9.6%	13.8%	11.9%	9.5%

The first table (Tab. 1) shows that more than half of the collaborative networks (59.8%) origin on the basis of an idea of developing new markets, followed by at a certain distance from the other objectives (32.7% for the realization of new products and 32.6% for the reduction of costs). The network size is not particularly important in the different level of response. The results referred to ICT networks involving more than two provinces are dominated by the goal of the new products and show less orientation to the development of new markets; this suggests the combination with the traditional manufacturing sector to a re-industrialization. On previous collaboration, the sample is equally divided (approximately 40%) on those networks with a pre-existing informal occasions and the others with no experience of cooperation; even in this case the size is not a discriminating feature. What it can be observed is that the biggest networks and ICT networks tend to set-up without a pre-existing collaboration experience, consequently relying on the common project to find the right trust and confidence for partnership. With reference to the incubation process, this is mainly managed by one/more network entrepreneur/s, with an important role that can be assumed in some cases by business associations and company manager/s. These professionals are particularly important in ICT networks, confirming the higher innovation impact in the managerial perspective also. Focusing on the level of internalization, results seem to confirm a typical feature of SMEs entering the network: these enterprises operate mainly in domestic markets and only a minority competes in international markets. This trend is even more pronounced in networks involving ICT sector, assumed to be a specialization with a supporting role for domestic business. Analyzing the main strategic objectives, there is a clear preponderance of business opportunities (and revenues) development rather than cost-reduction through process (primary and support) integration. With the increase in size this tendency is attenuated and augment the incidence of efficiency measures. In the case of ICT, the network development objective is strongly felt and aims to be realized, as seen before, through the creation of new products.

Looking at the organizational characteristics (Tab. 2), in more than one half of the cases network management is performed by one of the owners. This feature becomes less present in complex networks. It is also possible to note the significant contribution of managerial figures or experts, assuming a visible presence in the network formed by ICT companies.

Table 2. Organizational features of collaborative networks

	Breakdown by dimension				Focus
	Total sample (#214)	2-5 partners (#114)	6-10 partners (#58)	> 10 partners (#42)	ICT > 2 provinces (#21)
Network management					
- owner/s of one/more business partners	58.4%	61.4%	62.1%	45.2%	57.1%
- manager/s of one/more business partners	17.8%	15.8%	19.0%	21.4%	9.5%
- internal network manager	17.3%	16.7%	13.8%	23.8%	19,0%
- external appointed expert	6.5%	6.1%	5.2%	9.5%	14.3%
Business and action planning					
- no	39.7%	38.6%	43.1%	38.1%	23.8%
- yes, before the agreement	27.1%	27.2%	27.6%	26.2%	33.3%
- yes, on start-up phase	25.7%	25.4%	25.9%	26.2%	38.1%
Operational synergies					
- Marketing and sales	72.4%	70.2%	72.4%	78.6%	52.4%
- Production	39.3%	37.7%	37.9%	45.2%	42.9%
- R&D and quality	32.2%	38.6%	25.9%	23.8%	52.4%

As far as network project activities are concerned, a higher percentage of networks (about 40%) does not realize business and action planning, leaving the operational activities to be managed through spontaneous and reactive processes. ICT networks are more oriented to planning, confirming a greater attitude to management innovation.

Observing the kind of synergies developed, a strong focus emerges on marketing and sales processes, without ignoring the other purposes. ICT networks, consistently with their specialization and vocation to create new process and products, present greater synergies on the R&S processes and quality.

Finally, moving to measure the performances, Tab. 3 reports the summary of the results of the questionnaire. Investments are mainly concentrated in the marketing and advertising area, whereas the personnel training and new technologies investments are concerning much more the small networks; for ICT networks it is possible to confirm the importance of technological investments. Financial support received from banks and public institutions is not significant: in the majority of cases this support is still not required, demonstrating that the collaboration born with the intention to experiment real strategic synergies; in the case of ICT network it is possible to note a relevant percentage of funding received for innovation, internalization and R&S, coherently with the context and organizational characteristics mentioned. Perception of actual benefits resulting from the collaboration is at a medium standing, while the level of satisfaction of network coordinators it's a medium-high level, without a particular differentiation resulting from the dimension. Confidence on strategic objectives achievement is at medium and high intensity, regardless of the network complexity. These conditions do not influence the new partnership attitude that significantly decreases with higher dimensions. What happens to ICT networks is very relevant because with an equal level of satisfaction there is a very strong collaboration attitude.

Table 3. Performance of collaborative networks

	Total sample (#214)	Breakdown by dimension			Focus
		2-5 partners (#114)	6-10 partners (#58)	> 10 partners (#42)	ICT > 2 provinces (#21)
Investments					
- marketing and advertising	59.5%	54.0%	71.6%	60.0%	38.5%
- software, services and technol.	43.8%	52.4%	39.3%	30.0%	61.5%
- personnel education	24.0%	25.4%	28.6%	16.7%	38.5%
Banking support					
- not required	87.9%	87.7%	86.2%	90.5%	81.0%
- required and obtained	7.5%	8.8%	6.9%	4.8%	14.3%
- required and not obtained	3.3%	3.5%	5.5%	0.0%	0.0%
Support form public institutions					
- not obtained	72.0%	64.0%	82.8%	78.6%	42.9%
- obt. for innov., internat., R&D	20.6%	28.1%	13.8%	9.5%	52.4%
- obtained for networking support	7.5%	7.9%	3.4%	11.9%	4.8%
Perceived positive benefits					
- yes	47.2%	47.4%	48.3%	45.2%	42.9%
- no	52.8%	52.6%	51.7%	54.8%	57.1%
Coordinator level of satisfaction					
- excellent	11.2%	11.4%	10.3%	11.9%	9.5%
- very good	35.0%	34.2%	36.2%	35.7%	33.3%
- good	21.5%	24.6%	19.0%	16.7%	33.3%
- medium	13.6%	13.2%	15.5%	11.9%	0.0%
Confidence on strategic objs ach.					
- high	56.1%	55.3%	60.3%	52.4%	52.4%
- moderate	34.1%	36.8%	25.9%	38.1%	42.9%
- low	9.8%	7.9%	13.8%	9.5%	4.8%
Orientation for future partnership					
- yes	50.5%	58.8%	46.6%	33.3%	81.0%
- no	49.5%	41.2%	53.4%	66.7%	19.0%

Developing the last part of research, the following table (Tab. 4) reports the analysis of the impact of different strategic contexts and models ("engineered" vs "emergent"; focus in ICT with more than 2 provinces) on innovative performance, as defined in the previous paragraph. Particularly the differential incidences are calculated comparing specific cluster and the average results obtained on innovative performance against the same results referred to the whole sample. As can be observed, the innovative performance tend to be positive related to "engineered" networks, developing a linear impact on differential incidence for "strong" (+18.4%), "moderate" (+8.0%) and "medium" (+5.0%) level of engineered conditions. The lack of the same conditions, typical features of an "emergent" model, implies a growingly negative impact in case of "low" (-4.0%) and "weak" (-25.4%) levels.

Table 4. Differential impact of strategic contexts and models on innovative performance

	Engineered			Emergent		ICT > 2 provinces
	Strong (#18)	Moderate (#12)	Medium (#44)	Low (#130)	Weak (#10)	(#21)
Innovative Investments	+19.8%	-7.4%	+53.9%	-19.4%	-90.8%	-7.4%
Banking support	+9.2%	+0.9%	-5.2%	+1.0%	-7.5%	+6.8%
Institutional support	+7.2%	+12.8%	+2.2%	-2.1%	-10.6%	+31.8%
Coordinator satisfaction	+26.0%	+12.1%	+3.7%	-2.4%	-46.3%	+4.3%
Perceived benefits	+56.3%	+16.3%	-10.1%	-6.7%	-13.7%	+21.9%
Confidence on objectives ach.	-1.3%	+9.8%	+0.7%	+0.6%	-20.2%	+5.1%
Future partnership	+16.2%	+24.5%	-0.5%	-2.8%	-20.5%	+30.5%
Differentials in average	**+18.4%**	**+8.0%**	**+5.0%**	**-4.0%**	**-25.4%**	**+10.9%**

Statistics seem to confirm the attitude of network contract to produce different effects in function of organizational characteristics. Also with reference to ICT enterprises can be note differential performances visibly higher than average, which are positioned at the middle between "strong" and "moderate" model. Particularly important seem to be the results in term of institutional supports, perception of collaboration advantages and orientation towards future collaborations. These are very relevant circumstances to represent the effectiveness of networks whereby the potential synergies are perceived both internally and externally, in a long term collaboration perspective. This confirms the importance of greater innovativeness and management pro-activity related to this strategic context and organizational conditions.

5 Summary

The paper draws a phenomenological analysis of collaborative networked organizations of SMEs based on a survey addressed to a significant sample of ENAs formalized in the central regions of Italy.

Strategic context is mostly characterized by networks implemented on the idea of developing new markets, with no significant pre-existing collaboration, whose process of incubation is mainly promoted by one/more business owner/s, involving partners with a weak international competition profile and that choose the new segment development as first strategic objective of network. In ICT networks with a visible geographical distribution, the goal of new product development is prevalent and the role of managers in process incubation is stronger. Organizational analysis shows that the network management is mostly performed by one/more business owner/s (probably the same who promoted the incubation), leaving the operational activities managed on unplanned way and seeking for strategic synergies on marketing and sales processes. ICT networks are more incline to involve managerial experts and oriented to planning the operational activities. Investments are coherently concentrated in marketing and advertising functions, financial support received form banks and public institutions is not significant, perception of network benefits and confidence on strategic objectives achievement is good, though not reflecting on positive orientation for future partnership that remains at a medium level. ICT networks show a stronger attitude to capture financial support and a more positive attitude to collaborate. In conclusion, most of the networks analyzed are set-up for a real willingness to cooperate and not to exploit financial contribution; a central role on network incubation and management is played by entrepreneur/s following unplanned process of marketing and sales integration in order to reach strategic development of new business segment.

By further developing the analysis and focusing on the impact of different strategic contexts and models ("engineered" vs "emergent"; focus in ICT with more than 2 provinces), the research demonstrates that the innovative performance tends to be positively associated to "engineered" networks. Also with reference to ICT networks it can be noted visibly higher performances than average, especially in terms of institutional supports, perception of collaboration benefits and the positive orientation for future collaborations.

These results not only confirm theoretical perspectives, but also seem to trace an important route for the commitment of those who promote this tool to bring out the potential of SMEs, which may start to seize opportunities even from the systemic crisis that the Italian economy and his entrepreneurial paradigm is undergoing a long time now.

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A Performance Management Framework for Managing Sustainable Collaborative Enterprise Networks

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Abstract. Many enterprises have difficulties to understand how sustainability can be managed. This scenario requires new tools that aid to define and collect the necessary information for managing the performance of the network and assuring its sustainability at the same time. The purpose of this paper is to introduce an integrated performance management framework that fills this research gap and aid to manage the sustainability of the enterprise network from its strategy into its operations in order to provide a tool for managing the sustainability performance more efficiently and effectively. The framework has been applied within a bathroom furniture supply chain.

Keywords: collaborative enterprise networks, sustainability, performance management framework, case study.

1 Introduction

In the current global competitive environment, enterprises need to constantly adopt new strategies to remain competitive in the marketplace. One of these strategies is the adoption of a sustainable culture. There are numerous causes that make enterprises to pursue sustainability such as legal demands/regulation, response to stakeholders, competitive advantage, customer demands, reputation loss, and environmental and social pressure groups. In the literature, one can find success cases of implementation of sustainable practices. However, many enterprises have difficulties to understand how sustainability can be managed. This scenario requires new tools that aid to define and collect the necessary information for managing the performance of the network and ensuring its sustainability at the same time. For that purpose, performance management frameworks are tools that, if properly designed and implemented, may aid collaborative enterprises to manage the sustainability of their operations.

In addition, an organization's sustainability initiatives and its corporate strategy must be closely interrelated instead of keeping separate programs that are managed independently of one another [1]. Then, it is essential to note that a proper implementation of the sustainable culture of the enterprise network should be first included in the strategy, and then, derived from the strategy into operations. [2] define sustainable supply chain as '*the management of material, information and capital*

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flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social into account which are derived from customer and stakeholder requirements'. [3] define sustainable supply chain management as *'the strategic, transparent integration and achievement of an organization's social, environmental and economic goals in the system coordination of key interorganizational business processes for improving the long-term economic performance of individual enterprises and its supply chains'*. Based on the aspects that appear in the definitions, a proper performance management framework for sustainable collaborative networks can be derived including various characteristics. First, all the enterprises within the enterprise network should agree on common goals/objectives that are pursued by all the enterprises. Otherwise, monitoring performance will be an isolated task lacking value to management. Then, it is necessary to establish mechanisms to deploy the strategy into operations which can be measured, and therefore, managed through performance measurement elements (objectives, performance indicators, etc.). Second, all three sustainable dimensions (economic, environmental and social dimensions) should be managed within the structure of the performance framework. Third, the interorganizational processes must be considered in the structure of the performance management framework in order to manage the value flows to customers. Fourth, both individual enterprise and collaborative enterprise network performance levels have to be monitored and linked as it is needed a strategic and operations alignment between both levels in order to prevent collaboration to fail.

The purpose of this paper is to introduce an integrated performance management framework for collaborative contexts that meet all four characteristics and aid to manage the sustainability of the enterprise network from its strategy into its operations by including all the required aspects within its structure in order to provide a tool for managing the sustainability performance more efficiently and effectively. The developed framework has been applied within a bathroom furniture supply chain presented as case study.

2 Background

The study of the benefits and success of implementing practices of supply chain sustainability is at an initial stage of development [4]. This fact is probably one of motives why there are few works developed in this field, the majority published in the recent years. Some of these works have exposed frameworks that aid to conceptualise and classify supply chain sustainability literature such as the works by [2] and [3]. Other works present models for evaluating some aspects of supply chain sustainability such as supplier selection [5] or the selection of a supply chain configuration [6]. In fact, most of these works only consider economic and environmental sustainability and the social dimension has barely been considered [2].

Regarding the main focus of this paper, few works deal with the development of performance management frameworks for managing the sustainability of collaborative enterprise networks. In this section, the four characteristics exposed before (strategic focus, three sustainability dimensions, interorganizational processes, and individual and collaborative performance levels) are the key points to perform the literature review. It is observed that the works that present a performance management framework for collaborative contexts use to lack of a pillar for measuring sustainability dimensions and a complete solid structure. In this work, when we say that a work does not consider the sustainability dimensions, in fact we refer that framework specifically does not include the social and environmental dimensions. The economic dimension is always included within the performance management frameworks.

Performance management literature has proposed different frameworks for managing performance in collaborative contexts. Table 1 shows a summary of these frameworks regarding the consideration of the four characteristics: strategy deployment, sustainability dimensions, interorganizational processes and performance management levels.

Table 1. Literature review summary (x means that the framework does not have the characteristic)

Performance framework	Strategy	Sustainability dimensions	Interorganizational processes	Management Levels
Brewer & Speh [7]		x		x
Gunasekaran et al. [8]	x	x		x
Chan & Qi [9]		x		
Bititci et al. [10]		x		
Folan & Browne [11]		x	x	
Chalmeta & Grangel [12]		x		
Alfaro et al. [13]		x		
Romero et al. [14]		x	x	x
Westphal et al.[15]		x	x	x

As can be observed in the table, the environmental and social dimensions are overlooked in all the works. In addition, the deployment of the strategy is commonly introduced despite it is missing in one work ([8]), the interorganizational processes are missing in three works ([11], [14] and [15]) and the two necessary management levels are missing in four works ([7], [8], [14] and [15]). Therefore, the limitations exposed justify the lack of a framework that meets all four characteristics under a solid performance structure. The framework proposed on this paper aims to fill this research gap.

3 The Performance Management Framework for Managing Sustainable Collaborative Enterprise Networks

As stated in a previous section, it can be observed that there is a need of tools (methods, systems and procedures) that aid enterprises to manage sustainability within collaborative contexts following an integrated approach. The framework proposed in this section introduces these characteristics by adapting the performance framework developed by Alfaro et al. [13] whose methodology is founded on three phases: 1) definition of the strategic framework, 2) definition of the process framework and 3) monitoring. The characteristics of a framework for managing the sustainability of collaborative environments are related to the requirements that should be covered by the framework in order to be considered solid and integrated. This means that the framework should have all the proper functions to manage the context for which it was designed. Also, that framework should support the decision-making process of the enterprises and entities that collaborate. For that reason, it is necessary that it considers two levels: interorganizational level (where collaboration takes place) and individual enterprise level. Both levels should be aligned and linked in order to keep traceability among the performance elements that are to be defined and monitored.

At the individual enterprise level, the framework derivates from the vision and vision and reflects the most important aspects of the business. If this concept is extended within the interorganizational context, it can be said that it is a process of strategic planning for all the partners and implies a common understanding of their goals what facilitates the evaluation and degree of success reached in their objectives. Thus, the framework starts with a strategic approach for its adequate interpretation and application. Therefore, the starting point is the definition of the strategic framework (phase 1).

Figure 1 shows the composition of the performance management framework which distinguishes, at the same time, between two types of sub-frameworks: strategic and process framework. In detail, the definition of the strategic framework needs to incorporate all the performance elements mission and vision, objectives and key performance indicators (KPIs). All these elements at defined for the four performance perspectives: financial, customer, process, and learning & growth. These perspectives aid to structure performance measurement following relationships of cause-effect.

In addition, it is necessary to introduce one perspective oriented to manage sustainability that covers the environmental and social dimensions of sustainability. The aspects of the economic/business dimension of sustainability are already considered in the financial, customer and process perspectives. Then, the sustainability perspective supports the consecution of the other three perspectives located above, due to the fact that environmental and social practices are to support the internal processes, the customer value proposition (as we said customers demands are common causes of implementing sustainable practices) and the financial management of both individual enterprises and collaborative enterprise networks. The Growth and Learning perspective stands below the sustainability perspective because its purpose is to support the training, partnerships, and information technology aspects to assure the consecution of the rest of perspectives in the long term.

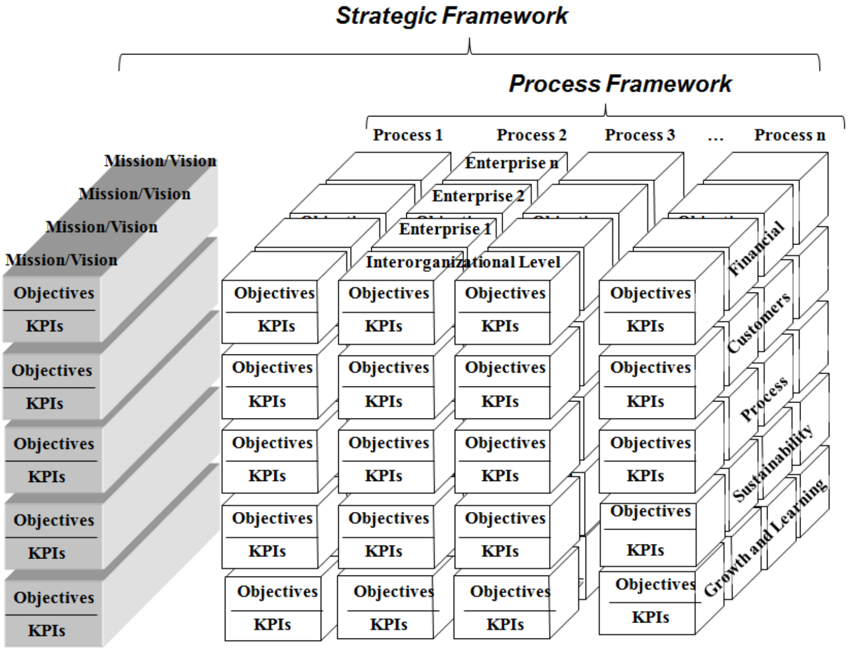

Fig. 1. Performance Management Framework for Sustainable Collaborative Networks

The content of the sustainability perspective will consist of a set of objectives and corresponding KPIs related to environmental and social sustainable dimensions. Some authors have proposed different structures for these two dimensions. In [5], it is presented an interesting classification of the content of these dimensions. On the one side, environmental dimension comprises pollution controls, pollution prevention, environmental management system, resource consumption, and pollution production. Regarding social dimension, it distinguishes between employment practices, health and safety, local community influence, contractual stakeholders influence and other stakeholders influence.

It is not the purpose of this paper to provide a full overview of the content of these dimensions but to present the elements that a performance management framework should have to manage them. For that reason, this classification is only given as example that may be considered but do not conform a definitive list.

Once the strategic framework is obtained, performance elements of the process framework (objectives and KPIs) are defined for those key business processes associated to the collaborative context (Phase 2). These key processes are processes directly linked to a common product/service produced by the partners or processes that support the success of the production of those products/services.

In the previous phases (phase 1 and 2), all the performance elements have been defined. Finally, the third phase aims at monitoring of all those elements in order to know which are the most important elements, i.e. what levels are the most relevant from a performance management point of view and where are located special indicators for a specific partner.

4 Case Study

The performance management framework has been applied within a Spanish bathroom furniture enterprise network. Specifically, as an initial stage, it has been developed the pilot for the furniture supply chain. From the mission and vision of the supply chain, the main objectives were defined. Table 2 shows the objectives and corresponding KPIs of the strategic framework. The strategic framework was established after two meetings of two hours with four managers of the supply chain and comprises fourteen objectives and eighteen KPIs what seems reasonable. As can be observed, for each objective, it has been needed to define at least one KPI to monitor its evolution. In some cases, e.g. profitability, two KPIs were necessary (KPI2=ROI and KPI3=ROA). The sustainability perspective comprises at this stage four objectives and five KPIs.

Table 2. Objectives and KPIs of the strategic framework at the Supply Chain Level

Perspectives	Objectives	KPIs
Financial	Reduce costs	KPI1 = product cost per family.
	Increase profitability	KPI2 = ROI
		KPI3 = ROA
Customer	Increase market share	KPI4=national market share
		KPI5=international market share
	Increase customer satisfaction	KPI6=customer loyalty
		KPI7=loyalty programs implemented
Process	Reduce lead time	KPI8=lead time
	Reduce non- quality parts	KPI9 = conformance quality
	Increase on-time delivery orders	KPI10 = % parts delivered on time
	Increase efficiency in process management	KPI11= efficiency per process
Sustainability	Increase recycling	KPI12= implementation of recycling sections
	Increase environmental management culture	KPI13 = ISO 14 000 certification
		KPI14= environmental programs implemented
	Increase Health & Safety culture	KPI15= H&S programs implemented
	Reduce H&S incidents	KPI16=H&S problems
Learning and Growth	Increase innovation capability	KPI17 = development of new programs
	Increase knowledge management	KPI18=implementation of knowledge management tool

After defining the strategic framework of the supply chain, the process framework was defined for two key interorganizational processes of the supply chain: new product development and production planning. Table 3 shows the objectives and KPIs for the new product development process. In this case, eleven objectives and fifteen KPIs were defined in two meetings of two hours by the new product development team composed of members from all the enterprises within the supply chain.

Table 3. Objectives and KPIs of the new product development process at the Supply Chain Level

Perspectives	Objectives	KPIs
Financial	Reduce raw material cost Increase profitability	KPI1 = raw material cost per product. KPI2 = internal rate of return KPI3=net present value
Customer	Increase perceived value of product Increase customer satisfaction	KPI4=customer meetings KPI5=customer relationship management KPI6=customer complaints
Process	Reduce time to market Reduce non- conformance parts of production trials	KPI7=time to market KPI8 = quality monitoring of trials
Sustainability	Reduce raw material needs Reduce waste Increase Health & Safety culture	KPI9= raw material consumption KPI10= % raw material reduction KPI11= waste per component KPI12 = H&S suggestions implemented KPI13= new product H&S standards
Learning and Growth	Increase innovation capability Increase knowledge management	KPI14 = follow-up meetings with all the members of the supply chain KPI15=improvements in tool for new product management

Once the process framework was defined for the supply chain, every enterprise has adapted its performance management system. Some of the enterprises of the supply chain have one performance management framework already implemented so that they have to modify it accommodate the new requirements from the supply chain level performance framework. However, some of the enterprises do not have a proper system and they are beginning to work in it. That is the reason why some aspects such as coordination and collaboration objectives and KPIs so far have not been introduced despite its importance. In one year, it is planned to review the status of the whole performance management framework but quarterly reviews are established as well to monitor its evolution. The sustainability of the network will come as the members use the information provided by the performance framework monitoring, analyzing the objectives reached and defining proper action plans when the objectives are not reached. This will help to create and manage operational supply chains due to the focus on monitoring the key aspects for developing the strategy into operations and monitoring its evolution.

The main conclusion from the partners is that the process followed to elaborate this framework has provided them knowledge about the main areas of interest of the evolution of supply chain as well as a tool for monitoring performance. For each objective, a percentage target has been established (i.e. Reduce by 10% raw material cost). In addition, a percentage of achievement of the different objectives is to be monitored through the collected data of KPIs. Decision makers of the supply chain have defined that at least the percentage of achievement of the objectives has to be 75% in order to meet sustainability requirements.

5 Conclusions

This paper has reviewed the literature regarding managing sustainable collaborative enterprise networks. From the review, we have observed that there is a lack of a proposal that meets the four characteristics that we consider essential for managing sustainability in these contexts (strategic focus, three sustainability dimensions, interorganizational processes, and individual and collaborative performance levels).

Based on the gaps coming from the literature review, we have introduced a new performance management framework, which includes all four characteristics and the necessary connection mechanisms within its structure in order to provide a tool for managing the performance of sustainable collaborative enterprise networks.

This framework considers five performance perspectives in order to manage performance. In fact, there is a need to consider a specific perspective for managing the sustainability dimensions (environmental and social dimensions) as they act as a link element for reaching the elements that compose the other performance perspectives. In addition, we have presented a case study of a pilot developed within a supply chain dedicated to manufacture bathroom furniture. The initial stage has focused in applying the framework to the furniture supply chain and two interorganizational processes: new product development and collaborative planning. Next development stages will consider its extension to the enterprise network level as well as other interorganizational processes.

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Performance Measurement Systems

PI Toolset Methodology for Virtual Enterprise Performance Assessment and Governance

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Abstract. This paper aims at describing a proposed Performance Indicators (PIs) Toolset, which has been developed to provide useful methodologies and tools to enterprises, especially Virtual Manufacturing Enterprises (VMEs), in order to support the management and evaluation of their service systems. Particularly, the identified PI Toolset helps VMEs to understand how well they are performing and contributing to their strategic goals and objectives.

Indeed, determining which activities should be monitored, controlled and measured through proper PIs is essential for a VME. In this context the proposed PI Toolset helps to select the significant activities, to manage governance processes, and to support the design and implement the specific PIs related to the precise use case objectives. Finally, the proposed Toolset defined a set of PIs that can be used to evaluate business processes related to governance issues.

Keywords: Virtual Enterprise, Service governance support toolset, Performance Indicators.

1 Introduction

Global industrial competition, current economic crisis and market turbulences have opened up more threats and also opportunities to enterprises both in manufacturing and service environment; furthermore, threats and opportunities generate exceeding pressure on enterprises to improve their capabilities. This paper investigates a key topic in management area based on the mutual interests of individual managers, decision makers, and also the capabilities of a network or supply chain: process evaluation through Performance Indicators (PIs). Therefore, enterprises need to employ different strategies with different context and circumstances in order to achieve a differentiated competitive advantage [1]. The competitive advantage will help enterprises to survive in an increasingly competitive context [2].

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Despite the facts that individual enterprises gain the opportunities through its own internal Tangible and Intangible (T/I) assets such as knowledge management and progressive R&D process; nevertheless, individual enterprises need to get closer to their partners in supply chain network and optimize their relations through the outsourcing process. Therefore, in order to be able to provide outsourcing process, individual enterprises need to participate in a collaborative network that has nowadays become crucial for any manufacturers and service providers.

With respect to the above mentioned context, individual enterprises need to shift from autonomous work toward collaborative network that can be defined as a common way by which all enterprises in supply chain are actively working together toward shared objectives. Consequently, collaborative networks are characterized by sharing T/I assets such as information, knowledge, risk and profits [2, 3 & 4].

Undeniably, enterprises need to provide some requirements in collaborative network environment such as restructuring their internal and external operating process; re-engineering the production and service system; redefine the roles and rules of members in network; employed multi skilled and flexible people and at last, but not at least preparing the proper IT tool in order to coordinate the relationship among the members. Therefore, collaborative networks need significantly to improve competencies in terms of dealing with new business models, strategies, organizational and governance principles, processes and technological capabilities [5] in order to be successful in a very competitive and rapid changing environment.

In this context, this paper aims to define and develop an overall Toolset to monitor VE based on Product-Service solution, through PIs and Product-Service oriented methods. Therefore, the proposed method should be applied to VE in order to efficiently control the product-service system within a Manufacturing Service Ecosystem. Meanwhile, in order to be able to produce significant results, an industrial case study is presented where the proposed PI Toolset is validated and adopted on it.

2 Research Background

A collaborative network can be defined as composed by various entities such as organizations, people and machines, and is characterized by geographical distribution, large autonomous and heterogeneity in terms of their operating environment and goals [6]. For its mature it needs to be supported by IT tools in order to set the interaction among the participants.

A relevant stream of literature mainly rooted that a collaborative network structure classified in classical and dynamic format. In classical format network is relatively stable with well-defined roles in organizational forms; nevertheless, nowadays more dynamic structure are emerging in industries. One of the most important organizational forms, which will be analyzed in this paper, is the so-called Virtual Enterprises (VE). VE is a temporary organization of companies formed to exploit fast changing opportunities. In this case, companies come together to share costs, skills and core competencies in order to address the business opportunities that they could not undertake individually [7, 8].

Although the combination of the core competencies of companies, the VE may become the best of everything enterprises and the key issue in order to fast reaction to market demands and business opportunities; Nevertheless, their practical implementation is still far from the expectations and also VE planning and creation, as well as several aspects of VE operation, are still difficult and need to be properly adapted even by advanced and competitive collaborative networks [7]. Some of the lacunae include the lack of common reference models and appropriate support tools following by below observed points [9-12]:

- Partners search and selection;
- Monitoring and coordination of task execution according to contracts;
- Performance assessment.

In this context, understanding the VE formation process, modeling its processes and developing useful supporting tools are still open challenges [2, 9& 13]. In order to provide a meaningful analysis of the research background, the “Servitization” process is introduced. Indeed, it is accepted as one of the most successful structure which has been used to extend the after sale service activities. Meanwhile, it has been used frequently by manufacturing enterprises that would like to shift from a pure product sales structure towards after-sales services, and bundle their products with services to satisfy the customer needs [14]. In this context, Servitization process has been used to enhance the services that have been provided to support the manufactured products.

Use case plays an important role and leads the VE environment as a focal firm where it is responsible and allocates the manufacturing and service tasks among the partners (upstream level), and also sharing the costs and resources. Meanwhile, Use case (Focal firm) acts as a product integrator and also is responsible for the final product/service and relationship with the customer.

As far as the use of VE as an organizational form of a collaborative network is concerned, different Performance Measurement Systems (PMS) developed during the past decades in order to facilitate the generation and selection of most proper PIs. Consequently, PMS is used in order to be able to monitor the service performance effectiveness and efficiency through exploiting the suitable PIs. During the past decades, several PMS (Models, Tools, Methods and Frameworks) proposed and developed by various researchers and business managers. The most important are PMSs such as PRISM, ECOGRAI, Integrated Performance Measurement System (IPMS), Balanced Score Card (BSC), Six Sigma, European Foundation for Quality Management (EFQM), and Matrix and Brown’s framework, which have been accepted and employed by various enterprises. [2, 15-23]. The basic idea behind PMS exploitation is to encourage the enterprises to continue improvement and also to support appropriate activities through the proper PIs exploitation. Furthermore, PMS is used as a key process in the management of VE and traditionally, is defined as a systematic process of gathering, assessing and reporting the predefined tasks and objectives status. In order to be able to have meaningful analysis a set of quantitative and/or qualitative indicators can be used to help the enterprises and decision makers to evaluate the collaboration benefits in this environment such as activities performed resources employed, and outcomes obtained [5].

Various authors expressed either positive or negative criticisms on the aforementioned PMS. For instance, EFQM and BSC highlighted in the literature as the most popular and employed by several enterprises today. Although, both models were initially designed for intra-organizational performance measurement in single companies and offer a measuring approach based on driver and outcome indicator to monitor and assess different perspectives in an enterprises; nevertheless, these models have a lack in terms of focusing on the strategy of collaborative network environment. Additionally, BSC proposed a closer measure to predefined objectives and has a faster and more processed reporting especially based on financial measures. So, the relevant PIs make sometimes difficult in terms of comparison because indicators are contextual and need to be customized for each enterprises or objectives [5, 25-26].

A relevant stream of the literature rooted some other criticism included: the nature of PIs used, dimensions retained, lack of procedures for the choice of PI's and procedure for the PIs connections, etc. Even the BSC, perhaps the most popular and used method, was deeply criticized about the reduced stakeholders [15].

In spite of these criticisms, it turns out that aforementioned PMS's present many similarities and differences, advantages and inconveniences. With respect to the mentioned methods, ECOGRAI method will be selected in this paper in order to design and to implement proper PIs in VE domains. The basic idea behind of ECOGRAI selection is that it has the opportunity to link with modelling tools such as Graph with Result and Activities Interrelated (GRAI) GRID and GRAI nets and also applied with the implication of the decision makers [2]. The selected method has a clear vision about the decomposition and the coherence of objectives in comparison to other most well known PMS such as BSC. Meanwhile, in ECOGRAI method is easy to have a very detailed view of the performance and also control of the performance [2, 26-27]. At last but not at least, the selected method covers the various functions and the various decision levels such as Strategic, Tactical and Operational in order to present a coherent distribution of PIs. Also, in order to manage the monitoring processes and to define the objectives, GRAI method will be used according to its proper integration between the focus on results and the consistency of the decision process [28]. Meanwhile, the selected method has a good possibility to analyze and to correct the coherence of an objective system in order to ensure that the operational objectives contribute to the strategic objectives.

In particular with regards to service performance, two research methodologies have been investigated and compared: Action Research Methodology (ARM) and Collaborative Management Research (CMR). CMR and ARM have some similarities as well as distinct features [29]. A comparative analysis revealed that both methodologies focus on developing a deeper level understanding and their main purpose is the identification, modification and transformation of the studied system [30]. Furthermore, both are concerned with system improvement and added value to the management realm. However, CMR is more oriented to capabilities' improvement and it can be adopted for both improving the capabilities of VE or even the capabilities of individual managers and decision makers by addressing specific aspects of management such as specific managerial actions or coordinating mechanisms among collaborative networks. In this way, CMR can be defined as an inquiry process that, through multiple studies, the accumulation of knowledge over time about different aspects of management, and across types of systems will clarify when and how managerial actions can make a difference [29]. The inquiry process of experiencing, understanding, judgment and action, as captured by Coghlan, is likely to confirm or disconfirm assumptions and is likely to result in general accumulation of managerial wisdom and scientific knowledge that eventually influence how management is taught and practiced [31-32].

3 Research Questions and Methodology

This section presents the main research questions to satisfy the above-mentioned open challenges in VE realm, and indicates an overall method that combined a set of existing methodologies to achieve the research objectives. Therefore, the adopted research methodologies have been applied in an industrial case study to demonstrate its validity.

3.1 Research Questions and Objectives

In order to succeed in the modern turbulent and competitive climate, VEs require significantly improving competences in terms of business strategies, new governance principles and performance assessments. Moreover, in order to leverage the potential benefits, assessing the performance of the associated members in the VE through a proper set of PIs can usefully support the lifecycle of the designed and produced solutions, i.e. Product-Service.

In this context the authors identified the following research questions about performance assessment and governance in VE:

- Which specific performance assessments should be considered while monitoring VE (based on Product-Service) when numerous companies cooperate within a Manufacturing Service Ecosystem (MSE)?
- Which specific aspects related to performance indicators and methods should be applied to a VE in order to efficiently control the Product-Service system within a MSE?

Such questions decline the overall research goal in two specific objectives; in particular, to answer the two research questions, the following three objectives have been defined:

- Development of a new methodology that helps enterprises selecting the activities to be monitored, controlled and measured through appropriate PIs;
- Definition of functions and actions at decisional levels (i.e. Strategic; Tactical and Operational);
- Preparation of a guideline to design, classify, implement and maintain effective PIs related to a specific VE with respect with its internal goals and objectives.

Moreover, the scope of research is focused on the analysis of the Service VE lifecycle by itself and the assessment of service performance for Service. As a consequence, the present research is based on the selection of a specific Use case focusing on a Service VE and the characteristics of the Service Lifecycle Management (SLM). Given the relative novelty of the subject, the literature lacunas in VE in which both manufacturing and service practices and performances can be considered according to the Use case objectives and strategies.

The proposed method starts from the investigation of existing methodologies about performance and service management lifecycle assessment. It includes a brief literature review based on major methodologies that have been used in research and short explanation of adoptable methodologies that can be used in order to develop the concepts/approaches proposed and methodologies adopted to validate that the concepts/approaches are applicable.

With respect to performance assessment requirements for Service in VEs, the research methodology is structured in the following steps:

- Monitoring Framework for Service Virtual Enterprises;
- Generating a PIs model suitable for the specific purposes;
- Defining a list of PIs for service VE;
- Inserting this list in an ICT tool.

Furthermore, this paper considers that Use case seeking the transformation at all level of organizational life; consequently, Developmental Action Inquiry (DAI) also will be included. In the following table the research tools adopted in the proposed methodology to be used in on Use cases. In particular, it contains the list of tools for each step. With respect to the first step, the methodology has been developed starting from reference models available in the literature and using both selected tools from CIR and DAI approaches. The second step considers PMS tools for PIs generation models. The third step the list of PIs defined before will be shared with decision makers and study team in order to select the most proper PIs according to the use case objectives and main strategies. The fourth step will consist of insertion of PIs into an ICT tool according to Use case requirements according to the Process Modeling approach. Finally, a Use case is adopted to test the applicability of the model, as well as to refine the methodology itself.

Table 1. Research Methodology

	Research Methodology **Adopted**	
	Approach	Validation
Monitoring Framework for Service VE	Literature Review- CIR and& DAI	Use Case
PIs generation model	Literature Review & DAI	Use Case
PIs for Service VE	Literature Review- CIR	Use Case
Insert into ICT Tool	Literature Review- Process Modeling	Use Case

4 PI Toolset

A PI Toolset has been created to support the managing and controlling issues of a VME. The stated Toolset includes various tools such as service governance framework, PI method and list of PIs that adopted together. By synthesizing the mentioned trio methods, PI Toolset will be able to create a coherent link between governance issues and the selection of specific PIs.

4.1 Service Governance Framework

The proposed service governance framework satisfies the first step fo the proposed methodology. It synthesized by GRAI model and Model Driven Service Engineering Architecture (MDSEA) within a VME environment in order to create a conceptual reference framework focusing on business objectives definition and governance issues. Particularly, the GRAI model has been used to synthesize coherently various governance concepts (at detailed and global levels) into a unique generic model to facilitate integration between decisional levels and functions. On the other hand, MDSEA has been adopted with a conceptual framework in order to classify PIs into a different level of decomposition (i.e. decomposition by level of abstraction and decomposition by level of decision). The MDSEA has been used in order to facilitate the classification and implementation of PIs into a different level of decompositions; it means decomposition by level of abstraction (BSM, TIM and TSM) and decomposition by level of decision (Strategic, Tactical and Operational). In more details, BSM (Business Service Modeling) level has been used in order to elaborate high abstraction level model from users' point of view. TIM (Technology Independent Modeling) level gives detailed features of the service. TSM (Technology Specific Modeling) level insert a particular type of technology such as machine technology that is belongs to implementation options.

The conceptual framework has been used to lay down the foundations for governance framework which can be then linked with coherent monitoring and controlling activities; and to help the selection of highly exploitable PIs related to End User governance objectives. Table 2 provides an overview of the correlation between the stages considered for the Service Governance Framework and the MDSEA levels of decomposition.

Table 2. Service governance framework

		Service Governance Framework							
		IDEATION	CONCEPT	REQUREMNTS	DESIGN	IMPLEMENT	OPERATION	DELIVERY	DECOMMISN
BSM	*STRATREGIC*								
	TACTICAL								
	OPERATIONAL								
TIM									
TSM									

4.2 PIs Generation Model

PIs Generation Model has been used to design, implement and classify the specific PIs related to the precise use case objectives. The (Fig. 1) Use case objective (i.e. Servitization) process has been modeled through the proposed framework and servitization characteristics have been specified such as functions and objectives at decisional levels. As described in Fig. 1 the following aspects can be observed: firstly, objectives at decisional level are defined through the proposed framework; secondly, a set of specific functions and actions have been defined through Value Reference Model (VRM) as decisional tools for supporting business processes; at the third level, an initial definition of specific PIs is carried out, and afterwards a personalized list of PIs is generated. At the end, the selected list of PIs is defined: they can be used to monitor and govern the service. VRM has been used deliberately in order to design and implement the related PIs. Indeed VRM provides a supporting tool to define and prioritize the PIs that are needed to govern business processes.

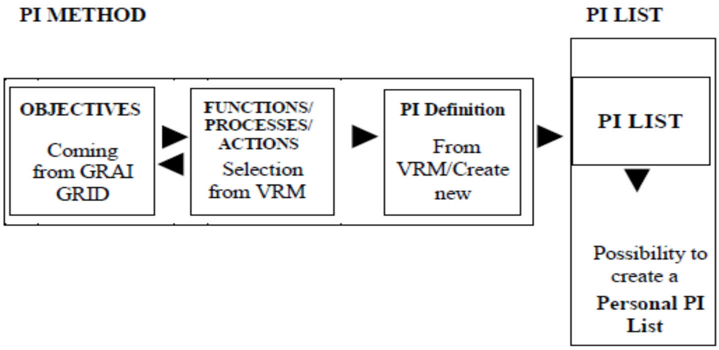

Fig. 1. PI Toolset: detail on PI Generation Model and PI List

4.3 PI List and ICT Tool Creation

The PI list has been used to evaluate business processes related to governance issues. In the Table, 3 proposed methods developed a “Tree” structure file in order to filter the selection procedure of PIs.

PI list classification in one side comes from VRM process categorization and on the other side comes from MDSEA. The PI List has been focused on VME creation with particular attention on BSM Level. Indeed the PI List is the results of service governance framework and PI Method. PI List is a supporting tool to assess service performances and manage the efficiency of enterprise resources. Meanwhile, a PI List structure has been created in order to facilitate the selection and the linkage of PIs to objectives and decision variables.

Finally, in order to support service design, management and evaluation within the manufacturing networks in an ICT environment PI Toolset has been implemented within the SLM Toolbox. By using the toolset the following points can be observed:

- Easy and coherent selection of highly exploitable PIs related to End User Governance objectives;
- ICT implementation of the support control toolset through the SLM Toolbox;
- End Users have the possibility to edit, change, save their PI List and share it with partners through the innovative ecosystem platform;
- Adequate measures for effectiveness, efficiency and productivity can be assessed in order to offer a satisfactory service system;
- The toolset can improve the efficiency of the service system by measuring the ability of a firm to reach its main governance goals within the VME perspectives.

Table 3. PI List structure

MDSEA	VRM process Classification	PI field	Dimension	PI metrics	PI formula

5 The Use Case Results

In order to produce meaningful results and optimize the proposed PI Toolset, the approach has been applied to an industrial Use case. The company is one of the largest European manufacturing industries in the white goods sector, aiming at providing its consumers with advanced services; therefore, the proposed PI Toolset has been developed and modified through industrial case study creating a real servitization process.

The current Servitization level in the selected company is rather low and limited to selling the physical product and only few basic services have been offered in a traditional way such as warranty, technical support and service center. The basic idea behind of Servitization process exploitation is to increase the product selling through differentiate the services according to the company profile. In particular, the company aims at realizing a new service focused on supporting the customers' usage by personalized services such as personalized best practice, machine monitoring and tailored commercial offers [15]. In order to provide the new services, Use case has been provided a new VE environment and selected the partners according to the preexisting suppliers profile and also new members from outside of its own ecosystem with respect to new VE defined activities and main objectives.

In particular, the company framework is actually characterized by the manufacturing company itself and a group of partners: it is actually organized in a vertical supply-chain adopting a product-oriented development process. Collaboration between the manufacturer and its partners and suppliers is limited to design stages and components' supply. The leader company recently designs and produces a "Smart Washing Machine" enhanced with embedded items (e.g. sensors, Zigbee module, router Wi- Fi) and software components (e.g. web service, data repository, web/mobile application) as well as an infrastructure to connect the product to an external network. The Use case focuses on enabling new services for such Smart Washing Machines: it aims at realizing a new service, called “Carefree Washing Service”, to provide the washing machine rent for free, a supply agreement comprising washing energy and detergent supply by paying an annual fee, and a web/mobile application for machine monitoring and customer training and coaching. Such Use case aims at enlarging the VEs by including also customers thanks to a direct relationship with them by facilitating the product use, educating the customers in a correct use and energy/cost saving practices, and collecting real-time feedback.

According to the Use case objectives, a set of functions has been defined and classified inside the framework of servitization (i.e. Customer decision, Customer ideation, Service product design, Service requirements). Then, according to the mentioned functions, main objectives have been defined at each stage (i.e. Strategic, Tactical and Operational). Table 4 represents the results related to the proposed framework. Finally, PI list has been represented in the Table 5.

Table 4. Service Governance Framework

	External Information	Customer decision	Customer ideation	Service -Product design	Service -Product Implementation	Service -Product planning	Service -Product delivery	Internal Information
STRATEGIC H= 2 Years P= 6 Month	Existing Services in competitive companies	Customer expectation in terms of services	Business plan for service proposition	Selection of design methodologies and partners	Selection of targeted goods and technologies	Annual service planning	Partner relationship organization	Business Strategy and Master planning
TACTICAL H = 1 Year P= 1 Month	Existing HW & SW Implementation technologies	Feedback on customer satisfaction	Assessment of existing services	Definition of PSS functions and design specifications	Action plan to modify production process	Planning of the specific service actions	General planning of service delivery	In- house Available technologies
OPERATIO-NAL H = 1 Month P = 1 Week	Advertising	Customers orders; Customers claims	Brainstorming meeting;	Detailed design planning	Implementation of modifications	Service scheduling; Feedback measurement	Short term delivery planning	Status of service production and service system

Table 5. PI List

MDSEA	Customer relationship	Service ideation	Product-Service System design	Product-Service system development	Product-Service system planning	Product-Service system delivery
STRATEGIC H= 2 Years P= 6 Month	ROI for each product-service (like the minimum ROI range); Net margin expected	Capability to implement cross-selling (through a CRM system)	Total cost of product-service system design	Global implementation costs	Amount of product-service sales for the next two years	Cost of delivery channels
TACTICAL H = 1 year P= 1 Month	Service Exploitation	Amount of sales per month	Time to design the PSS	Time to market	Turnover	Number of new customers/contracts
OPERATIO-NAL H = 1 month P = 1 week	Time to start up the service, Customer satisfaction rate	Increase of of the new ideas	Delay/advance in design	Checking of timing and costing (deviation in%) of master plan	% of WMs with Carefree Washing Service produced in time	Product-service frequency

6 Conclusions and Future Works

In this paper a methodology to define a PI Toolset for performance assessment in the VE has been proposed as an instrument to support service management and VME configuration. Indeed, it allows defining and representing an open structure (i.e. Service Governance Framework) to share knowledge and sources among the members inside the service ecosystem. Meanwhile, the PI Toolset is used as a decisional supporting tool to generate specific PIs related to end users' core activities. Particularly, the output of PI Toolset will provide a source of information to be used, visualized and shared among VME partners through ICT tools. PI Toolset can support VME to control and monitoring their performances in order to improve their level of service quality and, therefore, manage better the service governance. Indeed the PI Toolset is able to provide, collect and manage necessary information for helping the VMEs in identifying and understanding the needs and requirements of the service system and assessing current and future organizational and process capabilities of the service. The method is presented and tested on an industrial use case, whose preliminary results are shown and discussed. Obviously, this paper paves the way to a more detailed validation phase where the PI Toolset are improved through a huge number of use cases. Therefore, in order to generate additional positive results on use case servitization governance processes the following additional improvements such as visualization of performances, Internal audit and feedback on performances can be taken into account as further steps.

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A Performance Measurement System to Manage CEN Operations, Evolution and Innovation

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Abstract. Nowadays, many enterprises collaborate forming a collaborative enterprise network in order to achieve competitive and sustainable advantages. These collaborative enterprise networks are operating many times under a *glocal* approach, which means that they have less time to react, to properly evolve and more challenges to face, mainly the fact of operate both locally (product design, sales) and globally (manufacturing, distribution). In this context, collaborative enterprise networks need to manage not only their classic operations (costs, quality, response, flexibility, etc) but they also need to integrally incorporate to their management and decision-making systems their collaborative practices regarding evolution and innovation. Then, this work presents an evolved performance measurement system to manage collaborative enterprise networks operations including co-innovation and co-evolution practices. Such a system has got four phases and, through the identification and quantification of relationships among performance elements, it offers a new management approach, which will provide collaborative enterprise network decision-makers with additional and meaningful information.

Keywords: Collaborative enterprise network, operations, glocal, co-innovation, co-evolution.

1 Introduction

Currently, it is a common practice to do business in globalized markets under a collaborative approach, constituting a Collaborative Enterprises Network (CEN). Additionally, global markets dictate conditions difficult to achieve at the same time such as highly customized products/services (even locally customized), to be offered in high amounts (products/services produced and supplied from geographically distributed enterprises), within very short lifecycles and volatile business environments. This approach represents what it is widely known as *Glocal* approach: to think globally and to act locally. From a CEN point of view, this implies to coordinate many complex operations at a global level in order to supply products and services that are responding to the gathered locally identified customers' needs and tastes. The associated challenges are, even nowadays with all the technological and managerial advances at disposal, of enormous proportions. Further, if taking into consideration the timely factor, it seems evident that the customers' needs and tastes,

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the market evolution and trends and the own CEN are dynamic and should evolve over time. Focusing on the CEN level, its individual partners should be able to evolve together in order to be able to adapt to both customer and markets changes for not getting dismissed from the marketplace, what it can be seen as a *co-evolution* process of the CEN. In addition to this *co-evolution* issue, if a CEN wants to be competitive over time, it must be able to design and offer innovative products and services, which is known as *co-innovative* products and services process. In this process, customers could also be invited to participate during the innovation process, adopting new roles and even being formally part of the CEN [1]. But a CEN cannot be only a source of locally customized products and services to be produced and supplied in a global basis but it must also make it efficiently. This implies to control and manage the CEN's operations in order that the CEN will be cost-efficient, robust, with a high degree of responsiveness, etc. Then, tools and mechanisms that will help to properly manage CEN operations from a dynamic point of view are needed. This paper deals with the co-evolution issue from a decision-making point of view, presenting a methodology that will be able to improve both CEN's short-term decisions and CEN's strategic long-term definition.

The next section looks at the academic literature that have dealt, in some manner, with this approach, setting the basis for the framework developed in this work: A performance measurement system to manage CEN operations, whose base is to identify and quantify the existing relationships among performance elements, it is presented in the point 3. Lastly, point 4 highlights some findings from a real application of the proposed system.

2 Background

2.1 CEN Co-Evolution

As stating above, a CEN is dynamic and it changes over time, not only from an external point of view (due to exogenous factors) but also from an internal one (due to endogenous factors). All these factors are influencing over the CEN's lifecycle whose main states are next explained [2]. After a first phase of *Creation* where the partners are stated together with their duties, responsibilities, etc., the *Operations* phase takes place. It is within this phase when the CEN develops its main tasks of product/service design, manufacturing, distributing, etc. This is the natural state of a CEN. Within this *Operations* phase, it is the sub-phase called *Evolution* that takes place when there are non-significant changes in members, roles, etc. [2]. Nowadays, CEN evolution is not seen in isolation but it must be carried out under a collaborative approach, forming the called *co-evolution*. The ability to get adapted to environmental and internal changes within shorter and shorter product/services lifecycles, together with the need to efficiently and timely respond to changes makes individual evolutions of CEN members not longer efficient and demands a collaborative response. Therefore, there is a crescent need to manage such a *co-evo*lution of a CEN from an integrated point of view, assessing its degree and its impact over the whole CEN's operations. Finally, a

CEN may experiment a *Metamorphosis* when a great change in the CEN takes place or a *Dissolution* that it is when the CEN does not exit anymore [2].

Then, co-evolution practices and actions are becoming more and more important and, then, they should be incorporated in an integrated manner to the CEN's decision-making tools and mechanisms. It is important to point out that this work deals with all types of CEN, as long as they have previously, as starting point, formally defined a set of strategic objectives and associated KPIs.

2.2 CEN Co-Innovation

One of the most recent collaborative forms is the collaborative innovation or *co-innovation*. Within this co-innovation form, [1] mentions the next relevant features/elements:

- Understanding the innovation process.
- Brainstorming.
- Value identification.
- Mechanisms for safety/protection.
- Trust management.
- Supporting sharing activities.

All of these are important and to take into account when undertaking collaborative innovation practices. From an assessment point of view, the *value identification* is the one that has more to do with performance measurement systems. Further, at the CEN context, the value identification is carried out in a subjective way, as it is presented in [3]. They develop a set of qualitative assessments methods for assessing the called Value Systems in a CEN by applying fuzzy casual maps. The objective is to integrate multiple aspects regarding the alignment of value systems within a CEN, where different member has got different values and preferences.

Additionally, when looking deeper at the *glocal* concept, it is evident that nowadays the customer demands products/services that are more customized than ever. If these products/services are going to be operated through a CEN, this implies that new efforts regarding, among others, co-innovation should be done. Then, [1] identifies the called "customer involvement" as one of the most important task to accomplish. This implies that not only the CEN members, but also the customers, should participate when innovation is at stake. It is even mentioned that the customer could become a member of the CEN, extending therefore the approach of customers participating on product design of individual companies.

Therefore, *co-innovation* practices are an important part of the current CEN's operations and, therefore, they need to be integrally taken into account within the CEN's management system.

2.3 CEN Operations

Regarding a CEN's operations: how can be these controlled and managed in the current business ecosystem? There are numerous approaches developed during the last years that deal with managing a CEN's performance that is already working under operation [4,5,6,7]. All these frameworks manage performance by linking the stages of both creation and operation through the whole CEN lifecycle. However, none of them provides any direction on how to measure and manage overtime a CEN's operations by taking into account the results achieved by the performance measurement in the previous period as an input for the current period definition. Additionally, these works do not establish any meaningful link between the defined performance elements (mainly between the defined strategic objectives and the performance indicators), when it is widely accepted that these elements are intrinsic linked [8]; further, there is not yet any framework at the CEN context that identifies and quantifies these relationships. Additionally, a CEN's operations should be not taken as isolated in the current *glocal* business environment. Derived from the previously introduced, *co-evolution* and *co-innovation* are key issues that are directly and strongly impacting over a CEN's operations performance. Therefore, this work has gathered all this together and, in the next point, presents an innovative and evolved performance measurement system to manage CEN operations, integrating not only the classic operations such as cost, quality, responsiveness, etc, but also performance elements regarding the CEN's degree of *co-evolution* and *co-innovation*.

3 A Performance Measurement System to Manage CEN Operations (PMS-CEN OP)

This point presents the developed Performance Measurement System to manage CEN operations (PMS-CEN OP). The main tasks to be developed within each of the phases are next introduced:

- Phase 1. Definition of the CEN's targets and associated responsibilities. In this first phase, the accorded CEN targets are defined. This is a complex process, as all the different CEN partners must reach an agreement at both the strategic and the associated operational levels. Then, they must agree on the strategic objectives (called in this paper indistinctly targets) to be pursued during the next time-period (usually one year). It should be kept in mind that a given individual member of the CEN might have some own individual strategic objectives that are in conflict with some of the strategic objectives that the CEN aims to define. Negotiation processes must then be carried out, as this initial phase is key for the CEN's success. Regarding the CEN's strategic objectives, these will be defined according to the CEN's strategic line that needs to be covered in this precise moment. For instance, if the CEN wants to compete under a strategic line of "operational excellence", the strategic objectives to be defined will have to be about reducing the CEN's operational time, augmenting the CEN's responsiveness, augmenting the CEN's robustness, etc. Additionally, the PMS-CEN OP allows CEN decision-makers to define strategic objectives that have to do with both *co-innovation* and with *co-evolution*. These objectives can be defined under a more general context, and should focus on issues such as the CEN's co-innovative practices, success, members participating, degree of response, etc., and also on the CEN's co-evolution state, tasks, adaptations, etc. This will provide a complete definition of strategic objectives, moving then to define associate key performance indicators (KPIs). These KPIs will check out whether the associated strategic objectives have been reached or not. The KPIs will be of different nature regarding their frequency and units of measurement. The final task within this phase is to allocate responsibilities of each CEN member over each of the defined objectives. This is an innovative and important point in order to properly carry out the last phase of this framework. If the responsibilities of each member is well limited and defined and everybody has agreed on this point, when the leading (or cause) performance elements have been identified and quantified within the PMS-CEN OP, the actions to be taken will be more easily defined and assigned.

- Phase 2: Identification of metrics' relationships. Once the strategic objectives and associated KPIs have been defined, the PMS-CEN OP starts to operate and the KPIs start to measure and store data. This data contains important information, which is usually ignored, as it reveals patterns and behaviors that, when extended to the KPIs and strategic objectives levels, it is the source of valuable additional information. Then, it is possible to think in identifying relationships, in a quantitative manner, between the defined KPIs. Different techniques may be used depending of the number of observations, number of KPIs, missing values, etc. Some techniques that might be used are the well-known Multi-Criteria Decision Aid techniques; being widely used the Analytic Network Process [9]. On the other hand, it is also possible to apply statistical techniques such as correlation analysis, multiple regression or principal component analysis. The results are sets of cause-results KPIs. This mean that, when a cause KPI changes in value over time it makes that a result KPI changes too. From a decisional point of view, this means that this framework offers the possibility of focusing on less KPIs (the cause ones) when making decisions. Further, it allows bringing together relationships between all the defined KPIs, operational, *co-innovation* and *co-evolution* ones.
- Phase 3: Projection of relationships to targets/strategic objectives level. Additionally, the found relationships can also be projected towards the associated strategic objectives, carrying then out similar reasoning but at the strategic level (Figure 1 illustrates this tasks). This implies that, with the application of this framework, it might turn out that, for example, a certain *co-evolution* KPI (associated to the strategic objective of "Degree of adaptability to business requirements of the CEN") is the cause of a KPI that measure the global CEN cost (and associated to a strategic objective of "Reducing the CEN cost in a 10%"), when projecting these cause-effect relationships to the targets level, it will be possible to conclude that positive changes on the CEN's degree of adaptability are

leading to reach a lower CEN cost. This type of analysis is an innovative one at the CEN context and it provides decision-makers with important and additional information.

- Phase 4: Allocation of responsibilities. It is necessary to keep in mind that the PMS-CEN OP works at the CEN level but that there another lower level: the individual CEN members level. Then, once that the cause-effect relationships between performance elements have been establish and decisions made, this phase offers an innovative approach of responsibility allocation between the different members of the CEN.

Finally, it is important to point out that all the efforts carried out when applying the PMS-CEN OP should be taken into account in the next period when defining again the CEN's performance elements.

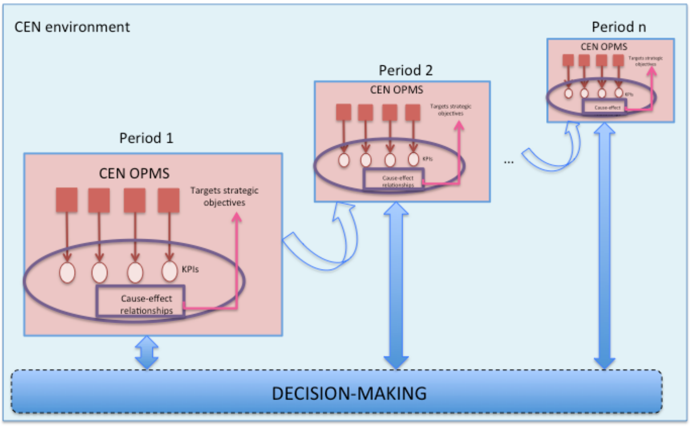

Fig. 1. PMS-CEN OP

4 Application

Generally speaking, it is possible to enumerate a list, from a general viewpoint, of useful KPIs to apply to measure CEN operations. Therefore, these KPIs are susceptible of being used at this context. Some examples of KPIs are the following: "Number of collaborative methodologies for improving resource efficiency and overall added value", "Definition of best practices and guidelines to re-engineer inter-company operations collaboratively in order reduce and eliminate wastes", "Number of business opportunities identified within the life-cycle of manufacturing products", "Number of supply chain reconfigurations", "Number of business model innovations", "Expected improvement of the overall equipment effectiveness/functional unit in the value chain", etc. However, each CEN will have different needs in terms of operations and defined performance elements as well as different maturity degree regarding the necessary expertise to implement the PMS-CEN OP.

This point aims to be illustrative in terms of presenting the main results coming from applying the PMS-CEN OP to a CEN that manufactures and supplies bathroom furniture. Then, as a result of applying phases 1, 2 and 3 several important (with strong intensity) targets cause-effect relationships were found. Further, 17 important cause-effect relationships were found and studied, being the different effect KPIs from the Financial (7), Customer (2), Internal Processes (6) and Learning and Growth (2) perspectives. Proper decision-making analyses were carried out for each of these 17 cause-effect relationships in order to improve the additional information to make better decisions at the CEN level and, extensively, being more efficient.

For instance, it was identified that the strategic objective F1 (Increment 5% net profit) was directly affected by F3 (decrement in a 10% product development costs), C5 (Increment in a 15% the percentage of new products based on customer input/design) and P1 (Decrement stock variability in a 15%). This means that the CEN should focus on achieving F3, C5 and P1 in order to successfully achieve F1. As a result of allocating responsibilities, it was clearly stated which CEN members should focus more on achieving these cause strategic objectives, resulting on a more coordinated and smooth actions. Since F1 was the most important strategic objective, it was decided to include it again in the next period PMS definition and, therefore, F1's cause strategic objectives (F3, C5 and P1) should be also included in such next definition, providing dynamicity to such a definition process.

This approach can be applied to any CEN that has a fully operating PMS in terms of defined objective and associated performance indicators. More applications would also enrich this initial approach and would, therefore, help to overcome the drawbacks found during its applications, being the main one the lack of knowledge of people in the CEN to apply and interpret the additional information that this evolved PMS points out. Additionally, it would be of great importance to set up some mechanisms that would make smoother and easier both the negotiation and definition activities within the CEN members.

5 Conclusions

This work has presented an innovative evolved performance measurement system to manage CEN operations (PMS-CEN OP). It includes not only the classic operations but it also incorporates both the co-innovation and co-evolution practices within the PMS-CEN OP, as in current competitive markets and under the *glocal* perspective these practices must be integrally taken into account and introduced within the CEN's management systems. Additionally, the PMS-CEN OP is dynamic (the main results of applying it in a certain period should be an input to the next period's definition) and it applies quantitative techniques in order to identify and quantify cause-effect relationships among the performance elements.

In terms of future research lines, it can be mentioned the need of further implementing the PMS-CEN OP to other CENs: Product, service, service-product. This will allow enriching this first approach and, therefore, it will turn into a better management tool.

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Measurement of Entrepreneurial Dynamism Capabilities and Performance in Collaborative Networks

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Abstract. In turbulent markets and scenarios that require extremely competitive and innovative organizations, the need to transform the resource base in accordance with the changing markets and technology is apparent. In order to do this, it is necessary to quickly identify and incorporate market opportunities, provide high capacity for learning, innovation and work collaboratively with other organizations in a network – in a collaborative way - to coordinate and transform their resource base. It is based on this information that this work aims to discuss the association between the role of an organization in a collaborative network and the development of dynamic capabilities, in response to environmental pressures and turbulence. Similarly, we seek to identify the impact (the improvement, or not) that generates the dynamics of organizations in a collaborative network. This paper brings two main contributions: the first lists a theoretical framework associating three main constructs: Dynamic Capabilities, Collaborative Networks and Turbulent Environments. The second proposes a conceptual model involving these three main constructs, facing adaptation, resilience and competitiveness of organizations.

Keywords: Collaborative networks, Dynamic Capabilities, Turbulent Environments, Virtual Organizations Breeding Environments.

1 Introduction

A number of studies highlight that the biggest challenges for managers in turbulent environments consist in making decisions quickly [1][2][3][4][5]. Most studies consider dynamic capabilities as a source of competitive advantage and as alternatives to guide these managers in rapidly changing contexts [6]. This context highlights the relevance of the Virtual Organizations Breeding Environments (VBE)[7][8][9][10][11] and the relations in collaborative networks [12][13] that enable organizations to increase resilience, maintaining the competitiveness and the capacity to enter into new businesses.

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 577–585, 2014.

To adapt to this reality and promote growth, organizations must be able to recognize the evolution of the environment, as well as anticipate and react quickly and effectively. This makes necessary to identify and incorporate market opportunities rapidly, provide high capacity for learning, innovation and work collaboratively with other organizations to coordinate and transform the resource base [14].

In a context of collaborative networks, business success is closely related to the synergistic interactions of the organizations and involves achievements that cannot be reached individually or demand a high cost of the parts, when separated [15][16][17][18][19][20][21]. It is in this context that companies share resources and skills to achieve their missions and goals [22][23][24][25][26][27]. The organizational interrelationships may have a powerful influence on competitive advantage by reducing costs, increasing profits, revenue, or market differentiation.

This work aims at understanding the association between the role of an organization in a collaborative network and the development of dynamic capabilities, in response to environmental pressures and turbulence. Similarly, we seek to identify the impact (the improvement, or not) that generates the dynamics of organizations in a collaborative network.

This paper has two main contributions: the first is a theoretical framework associating three main constructs: Dynamic Capabilities, Collaborative Networks and Turbulent Environments. The second consists in proposing a conceptual model involving these three main constructs, facing adaptation, resilience and competitiveness of organizations. This model will support a future empirical study. In this sense, we present three main assumptions that will guide the research development: **P1** The set of dynamic capabilities (organizational level) is extended by Collaborative Networks; **P2** - The result of a collaborative network is leveraged by the Dynamic Capabilities of organizations; **P3** - The level of environmental turbulence is positively associated with the above assumptions

2 Theoretical Background

Dynamic capabilities consist in creating resources combinations that are hard to reproduce, including an effective coordination of inter-organizational relationships on a global basis that is able to provide competitive advantage to the company. Dynamic capabilities are conceived as a source of sustainable advantage in Schumpeterian regimes of rapid change [28]. Pavlou and El Sawy [3] identify a set of capabilities focused on the detection of opportunities, learning, coordination and integration aiming at reconfigure the existing capabilities, in order to better match the environment. Given these scenarios, it is important to explore market opportunities quickly, providing high capacity for learning, innovation and integration [14].

By definition [29], the environment is the "pattern of all external conditions and influences affecting the life and organizations development." In turbulent environments, such patterns present continuous and substantial changes that are uncertain and unpredictable [30]. A turbulent environment is difficult to predict and is composed by disruptive changes [31]. Ansoff and McDonnell [32] provide a multilevel model with five stages (1 for minimum and 5 to maximum) of turbulence to categorize the current condition in which an organization operates.

Facing the need of rapid adaptation and resources reconfiguration, the establishment of Collaborative Networks appears as an emerging form of multidisciplinary cooperation between companies, involving different knowledge areas (eg socio-economic, cognitive science, operations research, organizational business and management, legal, social and ethical) to achieve common objectives [7] and respond, or even predict possible conditions imposed by the environment.

The operationalization of relations in collaborative networks may occur in specific (physical and conceptual) environments, known as Virtual Organizations Breeding Environments. Such environments are defined as an association of organizations supporting institutions related to them [10]. These organizations have the potential and willingness to cooperate with each other through the establishment of a cooperation agreement and an infrastructure for long-lasting interoperation, which has as its main objective to increase both their chances, as their preparation for a potential collaboration in the form of a Collaborative Network [33] [34].

Among the various cooperation activities cited by Vallejos [11] and the environment aspects needed for its operation, described by Loss [10], this proposal argues that the most appropriate form of cooperation (in this research context) occurs from Virtual Organizations or Virtual Enterprises operating in a Virtual Organizations Breeding Environments through Collaborative Networks. The arrangement that involves these organizations supports the maintenance and development of dynamic capabilities in high turbulence environments.

3 Methodological Procedures and Context Research

This research is proposed within the context of two ongoing projects in the CERTI[1] Foundation (Florianópolis, SC/Brazil). The first consists in the development of a VBE to host "innovative initiatives", seeking to converge efforts to generate value for nature conservation. It is focused in innovation to the conservation of private natural areas.

The second VBE is composed by an "Innovation Ecosystem", that identifies a purpose of innovation based on vocations, trends and potential for a given region. Based on this purpose, it integrates several actors, creating a synergistic and supportive environment. The organizations involved are connected to a differentiated market, formed by a coalition of "anchor companies" or angel investors. The knowledge generated in both VBEs aims to improve products, processes and business models for the Network.

The articles included in this study were obtained through a literature review in Scopus (Social Sciences & Humanities) and Web of Science databases (Social Sciences Citation Index / Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH)). The PRO-VE Proceedings of the last two years

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[1] Innovative Technologies Reference Centers / *Centros de Referência em Tecnologias Inovadoras* (`www.certi.org.br`).

(Collaborative Networks in the Internet of Services (2012) and Collaborative Systems for Reindustrialization (2013)) were also analyzed.

The theoretical framework associated to dynamic capabilities and turbulent environments were accessed through the keywords "dynamic capabilities" (*dynamic capability**) and "turbulent environments" (*turbulent**) used in the search fields “*Article Title, Abstract, Key Words*” for Scopus and “*Topic*” for Web of Science. The articles included were located in “*Article, Review Papers and Proceedings*” formats. The reference associated with collaborative networks and VBEs was designed from the PRO-VE 2012 and 2013 Proceedings. The filter selection was applied according to the following steps: (1) Identification of the converging papers from titles; (2) Selection or exclusion in accordance with the Abstracts and; finally (3) the systematization and classification of adherent articles.

According to Table 1, the first step selected convergent articles through the *titles*, *keywords* and respective *themes* analysis. A total set of 61 papers was obtained. A second check was performed (by the abstracts analysis) in order to select only those papers that directly addressed the topic. A final set of 39 papers were obtained that were then classified according to their (1) objectives, (2) the research method (3) variables; (4) context / application level; (5) results; (6) main conclusions and (7) proposals for further research. These steps were the guiding factors for the development of the Results and Discussion Section.

Table 1. Quantitative paper analysis for the development of research

Thematic	**Number of selected papers in the first stage**	**Number of selected papers in the final stage**
Dynamic Capabilities and Turbulent Environments	20	8
PRO-VE 2012	21	15
PRO-VE 2013	20	16
TOTAL	61	39

This work describes the first development stage of an instrument which aims to elicit organization’s performance metrics operating in collaborative networks. Three milestones will be achieved through the application of future empirical study based on this Conceptual Model proposed in the next Section: (1) Understanding the associations between the organizations dynamic capabilities and activities in collaborative networks, through different levels of environment turbulence; (2) Examine how the relationship between the variables influence the practices and process analyzed and organization performance; (3) Develop a methodology to measure dynamic capabilities and activities in collaborative networks according different environmental turbulence levels and organizational performance. The instrument proposed will be applied in organizations involved in the VBEs described above.

4 Results and Discussion

In turbulent markets and scenarios that require extremely competitive and innovative organizations, it is apparent the need to transform the resource base in accordance with the changing markets and technology.

Based on previous research models focused on measuring dynamic capabilities [3] and performance [7] in collaborative networks [10] [11] [35] [36] [37] [38] [39], this research aims to identify an optimal solution according to the different turbulence and pressures levels imposed by the environment [3] [32]. This section presents and discusses the main issues identified in the universe of the articles selected for this research. Among the 39 papers that formed the basis for the contextualization and conceptualization of collaborative networks associated with dynamic capabilities in turbulent environments, three contribute directly to the proposition of the Conceptual Model: *Understanding the Elusive Black Box of Dynamic Capabilities* [3]; *Business Model Development for Virtual Enterprises* [35] and *A Method to Quantify the Power Distribution Networks in Collaborative nonhierarchical* [36].

Pavlou and El Sawy [3] research brings two main conclusions. First, it identifies and articulates a set of dynamic capabilities, and proposes a measurable model to represent the nature of dynamic capabilities. Second, it empirically supports a structural model in which dynamic capabilities have an indirect positive effect on performance by reconfiguring operational capabilities in NPD, an effect that is positively moderated (reinforced) by environmental turbulence. According to the authors, this study has implications for (i) conceptualization, operationalization and measurement of dynamic capabilities, and (ii) to understand the effects of dynamic capabilities in turbulent environments.

Rojas et al. [35] proposes a set of business model elements to be used by the virtual enterprise in order to explore a new business opportunity for its network. The authors identify sixteen elements needed to define the business model of virtual enterprise. These elements structure five main areas: Customers, Value Network, Value Exchange, Value Capture and Network Governance. The contribution of the authors is one of the cornerstones the Conceptual Model proposed in Figure 1. Following the authors recommendation, we intend to apply the model in two distinct contexts of collaborative networks, in order to validate it. Finally, the variables proposed by Andres and Poler [36] and the 7 steps to estimate the power distribution within the network will also be considered to have a better view of power interaction and collaboration.

The Conceptual Model associated to entrepreneurial dynamism and performance in collaborative networks of organizations proposed below, is the result of refinement, adaptation and creation of new perspectives from the studies identified in the researches described above. Based on this, we made some adjustments in the original model proposed by Rojas et al. [35].

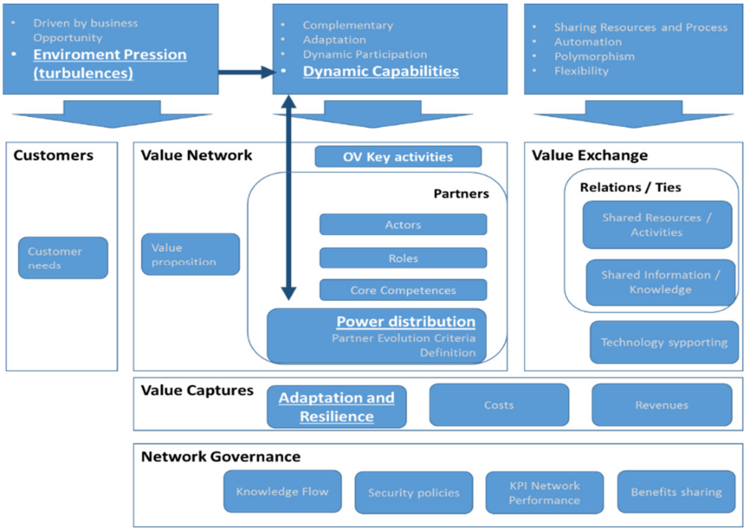

Fig. 1. Conceptual Model for business dynamism and performance in collaborative networks considering turbulent environments. Adapted from Rojas et al. [35].

The Conceptual Model will enable the system of metrics and indicators design for future application to organizations involved in VBEs cited in Section 3.

The presented Model considers the influence and pressure of high turbulent environments on the dynamic capabilities of organizations in collaborative networks. The relationship between dynamic capabilities and performance in a collaborative network has a positive direct relationship to the extent that the set of dynamic capabilities (measured according to the methodology proposed by Pavlou and El Sawy [3]) potentiate the result of a collaborative network (measured according to the methodology proposed by Andres and Poler. [36]) As the network relationships and results are able to be shared by all organizations involved, it also increases the possibility of dynamic capabilities development. A consequence of this process is the increase of the adaptive capacity and resilience of the organization while facing unstable, unpredictable and complex environments.

The present section briefly tried to understand how the literature addresses the dynamic capabilities and collaborative networks in contexts of high instability and rapid change. It is expected that the proposed conceptual model will further develop the operationalization and measurement of dynamic capabilities and collaborative networks to assist the quality of decisions in turbulent environments.

5 Conclusions and Further Research

The present research is still in its initial stage. We assume that there is a positive association between the environment pressure / turbulence, the development and maintenance of dynamic capabilities, and performance in organizations' collaborative networks. From a systemic literature review, we identified 39 convergent studies to our research problem. As the main result, three key papers were selected and served as a cornerstone to the Conceptual Model proposed. The validation of the metrics system must be concluded and performed by consulting experts in related fields. After the validation and refinements, we intend to collect data from the Virtual Organizations Breeding Environments companies presented in Section 3.

The data collection will occur in three stages: (1) Diagnosis of VBE entry, (2) intermediate Tracking evolution and (3) final diagnosis evaluation to validate the assumptions from the research. From the evolution of the present research, we aim to answer the following questions through future empirical study: (1) How organizations allocate their resources (processes associated with dynamic capabilities and performance in collaborative networks) according to the different turbulence environment levels identified and what is the impact on organizational performance? (2) Dynamic capabilities could leverage a collaborative network? (3) A collaborative network can actually be a precursor of organizational reconfiguration (dynamic capabilities)? (4) How it affects organizational performance in a turbulent environment?

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Risk Analysis

Reasoning on the Risks of Dynamic Manufacturing Networks through Cognitive Mapping

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Abstract. Dynamic Manufacturing Networks (DMNs) are increasingly deemed to be the evolution of typical supply chains in the manufacturing sector and a promising solution in the light of the enterprises' effort to remain flexible and competitive in today's rapid changing and demanding environment. The decision of joining a DMN however is quite important for any enterprise, since beside significant benefits it brings about changes in the way it operates, bearing thus also considerable risks. This paper attempts to cultivate an understanding around the risks of DMN participation, utilizing the causal characteristics of Cognitive Maps (CMs) for identifying the causes of unsatisfactory or unaccepted DMN operation outcomes. It further elaborates on how DMN risks are inherently dealt with through the IMAGINE framework that guarantees business alignment and interoperability.

Keywords: Dynamic Manufacturing Networks, DMNs, Risks, Cognitive Maps, CMs, Interoperability, Causal Relationships.

1 Introduction

With increasing competition in the global market, manufacturing enterprises are seeking ways to improve their core capabilities, streamline their processes, establish strategic alliances, and respond in a more agile way than in the past so as to leverage spontaneous business opportunities, and thereby position themselves for survival in the future [1]. One of the most promising solutions in their pursuit seems to be the concept of "upgrading" their supply chains to Dynamic Manufacturing Networks (DMNs). The DMN concept evolves and particularizes the notion of virtual enterprises [2] in the manufacturing sector, as it is a dynamic alliance of manufacturing entities collaborating for gaining mutual benefits [3-5]. Compared to a virtual enterprise however, a DMN is a real formation, though with loose ends and a quite flexible structure, which includes geographically dispersed OEMs and a pool of potential suppliers of various tiers.

For an enterprise, participating in (or forming) a DMN can be considered as a systematic way for cultivating extended co-operation with other members of its

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 589–596, 2014.

supply chain, and calls for modifications in its modus operandi, while it necessitates the network's dynamic management, so as to enable business alignment and active collaboration among the different network nodes [6]. In this respect, it also creates the need for stimulating and supporting communication concerning the impact of change, and thereby concerning the risks involved, which have to be identified and assessed [7], as the tighter relationships mean more dependencies between the companies.

This paper proposes an approach for reasoning on the risks of participating in a DMN, based on Cognitive Maps (CMs), i.e. mathematical models that hold the advantage of portraying information about a system more succinctly than the corresponding textual description [8], and suggest themselves as a means of bringing forth the way of thinking and making visible the perceptions of individuals. The paper leverages the causal characteristics of CMs as a modelling technique for generating a network of interdependent DMN risk-related factors and identifying the causes of DMN failure.

The proposed approach has both theoretical and practical benefits. Given the novelty and controversy around the concept of DMNs, such a succinct mechanism of conveying the dynamics of this new modus operandi and its associated risks is believed to be useful for any enterprise contemplating or undertaking major organizational changes towards its involvement in a DMN. Thus, the proposed model targets primarily DMN managers, high level executives, BPR consultants etc., assisting them to reason effectively on the risks involved in such formations and to devise appropriate mitigation strategies; nevertheless the explanatory nature of the model can also prove to be useful in a wider educational setting.

This paper consists of five sections. Section 2 introduces the novel and innovative concept of DMNs as well as the modelling instrument of CMs. Section 3 focuses on the application of the latter with the aim of stimulating reasoning on the risks involved in DMNs. Section 4 particularizes the identified concepts and developed CM in the case of IMAGINE, highlighting the paramount importance of interoperability. Finally, Section 5 summarizes the ideas presented and draws relevant conclusions.

2 Background

2.1 Dynamic Manufacturing Networks

A DMN is a coalition, either permanent or temporal, comprising production systems of geographically dispersed Small and Medium Enterprises (SMEs) and/or Original Equipment Manufacturers (OEM) that collaborate in a shared value-chain to conduct joint manufacturing [3]. Each member of the network produces one or more product components that can be assembled into final service-enhanced products under the control of a joint production schedule. Production schedules are monitored collectively to accomplish a shared manufacturing goal, while products are composed, (re-) configured and transformed on demand through dynamic and usually ad-hoc inter-organizational collaborations that can cope with evolving requirements.

The decision of joining a DMN is, as already discussed, quite an important one for any enterprise, since it is related to many changes not only to the way the enterprise collaborates with the external environment, but also to the way that almost all the internal processes are being performed; bearing thus also considerable risks. This is why it is important to cultivate an understanding of how the enterprise's participation in a DMN generates risks for the operation of the latter. To this end a closer look on the way in which a DMN is structured is required.

The DMN lifecycle, developed within the context of the IMAGINE FP7 FoF project [3], [9] is an innovative approach for modelling the entire lifespan of a DMN, ranging from planning and sourcing, to manufacturing and delivery. The DMN lifecycle places structure on the temporal order of the activities required for setting up and running a Dynamic Manufacturing Network, thereby encompassing the phases of i.) Network Analysis and Configuration, ii.) Network Design, and iii.) Network Execution, Management and Monitoring. The lifecycle is in fact initiated by a customer request that outlines the types and numbers of products to be produced, as well as the timeframe in which the product(s) should be ready. The Network Analysis and Configuration phase includes then the engagement of manufacturing partners, resources and other product-related information into a joint manufacturing schedule. The Network Design phase lies in combining all crucial manufacturing and physical processes, e.g., machining, forging, casting, and injection moulding in an end-to-end fashion, producing thus a chart of workflows that constitutes a working canvas for the entire DMN. Finally, the Network Execution, Management and Monitoring phase involves the actual deployment of the network and its processes and all the necessary activities for monitoring and troubleshooting its operation.

2.2 Cognitive Maps

Cognitive maps were first introduced by political scientist Robert Axelrod [10] in the 1970s as a means of representing social scientific knowledge. A CM is a network diagram depicting causes and effects [11], and is represented by a labelled, directed graph of nodes and edges. Nodes represent domain concepts and edges causal relationships between the nodes. The direction of an edge reveals the direction of a causal relationship, which is also called a feedback. A positive (negative) feedback from node A to node B means that an increase in variable A causally increases (decreases) variable B.

CMs are acknowledged as cognitive due to the fact that they use concepts to elicit and represent perceptions. They have been used in a variety of contexts, most prominently in operations management [12] as a means of facilitating brainstorming and communication. Thanks to their characteristics, CMs suggest themselves as a suitable method for capturing the complex interactions among concept variables in the DMN environment.

3 Causal Mapping of Risk Factors in DMNs

The proposed framework for modelling DMN risks through CMs has been developed as the result of a benefits and risks study carried out within the IMAGINE project [3], as a means of identifying business drivers for attracting enterprises into joining

DMNs. Data gathering was done through semi-structured interviews with industry stakeholders and information collected was analyzed using a grounded theory approach [13] that served to qualitatively identify all factors putting at stake the operation of both the single enterprise and the network as a whole. It is noted that the factors identified in this paper as well as their correlations are generic enough and can be applied to any DMN-related scenario. The list of concept variables elicited by the stakeholders' observations includes the following factors, provided thereafter along with a short explanation:

Lack of Appropriate Information, indicating incomplete or invalid information sharing as well as insufficiency of information exchange within the DMN network.

Unsuitable Partner Selection, denoting low compatibility and appropriateness of long/short listed, and thereby finally selected partners in terms of their capabilities, financial bid and quality offered.

Poor Network Configuration, referring to a low level of aptness of the baseline network configuration, including the preliminary, high-level production schedule.

Poor Network Design, indicating accordingly poor adequacy of the network design, including the final production schedule.

Poor Network Execution, Monitoring & Management, corresponding to ineffective handling and troubleshooting of the network operation.

Unwanted and Malicious Attacks, pertaining to the event of a third party gaining, usually through malicious software, unauthorized access to private computer systems or sensitive information, causing thus disruptions in the DMN information systems' operation.

Information Leaks, denoting the occasion at which some information, either sensitive or not, is revealed to unauthorized parties.

Strategic or R&D Knowledge Misuse, relating to the event at which some information leakage results also in important knowledge misuse by former DMN members or DMN competitors.

Disclosure of Unnecessary Data, referring to the unreasonable exposure of non-essential for the manufacturing course, but possibly sensitive information.

Project Failure, relating to the unfortunate event that the DMN fails to meet a particular project's requirements, the latter pertaining to time, quality or cost constraints.

DMN Dissolution, denoting the termination of the DMN operation mostly as a result of a key partner's withdrawal or the failure of a project undertaken.

Partner Withdrawal, pointing to the event that a DMN member drops out of the network and has thus to be replaced.

Key Partner/Supplier Withdrawal, identified as the above risk, however bearing more serious impacts, since the enterprise that drops out of the network is a key DMN member.

Partner Shortcoming, indicating situations in which a DMN member fails to meet the time, cost or quality constraints and specifications ascribed to it in the context of the manufacturing process.

Damage to DMN Reputation, mapping to the risk of the DMN reputation being negatively affected as a result of the individual partners' and whole network's inefficient performance.

High Integration Cost, referring to the investments required for individual partners to make their IT systems compliant with the DMN platform and engage in the DMN platform functionality.

Financial Exposure of Partners, pertaining to the financial risk undertaken by DMN partners due to their participation in the network.

Production Delays/Mistakes, indicating situations at which design or production flaws decelerate or retrograde the manufacturing process.

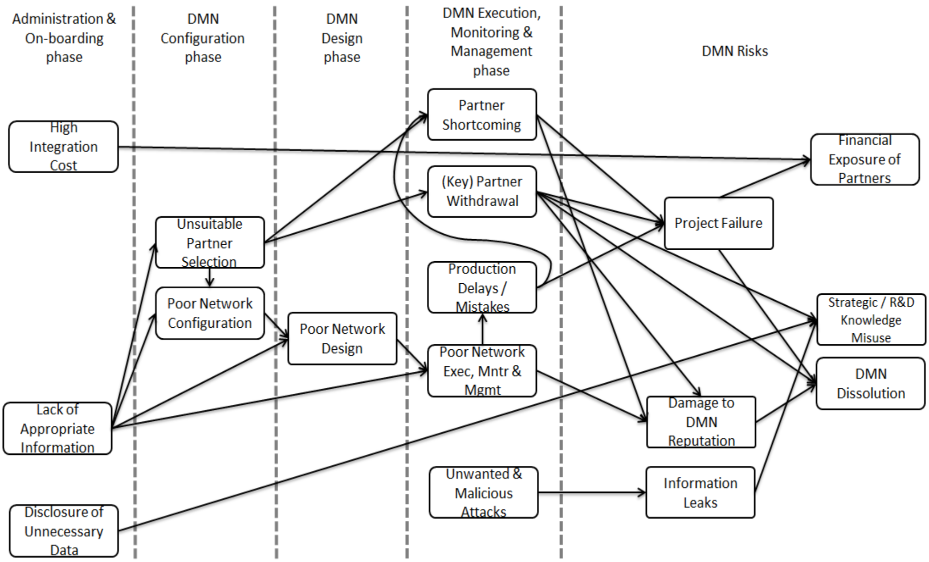

Fig. 1. Cognitive Map of concept variables relating to DMN risks

What is noticeable with this list is that some concept variables clearly constitute risk outcomes, i.e. effects or consequences of preceding problems, as in the case of "Project Failure" or "DMN Dissolution", while others even though not pointing directly to an unfortunate event, and being less critical, might contribute to the occurrence of such, in conjunction with other factors, thus being identified as risk-related factors. Additionally, some of the concept variables identified seem to be present in more than one DMN phases, while others are specific to a particular stage. Thereby, in modelling DMN risk-related factors, it has been found helpful to take into account the structure of the DMN lifecycle and map the former according to their occurrence within the physical stages of the latter. In view of facilitating this task, in addition to the three lifecycle phases described in Section 2.2, a fourth one, that of Administration and On-Boarding has been added, covering all the preparatory steps preceding the emergence of a request for manufacturing a product, i.e. the activities related to bringing together the DMN actors in the context of a vertical marketplace and making the necessary technical and organizational arrangements to ensure technical connectivity, access to the appropriate information etc.

What is required as a next step is the identification of cause and effect relationships between the risk-related factors and the actual risk outcomes. Below, the authors present some of the highlights of the raw correlations brought up by the stakeholders interviewed:

- An unsuitable selection of partners increases the chances of a partner not being able to perform as planned, which in turn amplifies the risk of a project failure.
- Exchange of invalid partner information across the network undermines the efficiency and effectiveness of network monitoring and management, thus possibly causing production delays and mistakes.
- A key partner's withdrawal holds the potential to damage the network's reputation or even cause the DMN dissolution, while in parallel raising the likelihood of project failure or knowledge misuse afterwards.
- Strategic or R&D knowledge misuse constitutes an important risk, which is additionally influenced by the disclosure of unnecessary data and the failure to prevent information leakages in general.
- The financial exposure of each partner is highly affected by the initial on-boarding cost as well as by the actual outcome of the DMN operation, i.e. the success or failure of the project undertaken.

Looking at the above list of correlations, one may notice that a risk outcome may be linked to several risk-related factors. For instance, a project failure may occur as a result of a partner shortcoming or withdrawal or a production delay/mistake not dealt with efficiently and timely, or even a combination of these factors. In other cases, the risk probability generated by a concept variable becomes a factor that leads to some other risk outcome. For example, the possibility of information leaks grows with the number of unwanted and malicious attacks, while in parallel raising the risk of strategic or R&D knowledge misuse.

The relationships between the factors possibly leading to unaccepted or unsatisfactory DMN operation outcomes seem therefore to be more complex than what the above simple list of cause and effect relationships implies. In this context, the authors leverage the instrument of CMs to create a richer picture on the risks involved in the novel and promising approach of DMNs, and thereby on the respective mitigation strategies required. The full set of cause and effect relationships among the identified DMN risk-related factors are presented in Fig. 1.

4 Reasoning on the DMN Risks: The IMAGINE Case

With the view of applying the CM of Section 3 in the case of the IMAGINE project, which actually targets the development and delivery of a novel methodology and the respective platform for effective end-to-end management of DMNs in a plug and produce approach, one has to highlight that the cornerstone of the latter is the DMN Blueprint Model. The former is a declarative meta-model that aggregates and modularizes production, manufacturing operations management and logistics information by specifying four types of inter-related blueprints [9], as follows:

The *Partner Blueprint (Partner BP)*, which provides both static and dynamic, business and technical information to facilitate partners' selection by a specific contractor;

the *Product Blueprint (Product BP),* containing all components required, i.e. machines, tools, personnel skills, materials, other equipment, for producing a product, as well as other entities necessary for the manufacturing work;

the *Quality Assurance Blueprint (QA BP)*, used to capture metrics for operations analytics, associating these with the end-to-end manufacturing processes, and

the *end-to-end Process Blueprint (E2E Process BP)*, which ties together the many discrete processes associated with all aspects of product development, while providing the ability to adapt to changing conditions and environments.

The latter, along with the IMAGINE platform which incarnates the DMN lifecycle and the DMN management methodology [9], are used to ensure business process alignment and interoperability, and thereby information sharing, collaboration and enterprise-wide visibility, compensating thus for most of the risks potentially encountered in the DMN environment.

The dynamic and real-time nature of the BP information caters for selecting the most appropriate set of partners in the first place, as well as for efficiently coordinating the complex grid of multiple and diverse actors, functions, processes and data flows involved thereafter, ensuring thereby effective operation of the network and constant fine-tuning of its performance in case of deviations in the production plan. In addition to that, the provision of different (privilege) access rights for different partners minimizes the needless exposure of sensitive information, while the service-oriented approach adopted for the design and implementation of the IMAGINE platform makes up for the on-boarding cost involved, confining related investments to the implementation of relevant adaptors. The risk of unwanted and malicious attacks constitutes an exogenous factor which imposes the application of efficient security and authentication mechanisms, while finally, potential unethical behavior on behalf of the DMN partners, resulting in important knowledge misuse or a member's withdrawal from the network may be further controlled and diminished through the establishment of contractual agreements with special clauses on information confidentiality and the use of intellectual property, as well as specific terms legally binding the DMN members not to be able to waive their responsibilities under specific circumstances.

In this context, leveraging the CM above, it can be deduced that most of the DMN risks are inherently dealt with by the IMAGINE framework and the BP Model in specific, which in turn comes forth as the main facilitator for achieving business and IT alignment and interoperability, and thereby for supporting the creation of shared value-chain manufacturing networks.

5 Discussion and Conclusions

This paper presented an approach to model risk-related factors in DMNs leveraging the causal characteristics of CMs. The approach has included the elicitation of DMN risk-related concept variables through semi-structured interviews and their correlation through CMs. The use of CMs in this process has been observed to facilitate communication, as well as to bring forth the role of the IMAGINE framework, and interoperability in particular, in ensuring business alignment and therefore addressing the majority of DMN risks. While the derived map is quite generic to cover the majority of DMN formations and is thus open to modifications depending on the particular case, it can promote debate and further investigation. This can in turn improve managerial decision-making, and thereby the process of risk identification, assessment and mitigation.

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A Risk Analysis Method to Support Virtual Organization Partners' Selection

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Abstract. The Virtual Organization (VO) concept has emerged as a promising form of collaboration among companies by providing a way of sharing their costs, benefits and risks when attending to demands. When manufacturing processes and physical distribution of products are involved, the process of VO creation demands the selection of both Logistic Partners and Industrial Partners. This VO composition requires several aspects to be considered to ensure the VO correct operation, synthesized in the form of risks. Proper risk analysis provides more solid means for managers to evaluate and further decide about the more suitable VO composition for a given business. This work presents an integrated and quantitative risk analysis method to support Partners' Search and Selection process within the VO creation phase. A set of algorithms have been developed to measure the risk considering a number of risk categories and performance indicators. A general example is showed and results are discussed at the end.

Keywords: virtual organization, partner's selection, risk analysis.

1 Introduction

Virtual Organization (VO) has emerged as a powerful enterprising strategy to leverage Small and Medium sized Enterprises to increase their value and better compete in the market [1]. This is possible due to its intrinsic properties, which provide a more systematic form of collaboration in dynamic business scenarios, involving autonomous, heterogeneous and geographically dispersed companies that join their efforts with the aim of attending given demands (collaboration opportunities - CO), sharing costs, benefits and risks, acting as one single enterprise [1].

One of the issues related to VOs refers to on how its members are selected. Most of works in the literature considers a VO as formed only by "industrial partners" (IP), i.e. the ones that "manufacture" the different parts of a good.

However, when the business involves manufacturing processes along a value chain, the VO composition should be *complemented* with other partners, namely logistics operators (LP). From the logistics theory point of view, by LP it is considered in this work the types 2LP and 3LP [2], responsible for the transportation,

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delivering and intermediate storage of goods between IPs and final customers. As such, different indicators are required for selecting LPs when compared to IPs [2].

It is assumed in this paper that both LPs and IPs are members of a long-term alliance, like a Virtual organization Breeding Environment (VBE) [3], so sharing some basic and common principles of collaboration, quality and performance.

Several works in the literature have approached the problem of selecting partners via an analysis focused on members' competences, capacities and historical performance [4-6]. Alawamleh *et al.* [7, 8] have pointed the importance of enlarging these dimensions considering risk analysis. The essential rationale is that, even taking those dimensions into account, there is a risk of failure in any event or partner and hence in the VO to succeed. Besides that, partners can be good when working individually, but not well *too* when collaborating with other partners in a joint business, as in a VO [9]. These aspects are critic as a VO reflects a sharing of duties among companies and it has an intrinsic dynamic nature of relationships [7].

Literature review has showed a lack of works that considers measuring risk upon the entire VO (i.e. IP plus LP) as well as that analyzes its partners regarding their collaboration quality and intensity within an integrated framework.

In general, the problem to be tackled in this research consists in selecting which are the most suitable LPs to be joined to a VO of previously pre-selected IPs that, when seen as a whole, have the lowest risk?

In previous works, authors have conceived a method to select LPs for given VOs [6] and to analyze LPs risks [10], so without considering neither IPs (i.e. the VO as a whole) nor evaluating how good they might be when working together. Therefore, that is core contribution of the proposed method in this paper. By means of a set of quantitative analysis, involved VO managers can have better conditions to evaluate how risky every possible VO composition is. Another facet of the value proposition refers to the systematization of the risk analysis and associated decision-making processes so providing more agility and transparency when creating new VOs.

The remainder of this paper is organized as follows: Section 2 addresses the partner's search and selection problem in the context of risk analysis. Section 3 introduces the proposed method for risk analysis. Section 4 presents an example of the method. Finally, Section 5 presents some conclusions about current achievements.

2 General Background

Risk management is an important foundation to several fields of decision and control management. In brief, risk can be defined as the probability of an event to occur and that causes a negative or positive impact on the organization's goals when it takes place [11]. In the context of this research, a risk is characterized by the potential of a partner (LP or IP) - that is in principle able to be member of a VO - to do not perform correctly its assigned task regarding the associated CO's requirements and hence hazarding the VO success.

A number of works on risk analysis have been proposed on networks (e.g. [4, 5, 10, 11, 13]), hence potentially suitable for VOs. They are important as offered some insights for devising the basics of the requirements to be supported, in more particular: partners should be analyzed both individually and collectively; all links between any two partners must be measured; there is a need to analyze all partners together when considering the interrelationships among them; such analysis should be made via some explicit and transparent performance criteria.

In that same line, there is a number of methods that can be applied to model risks and to support their analysis, as evaluated in [10]. ETA (Event Tree Analysis) [12] and ANP (Analytic Network Process) [5] were selected regarding those requirements. As this paper also embraces another dimension, which refers to how partners are able to or have successfully worked in past partnerships, a more proper method had to be evaluated. The *Intensity Analysis* [13] approach has been selected and so combined with ETA and ANP.

In the state of the art review, some works related to risk analysis for VOs have also been found out and have provided some designing elements to the proposed methods. For example, in [7] thirteen KPIs (Key Performance Indicators) were identified as general risk sources for VOs as well the importance of each one. In [14] the advantages of AHP/ANP over the other multi-criteria decision making methods to assess VO risk sources were discussed.

All the reviewed works in the literature have proposed contributions to isolated elements of the whole problem tacked in this research. In other words, none of them have devised approaches or methods that analyze risks upon both IP and LP individually and collectively in a systemized and integrated framework, and also considering partners relationships intensity for risk analysis purposes.

3 The Proposed Method

The proposed method corresponds to an incremental research work developed on top of three previous works. Firstly, a partners' search and selection work was developed to select the most suitable IPs for given VO, strongly based on IPs' capabilities [15]. After that authors developed an equivalent work but focused on selecting LPs, based on a KPI model composed of 15 indicators [6]. Later on authors complemented this last work by adding the risk dimension when selecting LPs, using four main KPIs: trust, communication, collaboration and commitment [10]. In the work presented in this paper, risk is also applied to IPs so to the whole VO. Besides that, it adds another risk dimension, considering the relationships "quality" among pre-selected VO members (IPs + LPs). For that, and based on the studies presented in [8], three aspects were taken as the most critical ones in terms of sources of risk: trust, commitment and information sharing. They were modeled as KPIs and their values were calculated using the method developed in [6].

The fundamental rationale of this additional dimension is that a VO could be composed by the best companies from the performance point of view but that never had worked together before. The premise is that this lack of previous relations can hazard the whole VO performance, i.e. this can put the VO in risk. Regarding this, the proposed risk analysis framework has three hierarchical layers, as illustrated in Fig. 1.

The first layer is responsible to handle the aspects related with partner's search and selection, including the selection criteria and the used KPIs [6]. The second layer provides an extension of a risk analysis method to select LPs and so to compose VOs, [10], also considering an analysis upon the pre-selected IPs and the relationship intensity between all of them. This layer evaluates the pre-selected LPs (represented by triangles) and IPs (rectangles). Finally, the third layer aggregates the results from the second layer to assess the risk level of the whole VO. It applies the Analytic Network Process (ANP) [5] method over the previous analyzed partners (LPs and IPs) to measure the aspects of collaboration among them and to further generate a so-called Global Risk Level (GRL) score for the VO. Managers can then compare this afterwards for the final decision-making about the most suitable members and less risky composition for a given VO. Next subsections detail each of these layers.

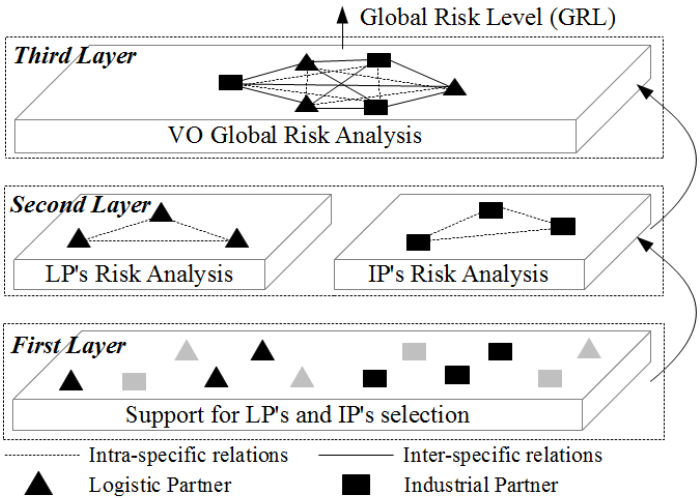

Fig. 1. General view of the proposed method

3.1 First Layer

The first layer provides the support for primary partner's search and selection (LPs and IPs). As already mentioned, this is made by means of a 15 KPI-based method that considers both intra- and inter-organizational indicators [6], which in turn takes into account technical competence, temporal availability, CO's requirements, and historical performance in past VOs [6, 16]. A KPI vector with 15 positions is created for each partner and this vector is further transformed into a normalized value called "level of collaboration". Decision-makers can then compare partners via their level of collaboration, including the possibility of weighting some priority KPIs according to the business requirements.

3.2 Second Layer

The second layer performs the risk analysis itself both for the group of IPs and for the group of LPs pre-selected in the first layer. This division into two subgroups is due to the fact that (mainly) IPs use to have some more strict relations with each other.

Formally, it is assumed that a VO is represented by a graph $G = (V, E)$, where V corresponds to a set with LPs and IPs, and E the relations between them. In order to handle the two different groups of partners, the graph G is split into two sub-graphs: $G' = (V', E')$ and $G'' = (V'', E'')$, where V' and V'' represents the set of LPs and IPs, respectively, and E' and E'' represent the relations among them. Besides that, there are two types of relations among the partners: *intra-specific relations*, which occur between IPs *or* LPs; and *inter-specific relations*, which consider the relations between LPs *and* IPs. Only intra-specific relations are considered in this second layer.

The process of analyzing the individual G' and G'' risks and the further collective analysis is showed in Fig. 2. It corresponds to an extension of the previous work [10] by adding the following three main modifications:

- automation of the previous method, removing the human mediation of the VO manager from the two stages of the method;
- enlargement of the types / sources of risks upon IPs and LPs but respecting the particularities of the two types of 'services' and hence the way they are analyzed for each of these two cases.
- modification of the collective analysis algorithm by considering the intensity of intra-specific relations, so a basis for calculating the risk of G' and G''.

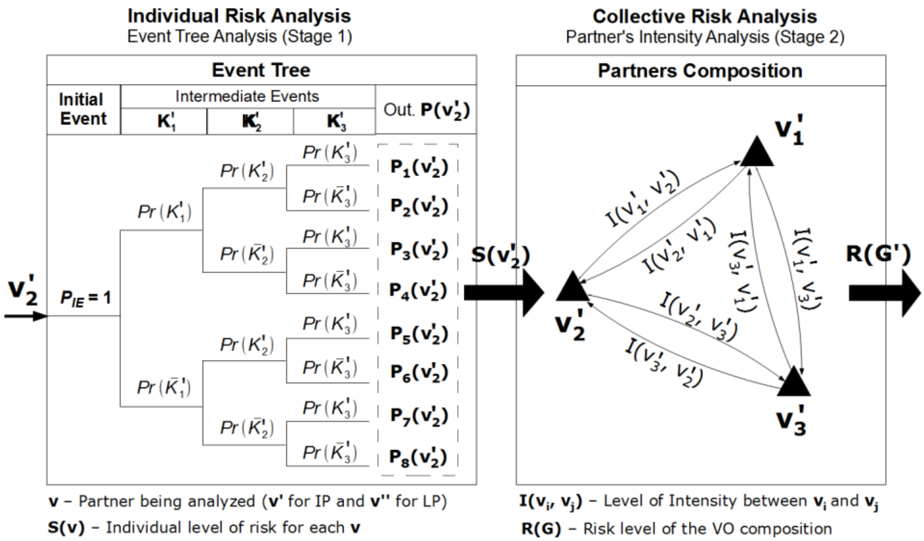

Fig. 2. The second layer of proposed method

For the sake of simplicity, the formalization procedures will just consider the operations for one of the two group of partners (G' and G'') since these operations are equally performed for the two groups. It can be formalized as follows:

Let $G' = (V', E')$ be a G sub-graph (as previously mentioned), where $V' = (v'_1, v'_2, \cdots, v'_n)$ represents the set of n LPs. Let $K' = (K'_1, K'_2, K'_3)$ be the set of three KPI (trust, commitment and information sharing) associated to each v'_n. Applying

ETA method upon each element of V' it will result $P(v_i') = (P_1(v_i'), P_2(v_i'), \cdots, P_8(v_i'))$, as the set of all possible outcomes from the 2^K event combinations in the ETA event tree (where 2^K represents the number of elements in K). The detailed procedures for obtaining $P(v_i')$ are in [10].

Once defined all possible outputs of P for each v_i', the method calculates the $S(v_i')$, which represents its quantitative risk level. The procedure for this calculation considers the application of a Harmonic Weighted Average (HWA) over all $P(v_i')$ values [17]. Therefore, the method will be able to analyze the G' risk from the set of obtained results $S(v_i')$, i.e., the risk of each partner.

The collective analysis of G' (i.e., for all $v_i' \in G'$) will be performed by measuring the level of intensity among the partners who compose it. The intensity (also referred as level of correlation) is a concept widely adopted in network theory for measuring how connected two or more elements are in a network [13]. In this work the intensity is modeled between two partners (i.e. LPs to LPs, or IPs to IPs) and considers two different indicators [13]: the *VO co-participation* and the *feedback*. *VO co-participation* between two partners v_i' and v_j' is referred as $C(v_i', v_j')$ and means the number of VOs that they have previously collaborated with. *Feedback* of a partner v_i' over v_j' is referred as $F(v_i', v_j')$ and means the average score that a provider v_i' gives to a partner v_j'. C is calculated equally in a bi-directional relation, while F is calculated separately for each of the two directions.

Given the two previous mentioned indicators, the intensity $I(v_i', v_j')$ can be calculated by averaging $C(v_i', v_j')$ and $F(v_i', v_j')$ values. Given that the two indicators have different evaluation scales (i.e. two partners can attend any amount of VOs, but the feedback is restrict in a scale from 0 to 10) then a normalization vector $n(f(x))$ had to be defined, where $f(x)$ represents the function to be normalized in a scale that varies from 0 to 1, as seen in Eq. 1. Thus, applying Eq. 1 the normalized VO co-participation $C_N(v_i', v_j') = C(v_i', v_j')\, n(C(E))$ and feedback $F_N(v_i', v_j') = F(v_i', v_j')\, n(F(E))$ can be obtained. The *level of intensity* is defined according Eq. 2:

$$n(f(x)) = \left(\frac{1}{max(f(x))}\right) \quad (1)$$

$$I(v_i', v_j') = \frac{C_N(v_i', v_j') + F_N(v_i', v_j')}{2} \quad (2)$$

Once again, from the intensity among all v_i' of G', it is necessary to perform a general calculation to obtain the risk level of G'. The risk level is represented by $R(G')$ (Eq. 3). The first part calculates the average of the individual risk levels of each $v_i' \in G'$, and the second part calculates the average of the sum of intensities $I(v_i', v_j')$ and $I(v_j', v_i')$. The values obtained are then averaged again in order to obtain the final level of risk.

$$R(G') = \frac{1}{2}\left(\sum_{i=1}^{|V'|} \frac{S(v_i')}{|V'|} + \sum_{j=1}^{|V'|-1} \sum_{k=j+1}^{|V'|} \frac{I(v_j', v_k') + I(v_k', v_j')}{2\,|V'|}\right) \quad (3)$$

3.3 Third Layer

The third layer of the proposed method performs a high-level analysis of the VO by aggregating the results provided by the second layer (i.e. the set of LPs and IPs) to calculate a Global Risk Level (GRL) of the entire VO. The Analytic Network Process (ANP) [5] was used by its ability to deal with interdependent attributes. Moreover, the ANP method is very suitable for decision-making problems that involve multiple criteria variables.

The ANP initial set up consists of identifying and structuring the elements belonging to three basic groups: goal (A_G), criteria (A_C) and alternatives (A_A). In this work, the goal (or objective) refers to calculate the Global Risk Level (GRL) of the VO. The criteria are represented by the outputs of the second layer, i.e., the set $A_C = \{S(x), R(x)\}$, where $S(x)$ and $R(x)$ represent the individual level of risk of each v_i' or v_i'' and the level of risk of G' or G'', respectively (the values of the criteria change according to the partner being analyzed). The alternatives are represented by the set $A_A = (v_1', \cdots, v_n', v_1'', \cdots, v_m'')$, comprising all the v_i' and v_i'' partners. Fig. 3 shows the network structure, which comprises the goal, criteria, alternatives, and the relationships (represented by the arrows).

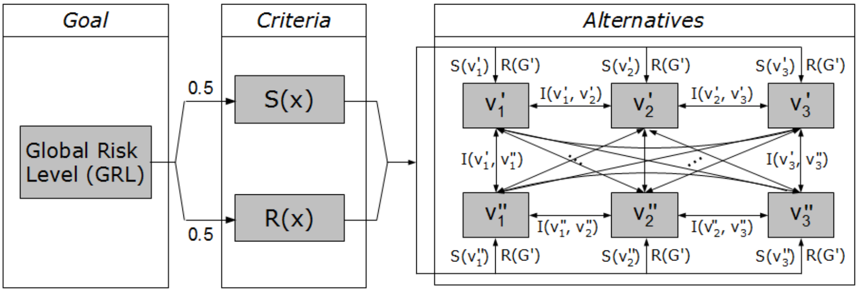

Fig. 3. The third layer of proposed method

Having structured the problem of VO risk analysis in terms of the three ANP clusters, the method's algorithm can be summarized in four steps:

1. Define relationship weights: At this step all the relationships between criteria (A_C), alternatives (A_A) and the goal (A_G) are weighted. These relationships, when normalized, represent the influence of an element over the other. However, they can be initially defined with non-normalized values. In this work, these relationships are split into three types: *relationships from goal to criteria* (i.e. the importance of the individual risk level of each partner and the overall risk of the composition of all partners); *relationships from criteria to alternatives* (i.e. the influence of the two criteria over a partner); and *relationships from alternatives to alternatives* (i.e. the level of intensity that a partner has one to another).

2. Build an unweighted supermatrix: In this step the normalized values [17] obtained in the previous step are added to an unweighted supermatrix S_U. This supermatrix models the relationships among all the elements of the system and it represents the importance of each element within its own clusters. The supermatrix S_U has dimension d, where $d = |A_A| + |A_C| + |A_G|$, i.e., the number of partners, criteria and the goal (Eq. 4). The relationships between criteria and between alternatives and goal are not considered in this work, so their values are assigned to zero in the supermatrix (Eq. 4).

$$S_U = \begin{array}{c} \\ v_1' \\ \vdots \\ v_m'' \\ S(v) \\ R(v) \\ G \end{array} \begin{array}{c} \begin{array}{cccccc} v_1' & \dots & v_m'' & S(v) & R(v) & G \end{array} \\ \begin{bmatrix} 1.00 & \dots & I(v_1', v_m'') & 0.00 & 0.00 & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ I(v_m'', v_1') & \dots & 1.00 & 0.00 & 0.00 & 0.00 \\ S(v_1') & \dots & S(v_m'') & 0.00 & 0.00 & 0.50 \\ R(G') & \dots & R(G'') & 0.00 & 0.00 & 0.50 \\ 0.00 & \dots & 0.00 & 0.00 & 0.00 & 0.00 \end{bmatrix} \end{array} \tag{4}$$

3. Build a weighted supermatrix: Given the unweighted supermatrix S_U obtained in the step 2, this third step performs the specification of a weighted supermatrix S_W, i.e, a stochastic matrix that represents the general importance of each element considering all groups (A_C, A_A and A_G) simultaneously. To make this possible, another normalization procedure is performed, where each element is divided by the sum of all its elements for each column (Eq. 5).

4. Calculate limit supermatrix: The last step on the ANP consists in calculating a limit supermatrix S_L, which is obtained by raising the weighted supermatrix S_W to power (i.e, $S_L = (S_W)^k$ for $k = 1, 2, \ldots$) until the convergence of its values (i.e., for every column $(S_L)_j$, $(S_L)_j = (S_L)_{j+1}$) is reached. This convergence will always occurs given the stochastic nature of the supermatrix S_W. The final results are represented by a column matrix X that is generated from any column $(S_L)_i$. The matrix X presents the level of risk of each partner in relation to the goal (Eq. 6).

$$(S_W)_{ij} = \frac{(S_U)_{ij}}{\sum_{k=1}^{d} (S_U)_{kj}} \tag{5}$$

$$X = \begin{array}{c} \\ v_1' \\ \vdots \\ v_m'' \end{array} \begin{array}{c} A_G \\ \begin{bmatrix} w_1 \\ \vdots \\ w_{n+m} \end{bmatrix} \end{array} \tag{6}$$

The Global Risk Level (GRL) of the VO can be obtained summing up all elements of the matrix column X.

4 An Illustrative Example

This section presents an illustrative example of the proposed method to provide a better understanding of its operation. Initially, suppose that a CO was created to attend to a given demand and a set of three LPs and three IPs were selected (via the first layer of the proposed method) to compose a new VO. LPs and IPs are represented, respectively, by two sub-graphs of G_{VO} (where $G_{VO} = G_{IP} \cup G_{LP}$), $G_{IP} = (V_{IP}, E_{IP})$, where $V_{IP} = (IP_1, IP_2, IP_3)$ and $G_{LP} = (V_{LP}, E_{LP})$, where $V_{LP} = (LP_1, LP_2, LP_3)$.

In order to measure the risk level of the G_{IP} and G_{LP}, they are submitted to the second layer of proposed method, firstly applying ETA calculation. In ETA, the risk (considering G_{IP} and G_{LP}) takes into account the quantification of three risk sources: trust, commitment and information sharing. Although it is not possible to show here how the KPIs associated to these sources were calculated, its values are necessary to obtain the set of probabilities $P(v)$, where $v = \{IP_1, IP_2, IP_3, LP_1, LP_2, LP_3\}$ as showed in Table 1. In this case, applying the Harmonic Weighted Average (HWA) calculation over all $P_i(v)$ values (i.e. the outputs of the ETA method - see description at Section 3), it can be obtained the individual risk level of each partner ($S(v)$), which is used to calculate the risk of the sub-graphs G_{IP} and G_{LP}. This procedure is performed equally for all the six partners (IPs and LPs) that are being analyzed.

Table 1. Results from event combinations for all partners of G_{IP} and G_{LP}

	$P(v)$								
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	S
IP_1	0.392	0.168	0.168	0.072	0.098	0.042	0.042	0.018	0.584
IP_2	0.612	0.153	0.108	0.108	0.068	0.017	0.012	0.003	0.767
IP_3	0.360	0.240	0.090	0.060	0.120	0.080	0.030	0.020	0.569
LP_1	0.494	0.026	0.123	0.006	0.266	0.014	0.066	0.003	0.614
LP_2	0.608	0.152	0.032	0.008	0.152	0.038	0.008	0.002	0.734
LP_3	0.810	0.090	0.090	0.001	0.000	0.000	0.000	0.000	0.885

Next step (yet at the second layer) refers to performing the collective analysis of G_{IP} and G_{LP}, which is carried out by means of the intensity analysis. Table 2 (left) presents hypothetical numbers of previous VO participations and the feedback of each relationship among all pairs v_i, v_j, where both $v_i, v_j = \{IP_1, IP_2, IP_3, LP_1, LP_2, LP_3\}$. The intensity of each two partners is calculated applying Eq. 3 and it is presented in Table 2 (right). Then the risk level R of G_{IP} and G_{LP} can be also calculated.

Table 2. (left) Quantitative values of VO Co-Participation and Feedback for all partners of G_{IP} and G_{LP}; (right) Level of intensity among all partners of G_{IP} and G_{LP}

	G_{IP}			G_{LP}		
$C;F$	IP_1	IP_2	IP_3	LP_1	LP_2	LP_3
IP_1	–	$15;5.5$	$27;7.1$	$33;6.8$	$65;9.1$	$41;8.3$
IP_2	$15;6.3$	–	$22;6.9$	$10;8.3$	$68;9.7$	$67;8.3$
IP_3	$27;7.4$	$22;7.6$	–	$49;7.0$	$26;8.3$	$14;9.8$
LP_1	$33;5.5$	$10;5.7$	$49;6.8$	–	$39;8.1$	$66;7.6$
LP_2	$65;8.7$	$68;9.4$	$26;9.5$	$39;7.4$	–	$62;9.3$
LP_3	$41;7.0$	$67;8.9$	$14;7.1$	$66;8.5$	$62;7.7$	–

	G_{IP}			G_{LP}		
I	IP_1	IP_2	IP_3	LP_1	LP_2	LP_3
IP_1	–	0.39	0.56	0.59	0.94	0.72
IP_2	0.43	–	0.51	0.52	0.99	0.91
IP_3	0.57	0.55	–	0.71	0.61	0.60
LP_1	0.52	0.36	0.70	–	0.70	0.87
LP_2	0.92	0.98	0.67	0.66	–	0.93
LP_3	0.66	0.96	0.46	0.92	0.85	–

$$R(G_{IP}) = \frac{1}{2}\left(\frac{0.584+0.767+0.569}{3} + \left[\frac{0.43+0.9+0.57+0.56+0.55+0.51}{2*3}\right]\right) = 0.730$$

$$R(G_{LP}) = \frac{1}{2}\left(\frac{0.614+0.734+0.885}{3} + \left[\frac{0.70+0.66+0.87+0.92+0.93+0.85}{2*3}\right]\right) = 0.783$$

The third layer of the method consists in aggregating the partners of G_{IP} and G_{LP} and the results of second layer (S and R) to analyze them as a whole. This is done using ANP method calculation, whose network structure was presented in Section 3. Three *normalized* relations (related to criteria, criteria to alternatives, and alternatives to alternatives goals) are assigned in order to build the unweighted supermatrix S_U. The normalization procedure for each column of the unweighted supermatrix is executed after that, resulting in the weighted supermatrix S_W. The limit supermatrix S_L can also be built up by raising S_W until their values converging. This matrix shows the risk level of each partner in relation to the goal. The final results are represented by a matrix X that is generated from any column of S_L:

$$\mathrm{X} = \begin{array}{c} \\ A_G \end{array} \begin{array}{c} \begin{array}{cccccc} v'_1 & v'_2 & v'_3 & v''_1 & v''_2 & v''_3 \end{array} \\ \begin{bmatrix} 0.10 & 0.07 & 0.12 & 0.09 & 0.08 & 0.13 \end{bmatrix} \end{array}$$

Finally, summing up all elements of X, the *Global Risk Level* of the VO G_{VO} can be calculated:

$$GRL = \sum_{i=1}^{|X|} X_i = 0.09 + 0.07 + 0.11 + 0.09 + 0.08 + 0.12 = 0.59$$

Considering this example, the VO as a whole has 59% chance of success. This value should then be used by the VO manager or responsible actor to decide how low or high this value is to be handled regarding the given CO. The whole method should be all over executed again (so including a new round of IPs and LPs' search and selection) for other evaluations looking for a less or for the lowest risky VO composition in the case such manager considers that the calculated risk is too high.

5 Final Considerations

This paper has presented results of an ongoing research on VO risks measurement and analysis. It provides an additional decision dimension to managers in the VO creation phase indicating not only the most capable teams of companies to form a VO, but also which are the less risky VO compositions for a given business.

Compared to the state-of-the-art in the area, the proposed method adds value when comprises the entire VO in the risks calculation, i.e. both industrial and logistics partners. Besides that, it considers partners relationships intensity and historical performance, having as the premise that a given VO composition would be less risky if partners have already worked together before in a good way.

The method is strongly based on performance management, whose information about partners is modeled as KPIs. The method is constituted by some steps, providing decision-makers with a more systematized, transparent and quantitative process of partners' search and selection. On one hand this helps VBE and VO stakeholders to identify and mitigate risk sources, both in the VO creation and further operation phases. On the other hand, this gives more confidence to managers for their decision-making, helps in the trust building among autonomous partners, and in the creation of a basis for continuous improvement. Actually, the essential purpose of the proposed method is not to automate the risk analysis process. Instead, it aims at providing VO managers with additional information about VO members and possible compositions for better and more agile decision-making, so helping to speed up the VO creation process.

The proposed method splits the problem solver into three hierarchical layers, which one using adequate techniques for risk calculation and modeling. Although implemented within a computing controlled environment and using hypothetical values, the achieved results gave evidences about its potentialities to be applied in real cases. However, other dimensions of the problem have to be dealt with for real VOs, such as the organizations, cultural and financial impacts of the implementation of a method like the one proposed. This is out of the scope of this current research though.

Three assumptions are important to be pointed out about the proposed model. The first one refers to assuming that companies are all members of a VBE-like long-term alliance, which tends to facilitate tremendously the collaboration among members and their performance measurement and management, key aspects for the proposed model. The second one is that the third model's layer inherits a "legacy" from two previous authors' works. Industrial partners and logistics partners are grouped separately (at the second layer) instead of being put all together into a large single group. This might facilitate the calculation of the optimum VO partners' combination/composition in terms of the best risk case, but this increases a lot the combinatorial problem and the algorithm's complexity. The third assumption refers to the type of partners a VO can have. In fact, "real" VO may comprise other type of "actors" (e.g. auxiliary services providers, regulatory institutions, etc.). In the current stage of our work it is assumed that such partners are equivalent to IPs in the sense they are responsible for relevant tasks of the given VO.

The model was evaluated only experimentally, in a simulated way, using hypothetical data. Actually it is very difficult to get data from companies and VOs, in particular the ones related to performance and historical behavior. The used data was however conceived based on the authors' experience on CNO and inspired in some VBE/VO pilots involved in a past EU project as well as in on current pilot being developed in the South of Brazil close to a mould-makers cluster.

The results obtained from the collective risk analysis (based on the qualification and quantification of the level of intensity between partners provided by the ANP method) lead us to realize that the method gives more transparency and assertiveness in the risk measuring process.

Future work mainly includes testing the method in near-real scenarios as well as extending the devised framework to also consider risks in the VO operation phase.

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Early Warning System Potential for Single Sourcing Risk Mitigation

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Abstract. Network governance is described as a framework of policies and business rules, which is applied to manage an extended organization. Nowadays, one of its main concerns is risk management (RM) and the operational risk mitigation is crucial to avoid disruptions, delays and quality fades. Single sourcing can be interesting to reduce economic costs enabling the product design but at the same time can synergize the above-mentioned risks. Traditional RM approach for sourcing risks is based on selecting reliable partners, sharing knowledge and creating standard procedures that need to be complied. But the development of sensing networks based on early-warning systems (EWS) based on performance metrics to support decisions will be a promising alternative.

Keywords: Risk management, governance, early warning system, performance measurement.

1 Introduction

Some real cases reveal that several global supply chain relationships that had begun on the premise of cost savings (e.g. offshoring or outsourcing) can be risky, not only due to natural disasters or accidents but also during the daily operation of the network. The quality problems experienced by Mattel in the sourcing of toys from China illustrate the issues [1]. In global networks, from the view of the customer-supplier relationship, the main sources of supplier risk comprise product development problems, suppliers' bankruptcy, performance loss and operational failure [2]. And it is important to remark that business structure, and especially in the case of single sourcing of important raw materials or components, the economic impact of the above-mentioned risks could be quite important. A typical practical example about the previous scenarios was a fire in one of the Philips plants that caused serious damage to its customer Ericsson, while the disruption to Nokia SC was minimal [3]. However, the risk cause should not be attributed to the structure of the network itself, the root cause is related to the management and governance. Single sourcing (SS) can

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enable a lean management strategy if collaboration between partners is close in order to integrate its business processes. Its benefits include cost reductions and increased return on assets, as well as better reliability and responsiveness to market needs [4]. But SS also exposes partners to certain vulnerabilities that must be properly managed. Product development or supplier bankruptcy can be critical risks that deserve singular risk management projects, but operational risks will immediately pose a great risk to customer firm (cost hike, quality deterioration…).

During the execution of business processes certain unexpected events happen to deviate processes from performance goals. ISO 31000 standard define risk as "the effect of uncertainty on objectives". This uncertainty, associated to each event, is determined by a combination of a pair of indicators: probability of occurrence and potential loss. After the risks assessment associated with each potential event, risk taxonomy can be created and the most damaging events are called Risk Major Events (RME). The main feature of RME is that if they occur, significant economic losses will be sure. Some typical examples of operational RME are: inventory disruption or inability to operational responsiveness. Certain previous conditions can substantially modify a RME (its occurrence and/or loss), the authors of the present work call this preconditions as Risk Triggers (RT). Some RT examples are: high rate of inventory obsolescence, a sourcing delay…Separately these preconditions can not be very important, but when they are combined or they occur previously to an RME, they could seriously affect the organization.

Supply Chain Risk Management (SCRM) traditional approach is based on periodical assessment of risks. This method is powerful but may have a reduced responsiveness when numerous risks of daily SC operations are studied. This work proposes real-time business process performance assurance methodology, based on the quality control approach [5], as a complement to improve the SCRM responsiveness. The aim is to achieve a smart governance of the network in which Early-Warning Systems (EWS) try to automatically maintain BP performance as high as possible by means of short-range measures. Furthermore, EWS has the possibility to alert the process owners when this path does not achieve the performance goal in order to prevent risk major events.

2 Conceptualization of the Problem

The notion of service-enhanced product brings new perspectives for value creation and differentiation in manufacturing. But complex and highly customized products and the inclusion of business services that add value to the product typically require the collaboration of multiple stakeholders. Because it is natural that each stakeholder has its own set of values and preferences and as a result, conflicts among them might emerge due to some values misalignment [6].

To understand the above-mentioned problem from an operational standpoint, the simplest configuration of a collaborative network (CN) has been studied. A single supplier and a manufacturer integrate the collaborative network. Supplier adds value to customer through processes like production or product delivering. Customers tend to assign sourcing risk to suppliers and they limit to control sourcing process performance. However this is not always true because, sometimes, customer does not properly collaborate with the supplier in defining the specifications, delivering on-time appropriate information and sharing risk and rewards. In this sense, an early warning system based on real-time measurement of process performance can be an excellent tool not only to prevent own risks but also to share valuable information with suppliers. Traditionally risks have been faced using the formal methodology known as "SAM". SAM is an effective multistep process in which sources of risk are identified (Specified), Assessed and Mitigated [7] but probably it can be more efficient to introduce certain aspects of smart network governance.

Risk management in collaborative networks (CN) should be supported on three pillars see Figure 1. Network configuration analysis starts with Business Process analysis and it determines the material, financial and information flows. Synchronously, organization should try to identify the main sources of risk. But risk management is not only based on facts and data, behavioral patterns are crucial too. The organization's character (understood as a set of behaviors and organizational values like trust, loyalty and liability among partners) is the key to identify real risks for the CN as a whole and to apply the best solutions at the lowest cost. At the next level, using performance measurement as an integrator, network model is ready to help decision-makers not only about operations management but also to be aware about certain risks associated to specific events. Then, risk taxonomy can be build and the best performance indicator to estimate them can be defined. From this point EWS can be designed for KPI or "Key Performance Indicator" real-time monitoring and contingency plan. And EWS will alert about risks and counter-measures will be launched according with the previously established contingency plan. But fast and effective policy will be decisive to apply a continuous improvement approach in order to polish an effective contingency plan that collect the best strategies against risk.

Table 1. Cause-Effect connections found between some sourcing risk triggers and performance metrics time evolution

SOURCING RISK TRIGGERS	METRIC EVOLUTION
Inappropriate inventory level	Stock level is low/high
Operational/Manufacturing stoppage	Number of process breakdowns augment
Supplier inability to conform specifications	% Bad quality orders augment
Inappropriate business process resources	Capacity utilization is extremely low/high
High rate of material obsolescence	Cost of materials obsolescence is continuous increasing
Shipment disruptions or delays	% Orders/lines received on time reduction

This proposal can be very effective, time-efficient and fair because global decisions will be based on real data not on power relationships. During the execution of risk assessment task is when real-time performance metric monitoring can be more relevant because it could exist a connection between the risks triggers (defined by its likelihood and economic impact) and the analysis of performance metrics evolution.

Our premise is EWS can detect previous events that are triggers for risk major events thus if they are detected in real-time, short-range preventive measures can be automatically launched to prevent consequences until root causes are deeply analyzed using SAM if it is a recurrent problem.

Starting from the taxonomy proposed by Franconetti and Ortiz [8], authors have conducted a cause-effect analysis in which each trigger was analyzed in order to determine its effects and then it was thought the monitoring of what performance metric could have anticipated the consequences. Table 1 examples show how real-time performance measurement systems could help to prevent risk consequences.

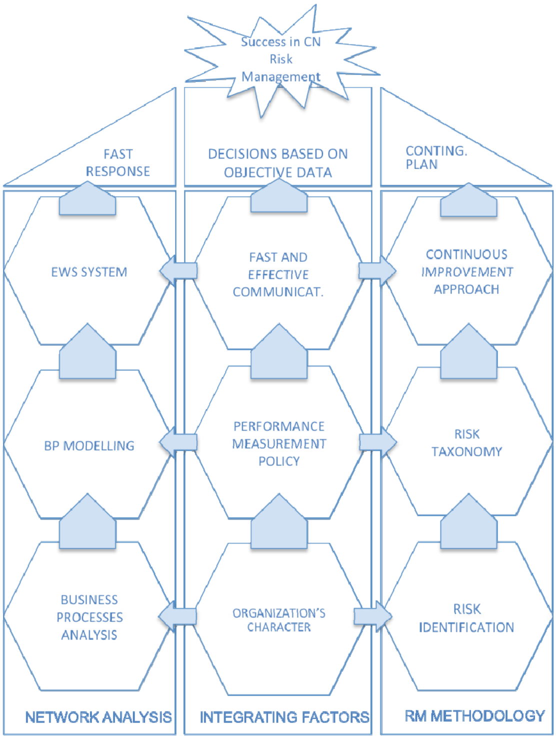

Fig. 1. Proposed approach to achieve competitive advantage using risk management

Blackhurst et al have successfully applied SAM methodology to analyze supplier's risk over time for an automotive manufacturer [9]. They use a multi-criteria scoring to calculate supplier risk indices in order to select the best option or periodically monitor the risk trends. Subjective assignation of weights to each category is used to rate them and avoid the always-unpleasant procedure of calculating occurrence probabilities. Probabilities are necessary to calculate a standard indicator of the potential loss used in SAM is known as "VAR" (value at risk). It is the product of the occurrence probability and the associated economic loss. The first drawback of this indicator is that economic loss is quite objective, but the probability must be predicted. If specific risk event likelihood is low and its inherent impact is very high, information about past decisions probably cannot predict the future, thus expert opinion and probabilistic approaches are used. The second is related to determine the VAR maximum percentage change as well as to establish the control limits that will activate the typical SAM long-range corrective actions.

However, when the risk exposure is moderated and the predictability, based on past decisions is high, probabilistic approach can be complemented using real time performance measurement. Banks and insurance companies have designed decisions systems based on performance key risk indicators that are continuously monitored and stored in the information system for future decisions [10]. The authors of this study believe in the appropriateness of this approach for managing operational risks because information systems (like ERP) collect a lot of information about past actions. So it would be advisable to use them not only in SAM methodology but also for continuous improvement of process performance. Relevant information will help to short risk management time cycle because computational systems and the process owners will collaborate to make decisions using quantitative and trusted information.

3 Early-Warning System Based on Performance Monitoring for Risk Management

Early-warning systems (EWS) must be based on the monitoring of reliable and representative signals from business processes. All BPs have objectives that are periodically evaluated through performance metrics measurement. There are different SC reference models, each emphasizing certain aspects considered fundamental, but most of them include key performance indicators to align processes with strategy [11]. Therefore, KPIs monitoring can be an excellent option for risk assessment. But real time data collection can be a daunting task, although with the help of Manufacturing Execution Systems (MES) this task can be greatly simplified. MES are computerized systems used in manufacturing that provide the right information at the right time. MES might operate across multiple function areas and they have modules for tracking and tracing of Overall Equipment Effectiveness (OEE) or other KPIs. The idea of MES might be seen as an intermediate step between, an Enterprise Resource Planning (ERP) system and a Supervisory Control and Data Acquisition (SCADA) [12]. Using these tools supplier and customer can simultaneously monitor KPIs and in each case the data will be recorded at their own ERP to assess its own processes. For instance, Guiledge and Chavusholu have worked in the automatic collection and integration of KPIs along the SC as enabler for process-oriented supply chain business intelligence. They have found that automated support for KPIs is feasible and achievable for the majority of ERP systems and it supposes a great advantage to make SC decisions as a whole [13]. The adoption of a reference model will guarantee the interoperability between partners thanks to information standardization. Hence it will be easier to share information and it will facilitate the understanding of the problem to the managers because all of them are familiarized with the model.

3.1 Business Process Control and Automated Alerts

The optimization of EWS includes the choice of signals to be monitored, the sensitivity of the alert level and the response to these alerts. Alerts are established at a certain level of each performance metrics, they are a borderline that BP does not cross when it is under control, now it will be explained how to determine these limits.

The concept of control limit (CL) is well known in statistical chart control and it has the aim of avoiding false alerts and detecting real warnings. This is important, because BPs performance can vary due to a cloud of small events generated by chance and they must be distinguished from real threats in order to avoid random automatic actions. Therefore, process owners establish a threshold δ to each performance metric monitored $F(t)$ in order to calculate de control limit for a certain instant t like $CL(t)= F(t-1) - \delta$. If $F(t)>CL(t)$, EWS assume process is under control and no automatic preventive action is launched. In other case, EWS alert process owners in order to reduce the time to recover BP performance. This is a more efficient approach than periodical SAM execution because resources are used only when necessary to overcome specific threats. In addition, it would be interesting to enable EWS to automatically launch certain short-range preventive actions. This would convert EWS in a real smart device that collaborates with humans to reduce performance loss until SAM study will be completed.

3.2 An Example of EWS Control

A very important procurement KPI is *"% of orders on time"*. Periodically, collaborative network meetings define business rules and performance goals after revising the KPI trace and risk reports. However, risks triggers can appear at any time (e.g. shipment delay), probably the performance risk indicator will be affected and the process starts to move away from target (this is defined as risk). If counter measures are only applied after a fixed time period, it is probable that major event exposure (e.g. inventory disruption) will be unacceptable because time between identification and actuation is too long. Nevertheless, EWSs can be an advantage because it detects small deviations from expected target and SAM process will be just in time initiated to reduce major event risk. Example of Figure 2 represents customer sourcing KPI real time monitoring. It has been agreed with supplier a performance goal of 90% orders on time as well as a lower control limit of 75% to avoid inventory disruptions. EWS. Procurement process owner has decided EWS save the maximum performance and it will launch an automatic alert if it registers a greater deviation than 3% over the maximum. If this occurs, collaborative SAM process with the supplier will be started. Both partners will identify specific orders that are causing performance loss in their ERP system and they will seek the causes and the best solutions.

Meanwhile SAM process is executed; there is the possibility that EWS try to avoid progressive performance deterioration using short-term counter measures. This preventive actions are inside the internal operations domain, they include actions as order deferring, rerouting using the processes interoperability or buffering. Its economic cost is much less than long-range actions like process/product redesign, business rules modification or new partner selection [14]. So it is acceptable that short-range actions will be automatically launched by EWS to prevent risk major events. Consequences of most of risk triggers shown in Table 1, can be prevented if EWS modifies sourcing scheduled program with specific actions. Table 2 contains some examples to illustrate the concept.

Table 2. Examples of EWS automatic short-range actions that can prevent sourcing risk major events after specific warnings detected

Warning Detected	Aim of automatic preventive action
Stock level is very low/high	Modify security stock level of selected items
Number of process breakdowns augment	Rebuild workload to schedule maintenance
% Bad quality orders augment	Re-scheduling poor quality orders
Capacity utilization is extremely low/high	Minor orders deferring
% Orders/lines received on time reduction	Increase sourcing time for this supplier

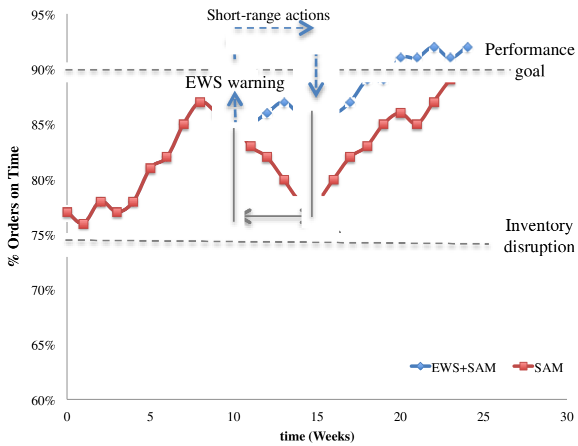

Fig. 2. Schematic representation of business process control using SAM and EWS

This work outlines the agility that can suppose this approach but there is still much work to be done. Future works will deepen the understanding of the interrelationship between the sources of risk using fault trees and the proposal of specific metrics and short-range measures for each one to be implemented in an expert system based MES+EWS tools.

4 Conclusions

Collaborative systems between humans and devices are interesting to overcome operational risks, improving time cycle of decision systems. However, this approach is based on quantitative information (like performance measurements) as well as a learning process to understand limitations and benefits of computational systems.

Risk triggers interact with business processes and they affect some performance metrics. These metrics, defined as representative key performance indicators, can be a potential tool to predict future risk major events (RME) because they detect the presence of previous triggers.

Traditional approach for risk management is based on SAM methodology; it is a powerful tool, but it presents some limitations like high time cycle or complex methods to determine the risk likelihood.

Automated EWSs can complement SAM. Real time monitoring of KPIs detects small deviations from performance goal. Using quality assurance methods, short-range preventive actions can be launched in order to avoid RME.

Information obtained from EWS is also crucial to generate risk assessment reports for risk management periodic meetings. Both parties can contrast to the opportunity cost they incurred since the last revision in order to decide a joint strategy to manage risk.

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Optimization in Collaborative Networks

Continuous Quality Assurance and Optimisation in Cloud-Based Virtual Enterprises

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Abstract. With the rise of cloud computing, enterprises increasingly rely for their daily operations on heterogeneous externally-sourced cloud services that span different levels of capability. Their IT environment is thus progressively transformed into an ecosystem of intertwined infrastructure, platform, and application services. To effectively manage the ensuing complexity, enterprises are anticipated to increasingly rely on cloud service brokerage (CSB). This work presents a conceptual architecture for a framework which provides solutions with respect to the quality assurance and optimisation dimensions of CSB in the context of virtual enterprises. The framework revolves around three general themes, namely *governance and quality control*, *failure prevention and recovery*, and *optimisation*.

Keywords: virtual enterprises, cloud computing, cloud service brokerage, reference architecture, governance, quality control, failure prevention and recovery, optimisation.

1 Introduction

The increasing adoption of cloud computing is altering the way in which IT resources have traditionally been managed and consumed, bringing about significant advantages for enterprises in terms of cost, flexibility and business agility [1,2]. The cloud computing paradigm crucially involves the use of computing resources that are remotely delivered over the Internet as a service, and which are entrusted by users with data, software, and computation. Cloud computing has evolved out of Grid computing [2,3] as a result of a shift in focus from an infrastructure aiming to deliver storage and

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compute resources, to an economy-based computing paradigm offering a wide range of abstract resources and services [3]. Such a shift is anticipated to impact the manner in which businesses and organisations share skills and core competencies within a distributed collaborative network.

More specifically, activities that take place within the confines of a dynamic multi-institutional virtual enterprise (VE) may involve heterogeneous externally-sourced cloud services that span different clouds and capability levels (IaaS, PaaS, and SaaS [4]). As an example, consider the following scenario (adapted from [5]). An industrial consortium formed to develop a feasibility study for a next-generation supersonic aircraft undertakes a highly accurate multidisciplinary simulation of the entire aircraft. This simulation integrates software components offered as a service by different consortium participants (SaaS offerings). Each component may be operating on a participant's proprietary infrastructure or, alternatively, on infrastructure provisioned as a cloud service (IaaS offering). At the same time, the simulation requires the development of new specialised software components. To this end, the consortium is provisioned the necessary software platform for developing these applications as a cloud service (PaaS offering).

Evidently, the IT environment of such enterprises is progressively transformed into an ecosystem of intertwined infrastructure, platform, and application services, typically delivered by a multitude of diverse service providers. As the number of externally-sourced services proliferates, it becomes increasingly difficult to keep track of when and how services evolve over time, either through intentional changes initiated by service providers, or through unintentional changes, such as variations in service performance and availability. Moreover, it becomes increasingly difficult to accurately predict the potential repercussions that such an evolution has with respect to a service's compliance to policies and regulations, and its conformance to service level agreements (SLAs). In addition, the proliferation of cloud services that offer similar functionality under comparable terms of provision, despite the obvious benefits, is adding to the overall complexity as the onus of discovering suitable alternatives inevitably falls on the service consumer.

In order to effectively deal with this complexity, future enterprises are anticipated to increasingly rely on cloud service brokerage (CSB) [6]. Reflecting frequently-cited views by analysts such as Gartner [7], Forrester [8], and NIST [6], CSB capabilities may be categorised along the following dimensions: (i) Service Discovery, (ii) Service Integration, (iii) Service Aggregation, (iv) Service Customisation, (v) Service Quality Assurance, and (vi) Service Optimisation.

This work reports on the conceptual architecture of a framework which provides solutions with respect to the latter two dimensions of brokerage capability. In particular, we envisage the development of a brokerage framework[1] which provides mechanisms that are organised around the following general themes: (i) *governance and quality control*; (ii) *failure prevention and recovery*, and (iii) *optimisation*. The 1st theme is primarily concerned with checking the compliance of services with declaratively pre-specified policies concerning the technical, business, and legal aspects of

[1] This framework is being developed as part of the EU-funded project 'Broker@Cloud'.

service delivery. It is also concerned with testing services for conformance with their expected behaviour, and with continuously monitoring their operation for conformance to SLAs. The 2nd theme is concerned with the reactive and proactive detection of cloud service failures, and the selection of suitable adaptation strategies to prevent, or recover, from failures. The 3rd theme is concerned with continuously identifying opportunities to optimise service consumption with respect to such goals as cost, quality, and functionality.

The rest of this paper is structured as follows. Section 2 presents a set of requirements for the proposed framework, and Section 3 proposes a reference architecture that meets these requirements; Section 4 discusses the various mechanisms which materialise this reference architecture. Finally, Section 5 presents related work, and Section 6 presents conclusions and future work.

2 Framework Requirements

We argue that the incorporation of mechanisms organised around the general themes outlined in Section 1 will assist cloud service brokers in providing assurances with respect to the reliability and optimality of services. To motivate the need for such mechanisms, this section revisits the example of Section 1 and identifies a number of relevant *functional capabilities* that these mechanisms materialise. Functional capabilities are associated with tasks or activities that transform inputs into outputs. They are high-level, possibly complex, services that are provided by a software system in order to fulfil a user need. In our work, functional capabilities express requirements upon the Broker@Cloud framework which pertain to the general themes of Section 1.

Suppose that a cloud platform (call it CloudX) hosts various services that may be potentially used by the industrial consortium (hereafter referred to as the 'VE'). Let a service provider offer a new application service (call it *fuelConsum_A*) which supports collaborative creation of simulations for the aircraft's fuel consumption.

2.1 Capabilities of the Governance and Quality Control Mechanisms

Before *fuelConsum_A* can be offered to the VE for consumption, a number of onboarding criteria may need to be evaluated to ensure compliance with the VE's business policies (e.g. pricing, availability, response time, deployment infrastructure etc.). This implies a *policy evaluation* capability (hereafter referred to as C1) which must be supported by the platform's governance and quality control mechanisms. Moreover, other checks may verify – for example, through the provision of an automated *functional testing* capability (referred to as C2) – that the programmatic interfaces of *fuelConsum_A* adhere to the specifications of the CloudX platform.

In addition, if *fuelConsum_A* is successfully onboarded and starts being consumed by the VE, its performance must be continuously evaluated with respect to the corresponding SLA. This clearly implies a *monitoring* capability (C3) that must be supported by the platform's governance and quality control mechanisms. The capabilities C1, C2, and C3 are summarised in Table 1.

2.2 Capabilities of the Optimisation Mechanism

Suppose now that, after onboarding *fuelConsum_A*, CloudX's optimisation mechanism identifies an optimisation opportunity with respect to a similar, albeit more expensive, service that the VE is currently consuming (call the latter *fuelConsum_B*). This clearly implies an *optimisation analysis* capability (C4 – see Table 1) which must be supported by the optimisation mechanism. An optimisation opportunity can only be identified relative to a set of consumer-expressed preferences regarding service consumption (e.g. service cost, reputation, etc.); it follows that the optimisation mechanism must also possess the capability to perform consumer *preference analysis* (hereafter referred to as C5). Upon identification of the optimisation opportunity, CloudX may recommend appropriate *optimisation actions*, e.g. the renegotiation of the terms of provision of *fuelConsum_B*, or its replacement by *fuelConsum_A*. This clearly implies that the optimisation mechanism must also possess an *optimisation recommendation* capability (C6).

2.3 Capabilities of the Failure Prevention and Recovery Mechanism

Suppose now that during the consumption of *fuelConsum_B* by the VE, an SLA violation is detected. CloudX's failure recovery mechanism yields appropriate actions aiming at alleviating the effects of the violation, such as the substitution of *fuelConsum_B* with *fuelConsum_A*. This clearly implies a *failure analysis* capability (C7 – see Table 1). In addition, CloudX's failure prevention mechanism *proactively* generates suitable adaptation plans if certain key service attributes (such as, for instance, availability and response time) are deteriorating; these plans aim at averting an imminent failure. For this to be possible, the failure prevention mechanism must possess the capability of incorporating appropriate *failure prevention* rules (C8).

Table 1. Functional Capabilities[2]

Id	Name	Description
C1	Policy Evaluation	Assesses a service's conformance with Broker policies.
C2	Functional testing	Assesses a service's conformance with its specification.
C3	Monitoring	Collects and aggregates service performance data.
C4	Optimisation analysis	Analyses optimisation opportunities.
C5	Preference analysis	Handles and exploits consumer preferences expressed as precise or imprecise criteria.
C6	Optimisation recommendation	Reasons about alternative optimisation actions and recommends the best alternative.
C7	Failure analysis	Generates appropriate failure recovery or prevention actions.
C8	Failure prevention	Expresses rules for proactively identifying service failures.

[2] This is not the full set of functional capabilities identified for the Broker@Cloud framework, but a suitable subset discerned for the purposes of this paper; the full set can be found in [10].

2.4 Platform-Neutral Descriptions of Cloud Services

The aforementioned mechanisms must clearly be able to interact with each other, as well as with the underlying cloud service delivery platform. To this end, an additional general theme is discerned, namely *platform-neutral description of cloud services*, which is concerned with the development of platform-agnostic methods for the declarative description of the information required by these mechanisms. For reasons of space, the *declarative* capabilities[3] associated with this theme are not considered here; the interested reader is referred to [9] for a specification of such capabilities.

3 Framework Reference Architecture

Our aim is to develop a framework which will be adoptable by cloud service intermediaries in order to equip their platforms with the functional capabilities of Table 1. This section presents a reference architecture for such a framework. The architecture is kept generic and minimal in order to increase its adoptability. The reference processes that comprise this architecture may be refined (adapted, extended, modified, etc.) by the adopting cloud service intermediaries in order to align them with the concrete architectural requirements of their platforms, providing that: (i) the capabilities that these processes entail are treated as black boxes; (ii) any interdependencies between these capabilities are dealt with by the adopting platform. These reference processes are categorised below relative to the main phases of a service's lifecycle, namely *Service Onboarding*, *Service Operation*, and *Service Evolution*. This allows a clear association between the capabilities of Table 1 and the particular phases of a service's lifecycle in which these capabilities are offered.

3.1 Service Onboarding Reference Processes

A service enters the Service Onboarding phase either when it is initially submitted, or when it is upgraded to a fresh version. The primary focus within this phase is the *Service Assessment* process. This process certifies that a new service, or an existing upgraded one, complies with the relevant onboarding business policies. It comprises two processes, namely *Policy Compliance Evaluation* and *Testing* (see Fig. 1[4]).

The former process checks that the service description is compliant with the relevant CSB business policies; it is thus associated with capability C1 of Table 1. If a service fails to comply, it is deemed unsuitable for deployment and the boundary escalation event *Compliance Failed* occurs. This event captures an inner escalation event in the *Policy Compliance Evaluation* process (see Fig. 5); it triggers, in turn,

[3] Declarative capabilities are specifications of data models or structures.

[4] We use BPMN diagrams to illustrate reference processes and their corresponding mechanisms (see Section 4). BPMN has been chosen because it is intuitive, whilst its modelling power is, according to [11], analogous to that of other comparable modelling languages such as UML 2.0 Activity Diagrams. For reasons of space, and to enhance clarity, the BPMN diagrams have been simplified; their full versions can be accessed in [10]; a BPMN tutorial can be found in [12].

the *Certification Failed* event which signifies the termination of the onboarding process. The latter process functionally tests the service in order to ensure that its description constitutes an accurate reflection of its behaviour; it is associated with capability C2. The event *Testing Failed* is analogous to the *Compliance Failed* event.

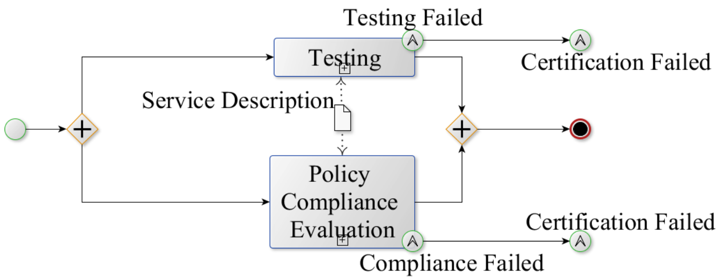

Fig. 1. Service Assessment reference process

3.2 Service Operation Processes

A service enters the Service Operation phase as soon as the first consumer subscribes to it. This phase comprises the *Service Technical Management* process which ensures the abidance of the service's behaviour by the corresponding SLA. It comprises two parallel processes, namely *Monitoring* and *Analysis*. The former process continuously checks whether a set of metrics that characterise the service's behaviour adheres to the SLA; which exact metrics are monitored is determined by the relevant policy in the *CSB Policies* store (see Fig. 2); monitored values are stored in the *Monitoring Data* store. The signal event *Service Deprovisioned* signifies that the service is no longer consumable and suspends monitoring. The *Monitoring* process is associated with capability C3 of Table 1.

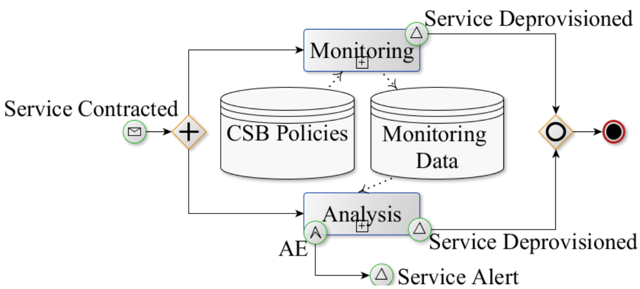

Fig. 2. Service Technical Management reference process

The latter process is associated with capability C7. It analyses the monitoring data in order to identify potential behavioural patterns indicative of a service failure. In such a case, the boundary event *AE* (stands for "Analysis Event") occurs which captures a corresponding inner escalation event. This triggers the *Service Alert* event which invokes the *Failure Prevention and Recovery Mechanism* (see Section 3.3).

3.3 Service Evolution Processes

The Service Evolution phase spans throughout the entire service lifecycle. Two main processes are discerned here: *Optimisation Management* and *Failure Prevention and Recovery Management*.

Optimisation Management. This process (see Fig. 3) offers optimisation recommendations to service consumers; Table 2 outlines its constituent processes.

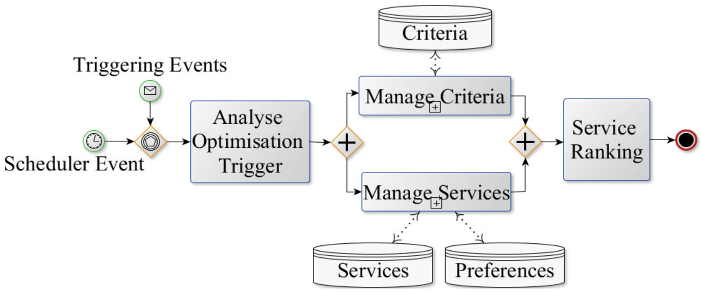

Fig. 3. Optimisation Management reference process

Table 2. Optimisation Management processes

Process	Description
Analyse Optim. Trigger	Strives to identify optimisation opportunities and thus it is directly associated with capability C4 of Table 1. It is initiated periodically (i.e. by the scheduler event of Fig. 3) or by a set of *triggering events* which are assumed to occur when a service is onboarded, deprecated, or when its contract changes; it may also be initiated when a consumer's preferences (regarding the consumption of a service) change.
Manage Criteria	Allows service consumers to express their preferences regarding service consumption with respect to a predetermined set of relevant service attributes or criteria. Preferences are expressed either as precise crisp values (for quantitative criteria, e.g. service response time), or as imprecise fuzzy values and linguistic expressions (for inherently qualitative criteria, e.g. service reputation). This process is directly associated with capability C5.
Manage Services	For each consumed service, collects consumer opinions relative to the imprecise criteria that characterise the service[5]. It then assigns an appropriate characterisation to each such criterion based on the majority of opinions. This ensures that per-service imprecise characterisations are consistent with current consumer opinions. This process is associated with capability C4.
Service Ranking	Discerns services that could be recommended to a consumer for replacing the currently consumed service. To this end, services within the same *functional category*[6] as the one being consumed are ranked according to the current precise and imprecise criteria characterisations, and the consumer preferences. This process is associated with capabilities C4 and C6.

[5] Precise criteria can be measured objectively and are not amenable to subjective opinions.

[6] According to their function, services may be categorised into functional categories – e.g. ‘map services’, ‘calendar services’, ‘fuel consumption simulation services’, etc. A functional category thus characterises the *kind* of a service.

Failure Prevention and Recovery Management. This process recommends appropriate actions for recovering from a service failure, or for averting an impending one; it comprises the processes outlined in Table 3 and depicted in Fig. 4.

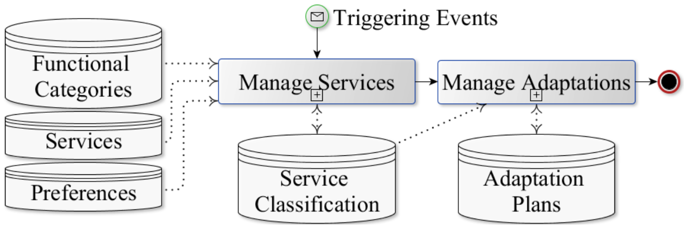

Fig. 4. Failure Prevention and Recovery Management reference process

Table 3. Failure Prevention and Recovery Management processes

Process	Description
Manage Services	Classifies services under appropriate functional categories (e.g. *fuelConsum_A* and *fuelConsum_B* are classified under the category *fuelConsum-Simulations*). These categories form the basis of recommending appropriate alternative services in case a service fails or is about to fail. This process is initiated by the same *triggering events* as the ones that initiate the *Analyse Optim. Trigger* process of Table 2; it is associated with capability C7.
Manage Adapt.	Discerns alternative services that could be recommended to a consumer if, for a particular service, the *Service Alert* event occurs (see Section 3.2). It thus ranks services according to their current precise and imprecise criteria characterisations, and the expressed consumer preferences. This process is too associated with capability C7.

4 Framework Mechanisms

This section elaborates on the mechanisms implementing the reference processes of Section 3. Table 4 outlines a number of requirements on these mechanisms. For reasons of space, we confine ourselves to the *Policy Compliance Evaluation* process (see Fig. 5); mechanisms for the rest of the reference processes can be found in [10].

Table 4. Architectural requirements on Broker@Cloud mechanisms

Availability	For each identified capability, there must be at least one mechanism specification and an associated mechanism implementation.
Dependency Handling	A mechanism assumed to operate as part of a collection of mechanisms must ensure interoperability with the other mechanisms in the collection.
Flexibility	A mechanism may be replaceable not only by another mechanism but also by an ecosystem of mechanisms which implement the same capabilities as the mechanism under replacement.
Replaceability	Methods must be provided for developing new mechanisms, or new implementations of existing mechanisms.

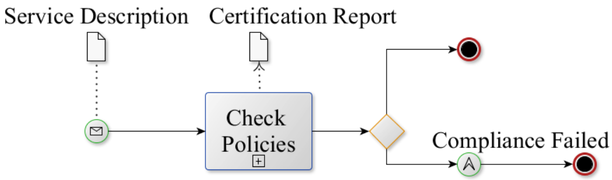

Fig. 5. Internal view of the Policy Compliance Evaluation process

The mechanism implementing the *Policy Compliance Evaluation* process determines whether a service description (SD) complies with the relevant CSB policy. To this end, it entails a number of processes which determine the compliance of key service-level attributes. These processes are intended to implement a general framework of policy-compliance checks, one which is potentially applicable to a wide range of services. Fig. 6 depicts an internal view of such a policy-checking process; Table 5 provides brief descriptions of the activities entailed by such a process.

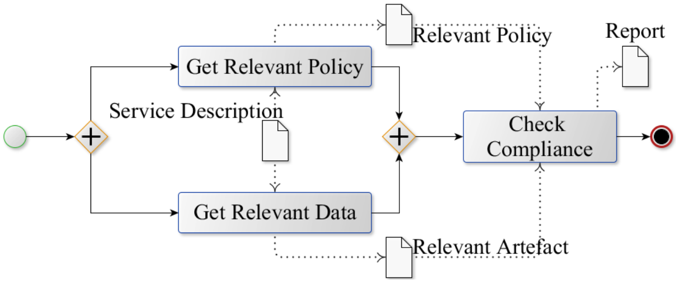

Fig. 6. Internal view of a policy-checking process

Table 5. Policy-checking process

Name	Description
Get Relevant Policy	Determines the applicable policy to the SD.
Get Relevant Data	Extracts from the SD those artefacts that are to be checked.
Check Compliance	Checks compliance of the SD artefacts with the policy; it outputs the outcome in the *Report* data object.

5 Related Work

To the best of our knowledge, there are no works addressing the quality assurance and optimisation dimensions of CSB in the context of VEs. [4] recognises the need for frameworks that guide the creation, execution, and management of services in cloud-based VEs; it does not, however, address the quality assurance and optimisation aspects of such frameworks. The rest of this section outlines work related to the three general themes of our conceptual architecture, namely *cloud service governance and quality control*, *failure prevention and recovery*, and *optimisation*.

Cloud service governance refers to policy-based management of cloud services with emphasis on quality assurance [13]. Current practice [14,15] focuses on the use of registry and repository systems combined with purpose-built software to check the conformance of services with relevant policies [13,14,16]. A major weakness in these works is failure to achieve appropriate separation of concerns between defining governance policies and evaluating data against these policies. This has a number of negative repercussions such as lack of portability and lack of explicit representation of policy interrelations. Turning to service certification, functional testing methods are largely interface-based [17,18]. Some attempts to specify complete behaviour have been suggested using (i) graph transformation rules [19], (ii) WSDL augmented with UML state machines [20], and (iii) SAWSDL augmented with pre- and post-conditions [21]. An extensive survey of the state-of-the-art in cloud service governance and quality control can be found in [22].

The field of adaptive service-based systems (SBSs) [23] investigates techniques for monitoring and adapting SBSs. SBSs share similar characteristics with cloud service ecosystems, hence techniques from the former domain can be readily adopted in our work. An extensive survey of the state-of-the-art in adaptive SBSs is provided in [9].

This survey identifies challenges relevant to cloud service failure prevention and recovery that are not addressed in the literature, including metrics for identifying failures, and scalable prediction techniques for identifying impending failures.

Cloud service optimisation has been primarily investigated from a cloud provider"s perspective [24,25], considering consumer satisfaction as a constraint rather than as an optimisation goal. From a cloud consumer perspective, Han et al. [26] propose a service recommender framework for assisting optimisation decisions based solely on IaaS considerations; they fail to consider the dynamically changing conditions that typically characterise cloud service ecosystems. In [27], a service optimizer is proposed to manage dynamic SLAs at the IaaS layer. These works focus exclusively on quantitative metrics which may fail to accurately reflect the relative ranking among services for optimisation purposes [28].

6 Conclusions and Future Work

Unencumbered by the physical constraints of data centres and hardware platforms, cloud computing is anticipated to give rise to VEs that tie together services from vast networks of providers, enabling the creation of a wide range of new, more competitive, and more agile products and solutions [29]. For this shift to be sustainable however, enterprises are expected to increasingly rely on cloud service brokerage (CSB).

This work has presented a conceptual architecture for a framework which provides solutions with respect to the quality assurance and optimisation dimensions of CSB in the context of VEs. Such a framework revolves around the general themes outlined in Section 1, whilst it offers a range of reference processes which are refineable to the level of functional capabilities. The framework is open to the specification of new capabilities, and to the specification of new reference processes. Moreover, it allows Continuous Quality Assurance and Optimisation in Cloud-Based Virtual Enterprises 631 adopters to only select individual capabilities providing that these are independently consumable.

In the future, we shall further elaborate and concretise the mechanisms of the proposed CSB framework. We are currently in the process of: (i) developing RDFSbased declarative models in Linked USDL [30] that will enable the interoperable exchange of service and consumer-preference descriptions, and the evaluation of these descriptions against pertinent CSB policies; (ii) developing APIs and prototypes for the CSB mechanisms of Section 3.

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Carrier Selection for Multi-commodity Flow Optimization in Cooperative Environments

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Abstract. Freight transportation decisions are critical economic and environmental factors in the design and management of networked manufacturing systems at global scale. Multimodal transportation options in combination with cooperative models between transport operators and together with manufacturers can contribute to define more economically and environmentally sustainable operations. This work addresses the problem of the selection of carriers in an international production and distribution network. The aim is to minimize costs and environmental impacts of freight transport. A cooperative decision-making setting between carriers in response to transportation demand of manufacturers is adopted. An integrated optimization-simulation approach is proposed to model the process of defining the optimal combination of transportation services in a multimodal transport network. Experiments show that collaboration based on shared modal capacity between carriers can produce transport cost reduction and service level improvements.

Keywords: Supply chain management, Simulation, Optimization, Carrier selection.

1 Introduction

Networked production requires effective integration of production and distribution planning. This is particularly relevant for complex products consisting of multiple components to be assembled and delivered (e.g., automotive industry). It is more and more important to develop comprehensive decision methods and systems able to (i) integrate different decision levels (i.e., strategic, tactical and operational) and (ii) consider a variety of decision variables (i.e., economic, social and environmental).

This work tackles the problem of carrier selection in an international production and distribution network. A significant literature stock covers organizational aspects and problem solving issues related to production and multimodal freight transportation planning [1]. In optimization approaches to production-distribution

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planning, the development of multiple performance measures in the objective functions, e.g., cost, service level, social and environmental impacts, is required [2]. Collaboration issues in supply chains have been extensively discussed in the literature. Horizontal cooperation in supply chains and carrier selection was demonstrated to be a source of potential benefits to increase carriers' profitability or improve service quality [3]. Carrier selection often requires multicriteria approaches within which environmental and energy use concerns are significant [4]. Collaboration among supply chain actors may enable new optimized configurations of supply chain networks. Therefore, optimization and simulation, as methods largely used in supply chain problems, can be applied to investigate collaboration settings in supply chains while including multicriteria considerations. Optimization was used to address collaboration in transport [5]. Combined optimization and simulation have been applied to collaboration settings among logistics operators and customers [6].

The literature is mainly focused on the analysis of integrated production and transportation from a strategic viewpoint. In mode choice and carrier selection problems, the inclusion of environmental impacts is under-represented [4]. This paper concurrently considers (i) optimization to support strategic decisions, and (ii) simulation to support tactical and operational decisions. Additionally, CO_2 emissions of freight transport are included in both optimization and simulation to address environmental sustainability. Effects of collaboration among carriers are investigated. Carriers may offer transport services in a collaborative way by aggregating themselves and operate on behalf of a multimodal transport operator. The multimodal transport operator is in charge for representing a coalition of carriers executing the transportation service and producing the multimodal document of transport [7]. The problem is how to select proper coalitions of carriers and transportation means to achieve economic and environmental performance goals. The system complexity often requires a decomposition approach and design issues can be disconnected from the tactical and operational ones. Hereinafter, we then present how (i) optimization methods can be used to design multimodal distribution, and (ii) simulation to allocate flows to connections throughout time considering randomness effects.

2 Methodology

The methodological approach consists of the integrated use of optimization and simulation (Fig. 1). The assignment of product flows from factories to final destinations over the multimodal transport network is a multi-commodity capacitated network design problem. A specific problem formulation taking into account cost and environmental impact of transport is presented in Section 2.1. The solution of the optimization model supports in a static way the strategic decisions about the carriers to be activated (e.g., service contracts) for each product and routes. Furthermore, the tactical-operational decisions regarding the service provision have to consider in a dynamic way further elements such as shipments from factories throughout time, frequencies of transport services, service capacity and randomness in service times. For this purpose, a discrete event simulation model is implemented (Section 2.2).

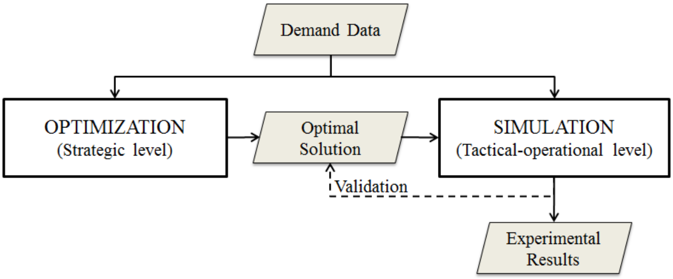

Fig. 1. Methodological approach: Optimization and simulation

First, the simulation model is validated by comparing the output to the solutions of the optimization model (dotted line in Fig. 1). Second, the simulation model is used to test alternative scenario settings by varying the capacity of scheduled services for each transport mode and, more importantly, the routing logic of product flows across the network according to a collaborative scenario setting between carriers. The simulation model processes transport demand data and solutions of the optimization model. It allows the evaluation of additional parameters and performance measures that is hard to embed in the optimization model, e.g., service frequency and times.

2.1 Optimisation Model and Sustainability Factors

Multimodality is modelled as an aspect of the classical multi-commodity flow problem. Gendron et al. [8] model a multimodal transportation problem as a multi-commodity capacitated network design problem defined on a directed graph $G = (N, A)$. Stecca et al. [9] add bill of material constraints and environmental sustainability considerations. In the model hereinafter presented, carriers can cooperate by offering a composite transportation service offered by means of a coalition. To each transport service an arc (i,j) is associated between a pair of nodes. Each transportation service may be operated by different carriers belonging to a predefined set of carriers M. The optimization model considers transportation and CO_2 emission costs. Fixed, routing costs and coalition set-up costs are also included. The problem is to select the most effective coalition to which transportation services can be outsourced. For each node $i \in N$ let $\Delta^+(i)$ be the nodes $j \in N$ such that $(i, j) \in A$ and $\Delta^-(i)$, the nodes $j \in N$ such that $(j, i) \in A$ and K be the set of the final products. Lead times are defined as $[a_i, b_i]$ for each $i \in N$ while $[ED, DD]$ is the earliness and lateness of the problem; it bounds the time of start and end of production and transport operations. Let moreover s_i the service time at node i, for each $i \in N$; t_{ijk} the time needed to traverse an arc $(i, j) \in A$ for shipment k; lts_k is expression of inventory in time units. The model considers alternative sources for final products. To each shipment (final product) $k \in K$ it is associated a subset of alternative origin nodes $O^k \subset N$ in which the shipment can be produced with $O = \cup O^k$. D^k $k \in K$ is the set of destination nodes for shipment k, while q_d is the quantity of shipment k to be shipped in destination $d \in D^k$, I^k are the subsets of intermediate nodes for shipment k with $I = \cup I^k$. For each node $i \in O = \cup_{k \in K} O^k$, a production cycle time for node i is defined as r_i; $m \in M$ defines the generic carrier while $l \in L$ represents a coalition of carriers. Coalitions are modelled in the following way. The coefficient b_{lm} of the matrix $b[L][M]$ is equal to 1 if the carrier l is inserted in the coalition m, 0 otherwise. A binary variable y_m will store which coalition will be selected. A carrier can be part of at least one coalition. The parameter a_{ijl} is used to model which arc a carrier can operate on. if $a_{ijl} = 1$, the carrier l can operate on the arc (i,j), 0 otherwise. The cost parameters of the model are: fc_m, the fixed coalition set-up cost for coalition m; fr_{ij} the fixed routing cost for arc arc $(i,j) \in A$; c_{ij}, the transportation price required per unit of shipments transported along arc $(i,j) \in A$; α, the cost of a tonne of CO_2 emission. Capacity parameters are: C_{ij}, the capacity of arcs $(i,j) \in A$; CP_{ik}, the production capacity of node i for product k. Other parameters are: $BigM$, a large constant; wsu_k; the weight of a unit of shipments of k in tonnes; e_{ijk}, emission factors where $(i,j) \in A$ and $k \in K$ in tonnes of CO_2 for unit of shipment k. The variables of the problems are: y_m, $m \in M$, a binary variable defining whether the coalition m is selected (1) or not (0); u_{ijk}, $(i,j) \in A$, $k \in K$ binary variable equal to 1 if shipment k is routed through arc (i, j), 0 otherwise; x_{ijk},$(i,j) \in A$, $k \in K$ the quantity of shipment k routed through arc (i, j); w_{ik}, $i \in N$, $k \in K$ the arrival time at node i for shipment k. The model can be formulated as follows:

$$\min \sum_{m \in M} fc_m y_m + \sum_{k \in K} \sum_{(i,j) \in A} wsu_k c_{ij} x_{ijk} + \sum_{k \in K} \sum_{(i,j) \in A} fr_{ijk} u_{ijk} + \alpha \sum_{(i,j) \in A} \sum_{k \in K} wsu_k e_{ij} x_{ijk} \tag{1}$$

subject to

$$x_{ijk} \le \sum_{l \in L} \sum_{m \in M} a_{ijl} b_{lm} y_m BigM \quad \forall (i,j) \in A, k \in K \tag{2}$$

$$\sum_{m \in M} b_{lm} y_m \le 1 \quad \forall l \in L \tag{3}$$

$$\sum_{i \in O(k)} \sum_{j \in \Delta^+(i)} x_{ijk} = \sum_{d \in D^k} q_d \quad \forall k \in K \tag{4}$$

$$\sum_{i \in \Delta^-(d)} x_{idk} = q_d \quad \forall d \in D^k, k \in K \tag{5}$$

$$\sum_{j \in \Delta^+(i)} x_{ijk} - \sum_{j \in \Delta^-(i)} x_{jik} = 0, \quad \forall k \in K, \forall i \in I^k \tag{6}$$

$$\begin{aligned} & r_k lts_k + w_{ik} + s_i + t_{ijk} - w_{jk} \le (1 - u_{ijk}) BigM \\ & \forall k \in K, \forall (i,j) \in A \end{aligned} \tag{7}$$

$$ED \le w_{ik} \le DD, \quad \forall k \in K, \forall i \in \{O, D\} \tag{8}$$

$$x_{ijk} \le C_{ij} u_{ijk} \quad \forall (i,j) \in A, k \in K \tag{9}$$

$$\sum_{i \in O(k)} \sum_{j \in \Delta^+(i)} x_{ijk} \le CP_{ik} \forall i \in N, \forall k \in K \tag{10}$$

$$x_{ijk} \ge 0, w_{ik} \ge 0, \quad u_{ijk} \in \{0,1\}, \forall k \in K, \forall (i,j) \in A, y_m \in \{0,1\}, \forall m \in M \tag{11}$$

The objective function (1) consists of a first term considering the coalition set-up costs. The second and third terms consider, respectively, variable and fixed transportation costs of each travelled arc while the fourth one the CO_2 emission cost. Constraint (2) links the flow variables to the service operated by the carriers of the selected coalitions. Constraint (3) imposes the carriers to belong to a single selected coalition. Constraints (4), (5) and (6) are flow constrains applied to multicommodity flow. Expressions (7) and (8) define time constraints, while functions (9) and (10) define capacity constraints and expression (11) the decision variables.

2.2 Simulation Model

The simulation model reproduces the sources of finished products with related quantities as well as the product routings over the transport network served by the available carriers. Freight transport modes are road, rail and sea. For each transport operator a fixed cost component is included while, for each service provided, the variable transport costs as well as the CO_2 emissions and related costs are calculated. Final market destinations are also modeled. The model is implemented in the simulation modeling framework Simio (Simio LLC). A screenshot of the model is presented in Fig. 2. The implemented model, loaded with the same transport demand data and solution of the optimization model, runs throughout a simulation time horizon of 52 weeks. 50 replications are made. The simulation model operates with a deviation of 0.1% in terms of total output (i.e., products delivered to final market destinations) and 0.06% in terms of total CO_2 emissions w.r.t. optimization. Half widths (95% confidence interval) of values of main measures analyzed in validation and further experiments are negligible. The model is then valid for the study purpose.

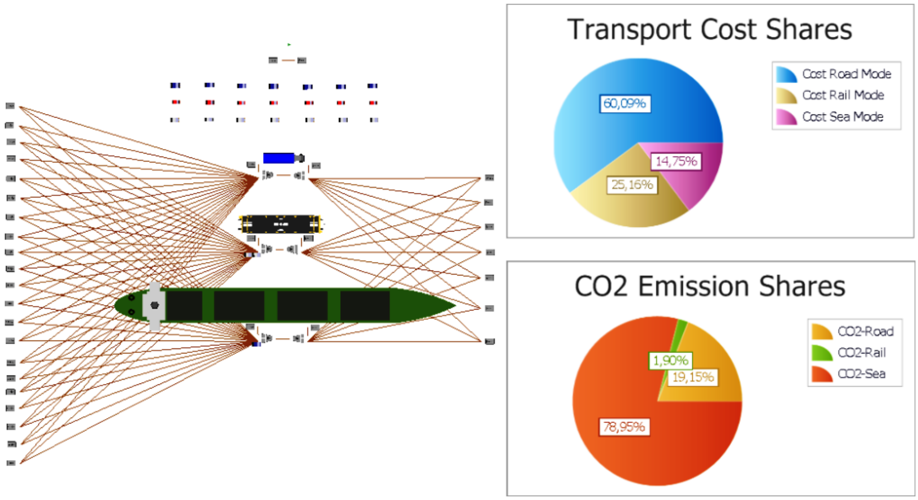

Fig. 2. Screenshot of the simulation model

3 Transportation Service Assignment

The optimization model considers the selection of coalitions to deliver the transportation service but no details on how the coalition has to provide the service over the arcs are given. A clearing procedure is required for the detailed allocation of transportation services. The procedure is executed by the simulation model. As a preliminary approach, a coalition including a set of carriers operating over the multimodal network can share the transport capacity for each transport mode over the routes connecting factories to market destinations. Product shipments are then routed over the network of services according to the distance from the final destinations. So doing, potential cost and territorial leadership of single carriers can be exploited. The collaborative setting is tested in simulation experiments.

3.1 Scenario Description and Computational Results

The scenario used for the optimization consists of three product types (sales data are generated starting from the statistics of ACEA, http://www.acea.be/statistics) and seven carriers which can serve seven market destinations. Transport demand is equal to 705,250 tonnes/year. Three carriers provide road transport services; two carriers offer rail transport while two carriers sea transport. Road, rail and sea transport costs are equal to, respectively, 0.14, 0.11 and 0.009 EUR/tkm[1]. CO_2 emissions of the road, rail and sea transport are equal to 93.1, 17.4 and 101 gCO_2/tkm, respectively[2]. CO_2 emission cost is 11.07 EUR/tonne CO_2 ($15)[3].

The simulation model makes use of the same demand data, parameters and number of activated carriers generated by the optimizer in the optimal solution. The simulation model is tested in two main scenario settings: (i) a baseline scenario not including the collaboration and (ii) a collaborative scenario modeling a coalition consisting of all the available transport operators. The studied case assumes distance ranges included in a European network. Basic simulation parameters for baseline and collaborative scenarios are presented in Table 1. The total cost of transport includes fixed costs for each transport operator, variable costs as well as CO_2 emissions costs. In the collaborative scenario, products are routed across the network (allocated to services) according to the following distances from the final destinations: up to 700 Km (road mode), between 700 and 1,400 Km (rail), longer than 1,400 Km (sea).

Table 1. Simulation parameters

Transport services	Service times (hours)	Frequency (services/week)		Capacity (ton./serv.)
		Baseline	*Collaborative*	
Road transport	Triangular (3,5,8)	56	84	250
Rail transport	Triangular (12,17,24)	14	28	450
Sea Transport	Triangular (18,23,30)	7	14	900

[1] http://ec.europa.eu/ten/transport/studies/doc/compete/compete_report_en.pdf

[2] http://www.developpement-durable.gouv.fr/IMG/pdf/Information_CO2_ENG_Web-2.pdf

[3] http://www.oecd.org/env/cc/40633555.pdf

Computational results are presented in Table 2. Computational results of the optimization show that the model can be effectively used to select the proper coalition. Test instances are built by comparing a baseline situation without collaboration to a scenario considering coalitions in which each coalition is able to cover all the modal transports. The baseline situation is used to validate the simulation model. The coalition covering all the modal transports is then passed to the validated simulation model for detailed experiment of the collaborative setting.

Table 2. Computational results of the optimization-simulation approach

Transport services	Optimization	Simulation - Baseline	Simulation - Collaborative
Total transport costs (EUR)	57,149,206	57,144,317	37,697,940
CO_2 emissions (tonnes)	73,460	73,416	76,776
Total output delivered (tonnes)	705,250	704,550	705,050
Road transport			
Tonnes Km carried (tkm)	282,537,000	282,537,000	157,921,250
Avg. number in station (tonnes)	-	20,325	48,356
Avg. time in station (weeks)	-	5.5	7.0
Rail transport			
Tonnes Km carried (tkm)	112,305,750	112,294,300	83,981,700
Avg. number in station (tonnes)	-	60,656	3,986
Avg. time in station (weeks)	-	15.2	2.40
Sea transport			
Tonnes Km carried (tkm)	447,543,250	447,115,550	600,118,950
Avg. number in station (tonnes)	-	134,573	46,718
Avg. time in station (weeks)	-	22.8	9.2

The related experiments highlight a reduction in transport cost by 34%. However, an increase in CO_2 emissions by 4.6% w.r.t. the baseline scenario (deviation between output delivered equal to 0.07%) can be observed. These effects can be justified by the shares of tonnes km (tkm) carried by each transport mode. In the collaborative scenario, remarkable reductions in tkm of the road mode (-44.1%) and rail mode (-25.2%) are compensated by an increase in tkm transported through the sea mode (+34.2%). On the other hand, the baseline scenario relies on a lower number of available carriers not allowed to share transport capacity on modal routes. The collaboration, which is ruled by the distance-based allocation of transport orders, produces positive effects on overall transport costs but also a slight increase in CO_2 emissions due to the specific transport mode characteristics. In the road mode transport operators carry larger quantities across shorter distances w.r.t. the baseline scenario. Conversely, lower product quantities are carried across longer routes in the rail and sea modes. Furthermore, the collaboration has very positive effects on in-transit inventory and service levels throughout the transport chain: an improvement in the sum of product quantities waiting for transportation and an average decrease in the related times can be observed. Lower workload and higher frequency of transport services contribute to these performance impacts. Lower levels of stored products across the transport network may also entail positive impacts on CO_2 emissions due to lower risks of excess production and product obsolescence.

4 Concluding Remarks and Future Research

This work aims to contribute to the solution of complex freight transportation problems which have to simultaneously address (i) strategic transport decisions and their operationalization as well as (ii) the minimization of costs and environmental impacts in an international production and multimodal distribution network. Collaboration between carriers is tested in the form of coalitions represented by transport operators. Collaboration based on shared modal capacity between carriers can produce a global reduction in costs and in-transit inventory as well as service level improvements. In the studied scenario, it however seems that environmental performance does not benefit from the tested collaboration mechanism. This last result suggests that more environmentally sustainable transport decisions could be also guided, e.g., by defining at policy level proper cost structures related to CO_2 emissions that transport operators should consider. CO_2 emissions of production operations are out of the scope of this work. Future works will explore multicriteria approaches as well as refinements of collaboration mechanisms and incentives.

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Equilibrium Assignments in Competitive and Cooperative Traffic Flow Routing

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Abstract. The goal of the paper is to demonstrate possibilities of collaborative transportation network to minimize total travel time of the network users. Cooperative and competitive traffic flow assignment systems in case of $m \geq 2$ navigation providers (Navigators) are compared. Each Navigator provides travel guidance for its customers (users) on the non-general topology network of parallel links. In both cases the main goals of Navigators are to minimize travel time of their users but the behavioral strategies are different. In competitive case the behavioral strategy of each Navigator is to minimize travel time of traffic flow of its navigation service users while in cooperative case – to minimize travel time of overall traffic flow. Competitive routing is formalized mathematically as a non-zero sum game and cooperative routing is formulated as an optimization problem. It is demonstrated that Nash equilibrium in the navigation game appears to be not Pareto optimal. Eventually it is shown that cooperative routing systems in smart transportation networked environments could give users less value of travel time than competitive one.

Keywords: competitive routing, cooperative routing, traffic flow assignment, Wardrop equilibrium, Nash equilibrium, Pareto optimality.

1 Introduction

One of the important trends during last decades is essential increasing the amount of navigation providers on the roads. The influence of competitive navigation services on a traffic flow assignment on transportation networks is not as good as expected. The problem is that competitive routing proposed by navigation systems to minimize travel time of their customers in case of huge amount of cars driving through the network could leads to decreasing the total travel time of network users. The basic reason for that is the conflict of interests between different navigation providers. From game theory point of view it means that Nash equilibrium traffic assignment leads to less value of total travel time compare to Pareto optimal solution.

Collaboration of navigation provider can be mathematically formalized as centralized traffic assignment which guaranties user equilibrium or system optimum on transportation network. The main principles for collaborative traffic flow assignments were formulated in 1952 by Wardrop who stated two principle of

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equilibrium traffic flow assignment in transportation networks [1]. In 1956 Beckmann proposed mathematical formalization of Wardrop's principles that is today considered as classical [2, 3]. One of the most disadvantages of this model is computational complexity for using in large networks. For details one can read articles [4, 5]. In the present paper we offer a method for finding in Wardrop's model the traffic flow assignment strategies explicitly in case of linear BPR-delay function.

Considering *competitive routing* we use Nash equilibrium optimality principle. We guess that comparison of cooperative and competitive routing efficiency is highly important to make a dicision either collaborative or competitive principle should be taken as a basis for smart transportation networked environments. Thus relation between Wardrop equilibrium and Nash equilibrium has to be explored. For the first time this issue was raised in [6] where origin-destination areas had been considered as players. Unfortunately such problem formulation as available in [6] is not connected with competitive routing. Another works on this topic mostly have not any analytical representation, for example [7]. In this work we compare Wardrop equilibrium and Nash equilibrium expressed explicitly and show that cooperative routing systems in smart transportation networked environment could give users less value of travel time than competitive one.

Thereby the present work is devoted to the following three interrelated problems: 1) receiving the explicit form of traffic flow assignment strategies; 2) finding relationship between Wardrop and Nash equilibria; 3) comparison of collaborative and competitive smart transportation networked environments.

2 Mathematical Models of Competitive and Cooperative Traffic Flow Routing

In this section we formulate competitive and cooperative traffic flow routing problems mathematically and find corresponding equilibrium strategies of assignments.

First of all, it should be noted that analyzing an arbitrary transportation network we rely on the idea according to which: any transportation network could be decompose to the set of subnets consisting of one origin-destination pair and certain amount of parallel routes [8, 9, 10]. On the one hand, such an idea is reasonable due to the fact that narrowing of the road (using the same link in different routes) leads to congestion [10]. On the other hand, parallel structure of transportation network contributes to avoiding the Braess's paradox [8, 9].

Hereby we consider transportation subnet presented by digraph consisted of one origin-destination pair and n parallel links. On this subset m Navigators act. Let us introduce the following notation: $N = \{1,\ldots,n\}$ – set of numbers of routes; $M = \{1,\ldots,m\}$ – set of numbers of Navigators; i – number of the route, $i \in N$; j,q – numbers of Navigators, $j,q \in M$; $F^j > 0$ – traffic flow value of Navigator j; $F = \sum_{j=1}^{m} F^j$ – aggregate traffic flow value of all Navigators; $f_i^j \geq 0$ – traffic flow value of

Navigator j through route i; $f_i = \left(f_i^1, \ldots, f_i^m\right)$ – vector of traffic flow values of all Navigators assigned through route i, wherein $f_i^{-j} = \left(f_i^1, \ldots, f_i^{j-1}, f_i^{j+1}, \ldots, f_i^m\right)$; $F_i = \sum_{j=1}^{m} f_i^j$ – traffic flow value through route i; $t_i^0 > 0$ – free travel time through route i; $c_i > 0$ – capacity of i-th route; $d_i(F_i)$ – delay of F_i traffic flow value on route i. Vector of strategies of Navigator j is $f^j = \left(f_1^j, \ldots, f_n^j\right)^T$ and $f = \left(f^1, \ldots, f^m\right)$.

Now we are ready to formulate competitive and cooperative traffic flow routing problems mathematically. According to [3] cooperative case is expressed by the following optimization problem:

$$\min_f z^{cpr} = \min_f \sum_{i=1}^{n} d_i(F_i)\ F_i\,, \tag{1}$$

with constraints

$$\sum_{i=1}^{n} F_i = F\,, \tag{2}$$

$$f_i^j \geq 0 \quad \forall\, i \in N, j \in M, \tag{3}$$

while competitive case can be expressed by the following non-zero sum game between Navigators:

$$\min_{f^j} z_j^{cmp} = \min_{f^j} \sum_{i=1}^{n} d_i(F_i)\ f_i^j \quad \forall\, j \in M, \tag{4}$$

with constraints

$$\sum_{i=1}^{n} f_i^j = F^j \quad \forall\, j \in M, \tag{5}$$

$$f_i^j \geq 0 \quad \forall\, i \in N, j \in M, \tag{6}$$

Hereby we can see that in cooperative case Navigators try to achieve system optimum of Wardrop for whole traffic flow [3], whereas in competitive case – each Navigator tries to achieve system optimum only for its own customers. However in competitive case any Navigator j is affected by other Navigators so that mutual influence of Navigators' strategies addresses us to find Nash equilibrium. Further we will use explicit BPR-delay function: $d_i(F_i) = t_i^0\left(1 + \frac{F_i}{c_i}\right)$ [11]. Without loss of generality to find Nash equilibrium we assume

$$t_1^0 < t_2^0 < \ldots < t_n^0. \tag{7}$$

Theorem 1. Subject to (7) Nash equilibrium in the game of Navigators is achieved by the following strategies

$$f_i^{j*} = b_i^j - \frac{1}{m+1}\sum_{q=1}^{m} b_i^q, \tag{8}$$

where

$$b_i^j = \frac{c_i}{t_i^0}\frac{F + \sum_{s=1}^{m} F^s + \sum_{r=1}^{n} c_r}{\sum_{r=1}^{n}\frac{c_r}{t_r^0}} - c_i, \tag{9}$$

$\forall\ i \in N,$ when

$$F^j > \frac{1}{m+1}\sum_{i=1}^{n} c_i\left(\frac{t_n^0}{t_i^0} - 1\right), \tag{10}$$

$\forall\, j \in M.$

Theorem 1 provides explicit optimal strategies for Navigators in the case of competitive traffic flow routing. To find optimal strategies in case of cooperative routing it is sufficiently to equate m to 1 in formulas (8)-(10). Indeed (1) shows that in cooperative case collaboration of Navigators is reduced to finding system optimal assignments on all routes for whole traffic flow (unlike optimal assignments on all routes for each Navigator in competitive routing). In other words in cooperative case Navigators try to find F_i^* and it is clear that in such a case f^* is not unique and limited only by condition $F_i^* = \sum_{j=1}^{m} f_i^j \ \forall\ i \in N.$

Theorem 2. Total travel time of whole traffic flow in case of cooperative routing is strictly less than in competitive case (Nash equilibrium is not Pareto optimal).

Theorem 2 states that Wardrop equilibrium leads to less travel time than Nash equilibrium. Moreover it indicates that applying cooperative or centralized traffic flow navigation systems in smart networked environments is more preferable than competitive systems in terms of travel time value.

3 Numerical Experiments

In previous section it was shown that employing of cooperative or centralized traffic navigation system in smart transportation networked environments leads to less travel time value than competitive systems. To illustrate this result we have investigated transportation network of one of the central districts in Saint-Petersburg – Vasileostrovsky district.

Consider Fig. 1. Denote two areas: origin area (red bold circle) and destination area (green bold circle). Moreover there are 4 potential routes from origin to destination: red line, orange line, blue line and green line.

Fig. 1. Transportation network of Vasileostrovsky district of Saint-Petersburg

Investigated district has the following parameters: $t_1^0 = 7{,}5$ and $c_1 = 300$ (orange line), $t_2^0 = 9$ and $c_2 = 400$ (blue line), $t_3^0 = 12$ and $c_3 = 500$ (green line), $t_4^0 = 13{,}5$ and $c_4 = 600$ (red line). Then we assume that the flow F = 1 000 has to be assigned and we compare final travel time of whole traffic flow when there is 1 (cooperative or centralized system), 2, 4 and 10 competing Navigators acting on the network. It is to be noted that in case of $m > 1$ Navigators we devide whole flow F between Navigators equally. Firstly we propose that there are only 3 routes (orange, blue and green lines). Results are shown in Table 1.

Table 1. Dependence of goal-function value on amount of competing Navigators (3 routes)

Amount of Navigators, m	$\sum_{j=1}^{m} z_j^{cmp}\left(f^*\right)$
1 (cooperation)	17337,06
2	17349,05
4	17375,89
10	17409,27

Thereby, when there is a little network with only three possible routes the more competing Navigators give assignment with the worse travel time of whole traffic flow F but it is not so crucial. Let us increase amount of routes adding just one new route. In such a case results are shown in table 2.

Table 2. Dependence of goal-function value on amount of competing Navigators (4 routes)

Amount of Navigators, m	$\sum_{j=1}^{m} z_j^{cmp}\left(f^*\right)$
1 (cooperation)	16178,624
2	16205,103
4	16264,417
10	16338,157

We can see that the bigger transportation network the worse results given by more competing Navigators.

It has to be mentioned that classical algorithms such as Frank-Wolfe algorithm would demand much more operations for getting the same results. Indeed it needs information about all links in the network and, consequently, dimension of the problem grows extremely when the network becomes larger. Interested one can see [5].

Proposed simple example of only one district of Saint-Petersburg shows that application of collaborative systems in smart transportation networked environments in large cities is more reasonable than cooperative systems.

4 Conclusion

In this work we conducted a comparative analysis of two smart transportation networked environments: one based on cooperative routing and another based on competitive routing. Mathematical expression of cooperative and competitive cases led to the conclusion that cooperative navigation systems could provide aggregate traffic flow of all transportation network users with less total travel time than competitive one. It is clear that government of any large city is interested in improving the transportation situation uniformly on the entire network. Thereby in terms of governance collaborative traffic flow navigation systems based on explicit assignment strategies in smart transportation networked environments are highly accurate and operative equipment for decision making in transportation area.

In our further works we are going to generalize obtained results for the large transportation networks. For this purpose we are investigating whole transportation network of Saint-Petersburg city using developed technique.

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Appendix

Proof of Theorem 1. Using Theorem 1 from [12] we can get the following expression

$$f_i^{1*}+\ldots+2f_i^{j*}+\ldots+f_i^{m*}=\left(\frac{\omega_j}{t_i^0}-1\right)c_i,\quad \forall j\in M. \tag{11}$$

Summing such expression by i and j we get

$$\sum_{s=1}^{m}F^s+F^j=\sum_{i=1}^{n}\left(\frac{\omega_j}{t_i^0}-1\right)c_i, \tag{12}$$

and, consequently,

$$\omega_j=\frac{F^j+\sum_{s=1}^{m}F^s+\sum_{i=1}^{n}c_i}{\sum_{i=1}^{n}\frac{c_i}{t_i^0}}.$$

Summing (11) by i and expressing F^j we eventually obtain the condition (10) subject to (7). ■

Proof of Theorem 2. Union of domains of functions $z_j^{cmp}(f)$ are wider than domain of function $z^{cpr}(f)$, thereby $\sum_{j=1}^{m} z_j^{cmp}\left(f^*\right) \geq z^{cmp}\left(f^*\right)$. Moreover equality is possible if and only if $m = 1$. Consequently, $\sum_{j=1}^{m} z_j^{cmp}\left(f^*\right) > z^{cpr}\left(f^*\right)$. ∎

Knowledge Management in Networks

A Retrospective Socio-Semantic Analysis of the PRO-VE Conferences

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Abstract. The IFIP WG 5.5 Working Conferences on Virtual Enterprises (PRO-VE) has created, in 14 editions, a remarkable scientific and professional community intersecting several disciplines and resulting in a new one: collaborative networks. In this paper we present the results of a retrospective study of the conceptual system evolution of PRO-VE providing an instrument to reflect about the field's past and future. Our approach was socio-semantic trying to devise the influence between the researchers social network and the evolution of the conceptual system. Firstly, we made a terminological analysis of every PRO-VE proceeding resulting in a picture of the main concepts used in each edition and their relative importance. Then, we used social network analysis techniques to conclude about the influence of the researchers on the conceptual system evolution. The results suggest a relatively stable set of concepts influenced by a network of core researchers. However, some marked evolution in the relative importance of the concepts can be identified.

Keywords: socio-semantic network, social-networks analysis, PRO-VE conference.

1 Introduction

Scientific conferences series are somehow archetypes of researchers communities creation, evolution and death. If we envisage conference research communities as strong knowledge communities [1], we assist at knowledge creation and dissemination in varying degrees according to its (time-based) relevance. If we look at them as collaborative networks [2] we assist at social capital creation and dismissal and trust building and destruction influencing directly and indirectly single or collective research activities. It seems then clear that the dyad knowledge-collaboration is not separable in the studies of conference research communities even if the majority of the published research on the subject focus on one dimension or the other. The PRO-VE conference series reaches this year its 15th edition. This round number was the spark that motivated us to study the PRO-VE community evolution in two intertwined dimensions: the conceptual system and the social system. This is not "just another bibliometric or scientometric study" of conference proceedings. Although the later seem to be much less frequent than the studies based on scientific

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journals, our goal was to characterise qualitatively and in detail the evolution of the conceptual system of PRO-VE. Yet, the conceptual system evolution cannot be studied detached from the community of researchers, as the relationships among them and the patterns of use of the concepts are fundamental for the understanding of such evolution. Our stance is thus socio-semantic, and the object of study is the socio-semantic network. The approach followed by us is original in several ways. The study of knowledge networks as socio-semantic networks is not new although not widespread [1]. The study of the conceptual system within these studies is normally restricted to keyword identification or extraction. Our approach relied in a comprehensive terminological and conceptual semi-automated analysis that enabled the re-construction of the de facto conceptual system of each conference edition. The study of the social network usually rely on the identification of co-authorship and citation analysis. Our approach relies on 2-mode (researchers–concepts) social networks analysis (SNA), enabling the study of the socio-semantic network. The rest of the paper is organised as follows: in the next section we briefly review some important related work, then we describe in detail the research design followed by the presentation of the results. Finally, the results are discussed, the limitations of the study pointed out and the paper is concluded. It is also important refer the authors motivation for this study. One of the co-authors is an active member of the PRO-VE community having participated in all but three conference editions. The other co-authors are young information science professionals, interested in understanding better the study of scientific communities.

2 Related Work

There has been recently a growing body of work on the analysis of communities and their temporal evolution in dynamic networks [3]. In the literature we can find some research studying scientific conferences, namely bibliometric and scientometric studies. [4] analysed semantically the proceedings of a conference in the area of international business. The study was done with a corpus that joined three years of proceedings. The main objective was to represent the current academic interest in the area, grouping keywords and analysing the most studied areas in the articles. Another bibliometric study is decribed in [5] analysing one year of a conference (DESIGN 2012). This study used the citations in the papers to describe citation trends by field, type of work and its distribution.

Within the PRO-VE conferences two papers addressed the social network and the conceptual evolution of the PRO-VE community. In [6] the authors exploited the concept of eigenvector centrality starting from the papers proceedings (2005-2009) and propose a weighted multi-hypergraph model to study the (eigenvector) centrally of PRO-VE authors and research topics. The model is roughly equivalent to our 2-mode network being the concepts taken from reference models and some text processing made to identify concepts through the papers “keywords”. As we will see bellow, our research go beyond this model by extracting terms referring to domain concepts in the form of multi-word phrases that constitute a substantial majority of all technical vocabulary. We also propose to reuse a unified socio-semantic model borrowed from [1]. The very same approach to the domain concepts identification from the proceedings corpus, distinguishes our research from [7] whose main limitation is to consider only single-word terms.

The empirical and computational study reported in [1] suggests that the dynamics of a community, i.e. communities of scientists, software developers, wiki contributors and others, can be amply described as the coevolution of a social and a socio-semantic network. The authors presents a theoretical framework based on a social network and a socio-semantic network. In this study we can see a description of the dynamics of a community comprising the social structure and socio-semantic structure. It is exactly in the work of Roth that we found our theoretical reference. A *social network* is denoted by $\mathbf{G}=(\mathbf{S},\mathrm{R}^{\mathbf{S}})$ where **S** is the agent set and $R^S = R \subset S \times S \times N$ denotes the set of dated links: a link $l=(s,s',t) \in R^S$ means that s is related to s' at t. Considering now **C** a set of semantic objects which we call "concepts" and which correspond here to terms or noun phrases considered as atomic units, a *socio-semantic network* is thus defined formally as a network $\mathbf{G}^{\mathbf{C}}$, made of actors of **S**, concepts of **C** and links between these elements: $\mathrm{R}^{\mathbf{C}}$ thus denotes the use of concepts by actors: an actor is linked to concepts he/she mentioned (e.g., in a paper from a proceeding). Thus, $R^C \subset \boldsymbol{S} \times \boldsymbol{C} \times N$, and a link $l^C = (s,c,t) \in R^C$ means that s used c at t. Although Roth studies computationally the coevolution of social and socio-semantic networks, in this paper we use only the socio-semantic network to study the evolution of the PRO-VE conceptual system.

3 Research Design

Recalling the research relevance and goals introduced in the beginning of this paper, our aim was to know more on how the PRO-VE community evolved regarding the technical and scientific topics (concepts) addressed in 14 editions of existence of the conference. Furthermore, we wanted to understand if there were traces of influence from the structures of collaboration of the researchers in the number and intensity of the addressed concepts. The specific research questions were:

RQ1. What were the main technical and scientific concepts addressed *de facto* in each of the PRO-VE conference editions? Are there any patterns of evolution?

RQ2. Is it possible to identify sub-sets of researchers having in common the use of similar sets of concepts (socio-semantic structures)? How did these structures evolved?

This research was fundamentally exploratory, and being so there were not strong hypothesis to advance. Nevertheless, a couple of them were advanced as preliminary answers to the research questions:

H1.1. There is a core set of concepts used in all the editions of the conference;

H1.2. The variability of the first ranked concepts after the core is high;

H2.1. A core set of concepts is shared by the majority of the researchers;

H2.2. There are groups of researchers that are likely to influence the adoption of new concepts.

The research strategy to answer the above questions recurred to two perspectives on the PRO-VE conferences: a conceptual (semantic) perspective and a social network perspective. The idea was to firstly identify and analyse the concepts that the researchers *de facto* used in the conference papers using terminology and natural language processing tools and then to identify and analyse the socio-semantic structures (sets of researchers and concepts they used) emerging from the conceptual analysis. This approach has several dimensions. Regarding the epistemology, our study is essentially interpretative, although strongly based on fact discovering through quantitative methods. Regarding the methods, the approach is multi-disciplinary as it was informed by and tools were used from terminology and natural language processing, along with social networks analysis techniques. The data sources used were the 14 PRO-VE proceedings in electronic (pdf) format. From these data sources, three basic data-sets (per year) were extracted: authors, papers/authors, conference-title/table-of-contents/editorial. The overall research design is depicted in the figure 1.

3.1 Terminological and Conceptual Analysis

The goal of this phase was to identify and characterise the conceptual system suggested by each of the fourteen PRO-VE conference proceedings and to identify some patterns of evolution. For that, a textual corpus of the conference proceedings was created and organised by year (for the sake of economy of space we will not describe the data-sets preparation methods). A twofold approach was followed: first, a NLP tool was used to extract the candidate terms[1] from each proceeding; second, a terminological and conceptual analysis of the candidate terms was performed to result in a ranked list of terms (concepts) for each conference year. The term identification was made with the help of an automatic term recognition (ATR) service: the TerMine service provided by NaCTeM[2]. TerMine is based on a domain-independent method (*C-Value*) for the automatic extraction of multi-word terms, from machine-readable special language corpora. As described in [8], *C-value* combines linguistic and statistical analyses with an emphasis placed on the statistical part. The linguistic analysis enumerates all candidate terms in a given text by applying part-of-speech tagging, extracting word sequences of adjectives/nouns based, and stop-list. The statistical analysis assigns a termhood to a candidate term by using the following four characteristics: (i) the occurrence frequency of the candidate term, (ii) the frequency of the candidate term as part of other longer candidate terms, (iii) the number of these longer candidate terms, and (iv) the length of the candidate term.

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1 In terminology, a (technical/scientific) term is a possible designation for a concept considered to be part of a given domain. A term must have the explicit or tacit agreement of the technical/scientific community dealing with the concept. A candidate term is a term that was identified in some source and that needs the validation of a domain specialist to be considered a domain term.

2 The National Centre for Text Mining (NaCTeM) - http://www.nactem.ac.uk/

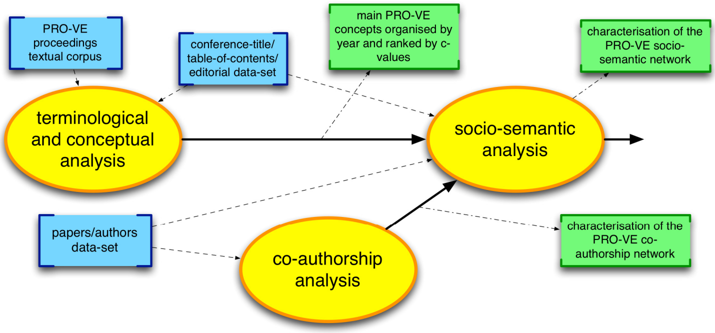

Fig. 1. Overall research design

From the several ATR tools we tested, TerMine showed the best performance by maximizing precision and recall, while minimizing noise. Most of the other tools available are optimized for recognizing single word terms, which is not what was required for analysing the PRO-VE proceedings. In fact, technical terms consist mostly of noun phrases containing adjectives, nouns, and occasionally prepositions. The discourse properties of the PRO-VE community are patterns of repetition that distinguish noun phrases that are technical terms, especially multi-word phrases that constitute a substantial majority of all technical vocabulary, from other types of noun phrase [10]. The TerMine service only provided a ranked list of candidate terms. The next and crucial step was to analyse the lists by specialists. Here, specialists are PRO-VE participants. We chose three specialists, actively working in the PRO-VE topics, with different degrees of participation in the fourteen editions (12, 8, and 3 participations). The conceptual analysis involved the following tasks performed by a specialist in the PRO-VE domains: (i) to go through the first 100 candidate terms returned by TerMine for each year, to clean non-terms and discard non-relevant terms; (ii) to make two rankings for each year, one of the first 10 and other of the first 20 terms using the C-Value termhood returned by TerMine; (iii) to fine-tune the rankings for each year by looking over the proceedings chapters and editorials[3]. This phase finished with the validation of each ranking by the above mentioned specialists.

3.2 Social Network Analysis

The goal of the social network analysis phase in our approach was to provide a description of the socio-semantic structure of the PRO-VE scientific community. SNA techniques were used to (i) to identify the network of relationships between authors and the concepts used in each conference proceeding, (ii) to identify meaningful sub-structures of concept-author relationships and (iii) to relate the

[3] For the conceptual analysis phase it would be expectable to use the keywords assigned by the authors to their papers. In PRO-VE, only from 2009 on keywords where used to describe the paper subject. For the sake of consistency, we decided not to use the keywords in the conceptual analysis.

co-authorship network with the socio-semantic network. For this we used mostly two-mode (2-mode) network analysis techniques. Due to the effort required to prepare the data-sets and to perform 2-mode network analysis, we selected a sample of 4 PRO-VE proceedings: 1999, 2005, 2009 and 2013. For each of the selected years, a rectangular data matrix of authors (rows) by concepts (columns) was built[4], according to the following protocol: (i) the set of concepts to be used is the top 10 ranking for the year in consideration; (ii) for each of the concepts, the full text of the proceedings was searched to count how many times the concept appears in each paper; (iii) this number was cumulatively added to intersection of the paper authors (row) with the concept (column). For each year, the resulting authors-by-concepts matrix is calculated as:

$$v_{i,j} = \sum_{p_{k,i} \in P} f(p_{k,i}, c_j)$$

where $v_{i,j}$ is the i,j cell value, $p_{k,i}$ is a paper co-authored by author a_i and included in the set of papers P of the proceedings, c_j is the concept being look up and f a function that returns the frequency of presence of c_j in paper p_k. Exclusion conditions were defined so as to discard papers were a term appears in a non relevant way. A $\min\left(f(p_{k,i}, c_j)\right) = 3$ was established. Also, if the concept appeared only in the title or abstract and not in the paper body, it would be excluded i.e, $f(p_{k,i}, c_j) = 0$.

Usually, 2-mode data in SNA can be analysed either as 1-mode or 2-mode. We used both, but focusing on algorithms and representations that highlight "sub-structures" instead of the characteristics of nodes (authors or concepts) within the network [9]. For our purposes, we selected the 1-mode networks to be run by the *k-core* analysis and the *core-periphery* analysis. The 2-mode network was analysed in terms of *degree centrality*. A *k-core* is a maximal group of actors, all of whom are connected to some number (k) of other members of the group. It allows actors to be included in the group if they are connected to other k members, regardless of how many other members they may not be connected to. By varying the value of k (that is, how many members of the group do you have to be connected to), different pictures can emerge [9]. In the case of our 2-mode network of authors-by-concepts, the k-core algorithm finds the maximal group of authors that use k concepts and concepts that are used by k authors. The *core-periphery* structure is an ideal typical pattern that divides both the rows and the columns into two classes. One of the blocks on the main diagonal (the core) is a high-density block; the other block on the main diagonal (the periphery) is a low-density block. In our case, when applying the core-periphery model to the author-by-author data, the model seeks to identify a set of authors who have high density of ties among themselves (the core) by sharing many concepts in common, and another set of authors who have very low density of ties among themselves (the periphery) by having few concepts in common. We chose degree centrality in terms of socio-semantic relations because, as suggested by [1] it may be

[4] In our case the 2-mode network is represented by a "author-by-concept" (rectangular) matrix. This 2-mode network can be transformed in two 1-mode networks: a "author-by-author" and a "concept-by-concept". These are represented by square matrices.

loosely interpreted as semantic capital: in other words, the number of concepts an actor has used is likely to render the variety of topics s/he has dealt with in the epistemic network.

The data sets were analysed by two software packages: NetMiner 3 from Cyram Co. Ltd. and UCINET 6 from Analytical Technologies.

4 Results

4.1 The PRO-VE Conceptual System Evolution

From the terminological and conceptual analysis described in the previous section resulted the top-10 and top-20 rankings of concepts for each of the PRO-VE proceedings. An extract of them is shown in figure 2. In the top-10 ranking, 43 distinct concepts were identified.

concepts 2009	c-value	concepts 2010	c-value	concepts 2011	c-value	concepts 2012	c-value
virtual breeding environment	484,5	collaborative network	586,8	virtual organization	430,1	collaborative network	426,6
collaborative network	340,1	virtual breeding environment	303,5	collaborative network	404,3	virtual breeding environment	310,6
virtual organization	336,1	virtual organization	256,3	social capital	184,5	virtual enterprise	245,9
virtual enterprise	268,8	supply chain	236,0	virtual breeding environment	175,8	business process	157,1
senior professional	175,3	business process	180,9	business process	133,3	business model	104,3
supply chain	173,3	supply network	89,2	supply chain	108,4	virtual organization	95,3
social network	101,7	information system	87,6	social network	87,1	cloud computing	76,3
business process	97,6	senior professional	76,0	virtual enterprise	84,3	supply chain	70,2
project management	76,6	collaborative network member	75,9	supply network	64,8	service composition	67,6
virtual community	57,3	collaborative process	72,5	collaborative network member	55,7	collaborative system	54,0
knowledge management	56,8	business model	72,3	process model	54,3	process model	47,0
collaborative process	56,6	service provider	67,9	performance management	53,6	information system	45,7
reference model	55,9	virtual enterprise	65,5	performance measurement	52,6	service dominant strategy	45,5
business model	53,6	business service	64,8	business opportunity	52,0	collaborative process	45,4
web service	52,7	performance measurement	63,1	collaborative relationship	42,0	service provider	43,9
virtual team	50,6	network member	60,3	network member	41,1	collaborative relationship	43,0
epal environment	50,0	social capital	57,3	collaborative networks	39,8	reference model	42,0
VBE member	47,0	business opportunity	53,6	knowledge management	39,2	VBE ontology	41,8
innovation process	44,0	reference model	52,5	maturity model	38,1	software service	40,7
information system	43,9	security awareness	51,2	open supply web	35,5	business case	38,1
295000		290000		199000		215000	

Fig. 2. Extract of the rankings of concepts for each PRO-VE proceeding

Analysing the rankings for the whole existence of PRO-VE, it is possible to extract a conceptual core i.e., the *foundational concepts* of PRO-VE defined as the maximal sets of concepts that span a maximum number of years. The results are the following:

$C_{max1} = \{virtual\ organization, virtual\ enterprise, business\ process, supply\ chain\}$ (span: 14 years)

$C_{max2} = \{collaborative\ network\}$ (span: 11 years)

$C_{max3} = \{virtual\ breeding\ environment, business\ model\}$ (span: 10 years)

The foundational concepts represent approximately 16% of the total distinct top 10 concepts. We call *contingent concepts* to the concepts that were included in the top-10 ranking for at most 2 consecutive years and then disappeared. These concepts are likely to appear and disappear due to combinations of factors such as the "fashionable" research topics and technologies, major on-going projects or even the suggested topics from the “Call for Papers”. The contingent category represents 43% of the total. A third class of concepts are those who are neither foundational nor contingent. We call these *regular concepts*. These are:

C_{reg}={*knowledge management, information system, business opportunity, virtual team, virtual community, web service, VBE member, VO creation, social capital, social network, CN member, VBE member, VE member, collaborative process, supply network, service design*}

Within the foundational concepts, it is interesting to analyse the case of *collaborative network*. This concept is mentioned for the first time in 2000 by Devine and Filos and more consequently used in 2002 by de Joode. In 2003 papers referring to this concept continued to grow and finally in 2004 *collaborative network* was definitely consolidated (top-10). From 2005 on, the *collaborative network* concept acquired a status of the most important concept within the PRO-VE community by being proposed to name a new scientific discipline [2]. Another interesting result comes from looking at the average of the C-values for each of the core concepts (see figure 3). *Virtual Breeding Environment* has the highest C-value average which is indicative of the importance of this concept within PRO-VE. Figure 3 represent the PRO-VE conceptual core together with a set of relationships between concepts. These relationships were established by the three specialists after debate. Of course this is just a possible set. Other specialists could come out with a different set. It would be not odd to look at this concept map as an upper-level ontology of PRO-VE.

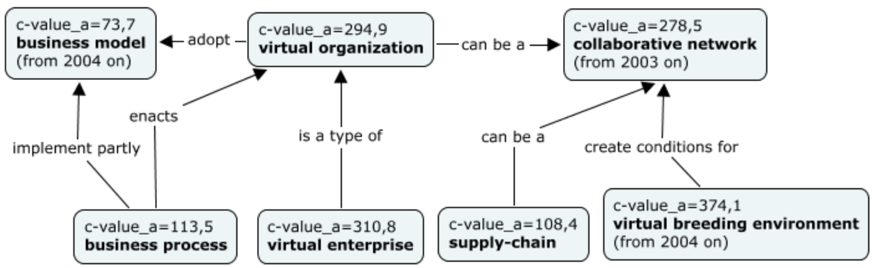

Fig. 3. A possible upper-level ontology created from the PRO-VE foundational concepts (c_value_a=average C-value)

4.2 The PRO-VE Socio-Semantic Network Evolution

As mentioned in the previous section a sample of four years was selected to analyse the PRO-VE socio-semantic network: 1999, 2005, 2009 and 2013. For each of these years the *k-core* and the *core-periphery* analysis were run respectively on the actors-by-concepts and actors-by-actors data sets. *Degree centrality* was calculated for the 1-mode networks (authors-by-authors and concepts-by-concepts) generated from the 2-mode one. Figure 4 shows a spring-like representation of the socio-semantic network. We can qualitatively observe which concepts are more used and, conversely, which authors use more concepts. The representation of the network follows an algorithm that group spatially the nodes having more connections. This can be also observed by looking at the size of the nodes which is proportional to the degree centrality of the actor or concept.

An extract of the degree centrality values for the first five authors and concepts is shown in table 2. This representation enables a qualitative appreciation of the socio-semantic network. Using simultaneously the scores of degree centrality both for the authors and the concepts, a more detailed assessment can be made. The centrality of some authors and some concepts is immediately evident. Although not shown in the network representation, each edge linking an author to a concept is weighted. This explains for example the relatively high degree of the concept near the top left corner (actually *senior professional*) even if it has fewer authors talking about it than the concepts more centrally located. This can for example indicate a couple of papers intensively referring the concept. As defined above, a *k-core* is a maximal group of actors, all of whom are connected to some number (k) of other members of the group. The k-core algorithm was applied successively to the 1-mode bipartite matrix of each year. We selected the highest k from each year resulting in the groups represented in the next table. The k-core algorithm tries to find the maximum k for which there is a maximal group of authors connected to k concepts and vice-versa.

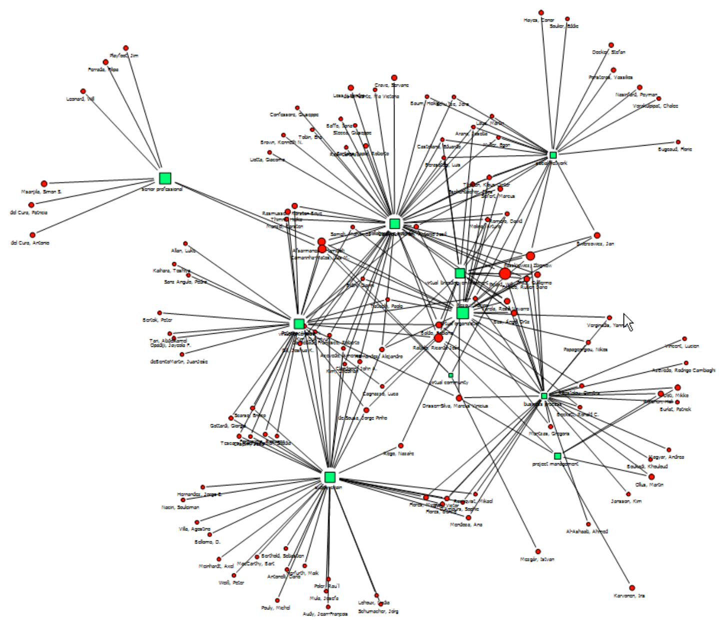

Fig. 4. PRO-VE 2009 socio-semantic network (node size~degree centrality)

Table 1. The five highest scores of the degree centrality for each year (NetMiner)

Year	Rank	Authors	Degree	Concepts	Degree
1999	1	H. Afsarmanesh	432,000000	virtual enterprise	1.071,000000
	2	L. M. Camarinha-Matos	421,000000	information management	303,000000
	3	C. Garita	171,000000	business process	244,000000
	4	Y. Ugur	162,000000	virtual organization	221,000000
	5	L.O. Hertzberger	154,000000	virtual enterprise coordinator	215,000000
2005	1	Hamideh Afsarmanesh	593,000000	virtual organization	2.641,000000
	2	Luis M. Camarinha-Matos	400,000000	virtual breeding environment	786,000000
	3	Martin Ollus	375,000000	collaborative network	694,000000
	4	lire Salkari	151,000000	virtual enterprise	566,000000
	5	Iris Karvonen	151,000000	business process	453,000000
2009	1	Picard, Willy	323,000000	virtual organization	2.641,000000
	2	Paszkiewicz, Zbigniew	209,000000	virtual breeding environment	786,000000
	3	Rabelo, Ricardo José	197,000000	collaborative network	694,000000
	4	Camarinha-Matos, Luis M.	185,000000	virtual enterprise	566,000000
	5	Afsarmanesh, Hamideh	173,000000	business process	453,000000
2013	1	Luis M. Camarinha-Matos	219,000000	virtual organization	992,000000
	2	Fábio Müller Guerrini	130,000000	collaborative network	952,000000
	3	Filipa Ferrada	118,000000	business process	493,000000
	4	Ana Inês Oliveira	118,000000	virtual breeding environment	414,000000
	5	Ricardo J. Rabelo	117,000000	process model	342,000000

The results (see table 3) suggest that in PRO-VE 2005 there was a relatively big group of authors addressing 4 concepts and also a relatively big group of concepts addressed by 4 authors. The other years, regardless the value of k, this group is quite small. Table gives an idea of the connectedness of the 5-core and 3-core groups for 2013. A categorical core-periphery model enables to subdivide the authors-by-authors 1-mode network in two groups of authors: one exhibiting a very strong resemblance in the concepts and number of concepts addressed (the “core”), and other with very few communalities (the “periphery”).

Table 4 shows the evolution of the “cores” for the four years in analysis. Each “core” of authors has an high density of ties among themselves because they addressed many concepts in common. We can observe a small “core” in 1999 and “cores” with almost the double of members in 2009 and 2013.

Table 2. k-core results for the maximum k in each year (concepts in bold) (NetMiner)

1999	2005	2009	2013
5-core	**4-core**	**4-core**	**5-core**
A. Frenkel	Ana Ines Oliveira	Bas, Ángel Ortiz	Américo Azevedo
Alexandra Augusta Pereira Klen	Arturo Molina	Franco, Ruben Dafıo	Andrea Zangiacomi
C. Garita	Falk Graser	Paszkiewicz, Zbigniew	Eva Coscia
C. P. Lima	Hamideh Afsarmanesh	Picard, Willy	João Bastos
H. Afsarmanesh	Ingo Westphal	Prats, Guillermo	Rosanna Fornasiero
L. M. Camarinha-Matos	Iris Karvonen	Varela, Rosa Navarro	**collaborative network**
L.O. Hertzberger	Ivan Silveri	**virtual breeding environment**	**virtual organization**
Luiz Marcio Spinosa	Jens Eschenbacher	**collaborative network**	**business process**
Ricardo. J. Rabelo	Kim Jansson	**virtual organization**	**business model**
V. Santos Silva	Iire Salkari	**business process**	**supply chain**
Y. Ugur	Luis M. Camarinha-Matos		
virtual enterprise	Martin Ollus		
business process	Nathalie Galeano		
virtual enterprise member	Toni Jarimo		
virtual enterprise coordinator	Ugo Negretto		
virtual enterprise environment	Urho Pulkkinen		
information management	**virtual organization**		
	virtual breeding environment		
	collaborative network		
	virtual enterprise		
	supply chain		
	virtual breeding environment member		
	virtual organization creation		
	virtual organization management		

Table 3. Categorial "cores" resulting from the core-periphery analysis of the authors-by-authors network

1999	2005	2009	2013
A. Frenkel	Arturo Molina	Ruben Dario Franco	Peter Weiss
L. M. Camarinha-Matos	David Guerra	Angel Ortiz Bas	Simon Biggs
L.O. Hertzberger	Nathalie Galeano	Jan Swierzowicz	Adriano Fiorese
H. Afsarmanesh	Iris Karvonen	Fabiano Baldo	Fabio Miller Guerrini
C. Garita	Iire Salkari	Ricardo Jose Rabelo	Filipa Ferrada
Y. Ugur	Martin Ollus	Rosa Navarro Varela	Lorenzo Tiacci
	Hamideh Afsarmanesh	Zbigniew Paszkiewicz	Reza Vatankhah Barenji
	Luis M. Camarinha-Matos	Willy Picard	Mohammad Safahi
	Ricardo Camacho	Guillermo Prats	Ana Ines Oliveira
		Luis M. Camarinha-Matos	Olaolu Sofela
		Simon S.Msanjila	Angelita Segoria Gasparotto

5 Discussion

We will discuss now the results presented in the previous section, using for that the hypothesis formulated in section 3.

H1.1. There is a core set of concepts used in all the editions of the conference

This hypothesis is confirmed as we identified, through the longitudinal terminological and conceptual analysis, a common set of concepts present in the top-10 ranking. These are the *foundational concepts* of the PRO-VE research community. The degree centrality measure of the concepts and the concepts returned by the k-core analysis seems to further confirm the hypothesis.

H1.2. The variability of the concepts not in the core is high;

Approximately 53% of the concepts in the top 10 are contingent, meaning that they are addressed in at most two consecutive editions of the conference. This suggests an high variability of the non foundational concepts. However, if we take the top 20, the variability ceases to be high as very few concepts entered anew for the top 20 each year.

H2.1. A core set of concepts is shared by the majority of the researchers

The results from the k-core analysis seem to suggest the contrary. Neither the foundational concepts all appear in the k-core nor the group of authors in the core is the majority. Even if we consider a lower k this is nor confirmed. For example, in 2009, the 2-core — the set of authors using two concepts — includes only 57% of that year's proceedings. This way, we cannot talk about epistemic communities, as defined by [1], within the PRO-VE community. To be considered an epistemic community, a group of authors should all share all the concepts in a given set.

H2.2. There are groups of researchers that are likely to influence the adoption of new concepts.

Although this is perceived empirically, it doesn't follow from the results of our study. From the degree centrality measures, the authors Camarinha-Matos and Afsarmanesh are likely to be the main influencers, given their centrality in the network. However, this is not confirmed neither the k-cores nor in the core-periphery analysis.

The conceptual system of PRO-VE evolved, but not as much as we expected. There is a core set of seven concepts in the top 10, which makes the concepts used in the majority of the papers very stable: the last foundational concepts appearing by the first time in the top 10 backs to 2004. On the contrary, the groups of authors sharing more concepts is not very stable throughout the years, as can be observed in the results of the k-cores and core-periphery analysis. On the other side, the more central actors are also more stable. The limitations of this study lie mainly in using a derived social network. In fact, it is formed by linking the authors that co-use of the same concepts in their papers. This prevents an orthogonal analysis between the social network and the semantic network (conceptual system).

6 Conclusions

It was a long way for the PRO-VE community since the dominance of the concept *virtual enterprise* in 1999 to the relevance and centrality of *collaborative network* in 2013. It was also a long way from 1999 where Camarinha-Matos and Afsarmanesh had a degree centrality more that the double of any other to 2013 where the centrality is more distributed between the more central researchers.

In spite of this evolution, it is our opinion that the evolution of the PRO-VE socio-semantic network is not enough to produce a more visible evolution in the knowledge communicated in the PRO-VE conferences. Apparently, the newcomers largely reproduce the "official" conceptual system (*foundational concepts*).

This study can be greatly improved, opening new possibilities for research. The more important improvement is to develop the social network model in order to include a temporal dimension. Besides building the usual co-authoring network for each year, the dynamics of this network could be captured by creating a cumulative function in the form $N_{ca}(t_k) = f(N_{ca}(t_{k-1}))$, where $N_{ca}(t)$ is a co-authorship network in the year t. This would provide a more detailed ways to analyse the evolution of the PRO-VE socio-semantic-network.

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Combining Collaborative Networks and Knowledge Management: The SENAI Case

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Abstract. This work describes a practical case combining collaborative networks and knowledge management, at SENAI environment. SENAI was founded in 1942 to support the Brazilian industry through professional and technological education, and services. In 2011 SENAI started implementing a national program targeting the industrial competitiveness all over the country. Such an ambitious program relies upon several key elements and this work is focused on the most strategic one: culture. Logically such a challenge requires the combined effort of many actors and instruments as well. Those reported in this work are collaborative (technical) networks and knowledge management. On the one hand, the framework adopted to support the development of such networks is presented. On the other hand, knowledge management concepts and mechanisms were introduced in the scenario aiming at improving and catalyzing the results achieved by those networks.

Keywords: Collaborative networks, Knowledge Management, Cultural barriers.

1 Introduction

The global context of economic crisis brings opportunities and concerns for the Brazilian industry, sensitive to the business cycle and international competition. In order to stand out in this scenario of changes, the industry needs a more efficient and effective production, where technological innovation is a permanent asset required in all fronts.

One of the strategies that organizations are adopting to face these challenges is to change their relationship with customers, suppliers and even competitors, to work collaboratively on networks [1]. The survival of an organization has become a competition for participation in the emerging opportunities and not for market share

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 664–672, 2014.

[2]. One way to prepare a competitive organization is through the development of competences differentiated from others. In collaborative network, an organization must have a differential that enables the complementation with other organizations in the work development.

The Brazilian National Service for Industrial Apprenticeship (SENAI) was created to serve the industry. In 2011, was developed the SENAI Support program for industrial competitiveness, to promote professional and technological education, innovation and technology transfer to make the Brazilian industries more competitive. SENAI has a physical structure in all Brazilian States, those structures were created over 70 years. In each state, SENAI has autonomy to meet the demands of local industry. The present work starts changing the culture of collaborative work, understanding that SENAI developed competences that can be leveraged working on technical networks. Therefore to enable the SENAI Support program for industrial competitiveness the new collaborative network culture becomes strategic.

For historical reasons, after 70 years essentially targeting "professional education" in an autonomous way (i.e., SENAI representations at each state work in an isolated way), a deeply rooted culture on this matter was built. Nowadays, Brazilian industry is also asking from SENAI the right support to jump into the innovation arena through a huge innovation program covering the whole country, involving more than a hundred of institutes providing innovation and technological services to the national industry. In this context, many challenges were naturally raised and this work points out some issues and possible solutions to overcome them. Two well-known institutions are SENAI partners in this quest: Fraunhofer (through the *Institut für Produktionsanlagen und Konstruktionstechnik* – IPK and other institutes) and Massachusetts Institute of Technology – MIT (through the Industrial Performance Center – IPC).

This paper describes the design and implementation of collaborative work in SENAI technical networks, introducing the framework developed and its deployment strategy, especially focusing on the cultural-related matters. Additionally, the work carried out in the innovation program, where Knowledge Management plays a role, is also discussed here, again focusing on cultural matters. Fraunhofer and IPC roles are also presented and future of the innovation program is shortly discussed.

2 About SENAI

By the end of 2012, Brazil was ranked as the sixth top world economy. In a country where 80% of the population lives in urban areas, the industry is absolutely the strategic vector of development. Brazilian industry answers for 27% of total salaries and employs one out of each four Brazilians registered in the employment booklet. It represents about 70% of the exports and 22% of the Gross Domestic Product.

Under that perspective, SENAI targets professional education for the industrial sector, also helping to reduce both economic and social differences. In an increasingly more competitive and demanding market, programs for management improvement, productivity increase and creation of social-environmental responsibility culture become essential to best qualify workers and companies.

SENAI is one of the five largest professional education organization in the world, the largest in Latin America. Since its foundation, in 1942, it has already graduated more than 52 million students. Last year, SENAI received nearly 2.7 million people. All across the country, its courses train professionals required for the development of 28 areas of the Brazilian industry, including young apprentices, qualified technicians, technologists and specialized professionals.

SENAI has over 800 education centers throughout Brazil, including vocational education centers, training centers, technology centers and mobile training units. Along its over 70 years of history, SENAI has provided attendance to thousands of Brazilian enterprises.

The SENAI Support program for industrial competitiveness was conceived based on two main pillars, namely education and support in technical and technological areas. Whilst the former aims to surpass four million enrollments in 2014, the latter aims to create 25 SENAI Institutes of Innovation and 62 SENAI Institutes of Technology. However, in order to meet those challenging goals is mandatory to develop a new culture of collaborative work among the whole SENAI universe.

3 Framework Supporting Instantiation of SENAI Technical Networks

In order to start leveraging a culture of collaborative work SENAI developed a framework based on the AmbianCE model proposed by Vallejos et al. [3, 4]. This framework is based on three steps (Figure 1), namely:

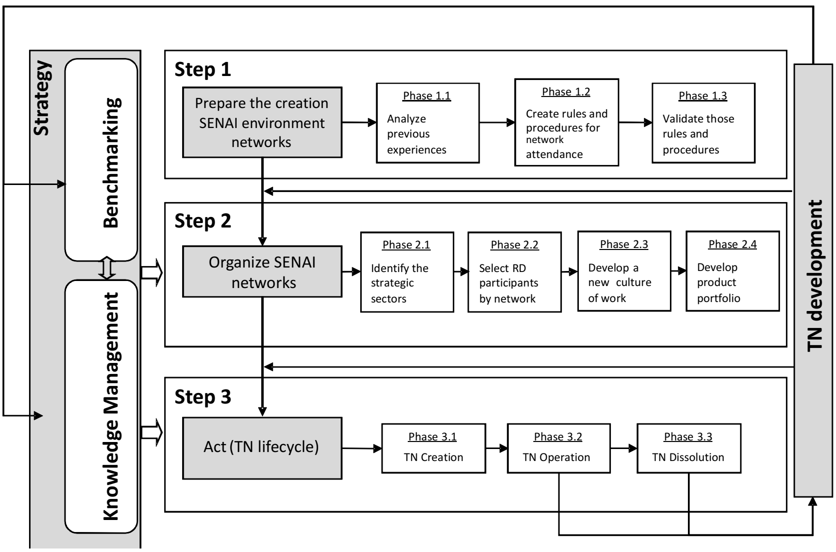

Fig. 1. Framework for the SENAI Networking

- *Step 1*: Prepare the creation of SENAI environment networks. This step is divided in three following phases: analysis of previous experiences on successful networking, creation of rules and procedures for network attendance, and validation those rules and procedures.
- *Step 2*: Organize SENAI networks. Covers: the identification of the strategic sectors to form SENAI networks, selection of Regional Departments (Brazilian States) that will take part of each network, development of the roots to promote the collaborative work culture, and development of portfolio of products for each network considering its competences.
- *Step 3*: Act (technical network lifecycle). Organized into four phases [5, 6], namely: technical network (TN) creation, TN operation, TN development, and TN dissolution.

A strategy to deploy this framework in SENAI networks will use Knowledge Management supported by a system of benchmarking, developed by Vallejos et al. [4].

Figure 2 presents a scheme where the SENAI units interact to attend a business opportunity through technical networks. The figure represents a network attendance 1 (NA1) being coordinated by the Ceará Regional Department (Ceará RD) and having as collaborators RDs of other states such as Rio de Janeiro, Santa Catarina, and Minas Gerais. At the same time a network attendance 2 is settled (NA2) being coordinated by Minas Gerais RD with the collaboration of other RDs.

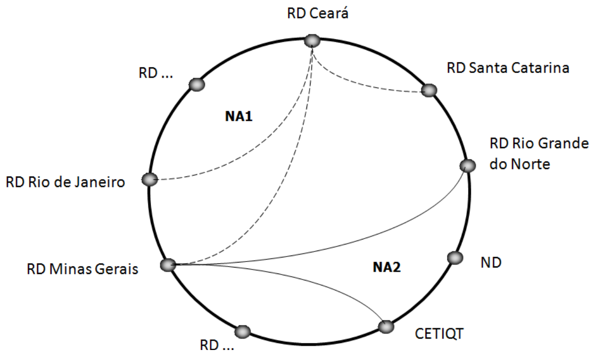

Fig. 2. SENAI technical networks attendance schema

The technical network has to be very dynamic and flexible, based on two “ifs”: if responsibilities of all members are clearly defined, and if rules and procedures are established with the agreement of all participants. This necessarily involves the narrowing of the relationship and the development of trust among the members of the network. Developing trust is necessary to recognize and develop the competences of those involved in the network. Soon, it may be stated that in order to form a network it is necessary to change the culture of labor relations referring to the notions of competences, trust, and collaboration.

The change of basic concepts like culture, competences, trust and collaboration, also represents an opportunity for the institution to reorganize a powerful set of procedures and indicators, in order to encourage networking work, thus enabling a more agile performance.

4 Creating, Deploying, and Operating SENAI Technical Networks

The creation and deployment of SENAI technical networks is based on the following phases:

- Creating a network. In order to create a technical network, SENAI ND considers: a) the demand of an industrial sector; b) establishment through National strategic planning; c) RDs proposition; and d) National Network Market proposition. Any technical network must involve six to nine RDs, promoting the new culture of collaborative work and conducting pilot projects (business focused).
- Organize a network: once the network starts producing good results, it can be extended to include six to nine DRs who already have maturity in the technical area. This is the consolidation phase of the network and its development should brings the guarantee that there is a new job culture in the whole system SENAI being put in place.
- Expansion of a network: the initiative to participate in the expansion of the network will be up to DRs who show interest, following the requirements and skills necessary for election. It is desirable to open it to all DRs in the latter stage, because we firmly believe that there is a potential market in attendance through network all over the country.

Once a technical network was created and organized it is necessary to internalize the operational procedures. The success of a technical network is based on the ability to create and establish temporary cooperation among RDs to answer business opportunities.

Technical networks target the search for supplement of internal competences offered by SENAI in education, technology, and innovation, in order to answer to industries needs in effective form. The technical network attendance life cycle covers the following:

- **Creation:** is the phase in which the technical network attendance is configured to better attend that industry necessity. In this phase the business opportunity is detected and the interlocutors are responsible for defining which RD will be Technical Coordinator and which RD or RDs will be Operators.
- **Operation and Evolution:** phase in which the technical network is performed based on the work plan agreed between the stakeholders, with systematic monitoring, ownership of results and records of occurrences, based on the rules and practices of project management. When problems occurs during the operation phase and is necessary to restructure the team or

process planed, the Evolution phase is executed. In the Evolution phase is possible to incorporate other RD or stakeholder during the Operation phase.

- **Dissolution:** phase in which, after product delivery and acceptance by the customer, gains and losses generated by the technical network are distributed. The gains may be tangible (e.g. financial, equipment, laboratories) or intangible (e.g. information, knowledge, patents, methods).

5 Validation of Framework for SENAI Technical Networks

In order to validate the framework, governance, policies and procedures of SENAI technical networks, the strategy was to create a new technical network: the textiles network. This sector is priority because is suffering a fierce competition and is one of the main financial contributors to SENAI. Six RDs were selected considering: expertise and experience in work development within local companies in the textile area, and the local market in that RD.

Each RD pointed a technical interlocutor and a market relationship person. After that, meetings and activities to develop the new culture of work were performed, considering: the culture of competence (all RDs recognized the competences of each RD involved), the culture of trust (better knowing and understanding each representative/RD involved) and the culture of collaboration were set (developing network attendances NAs). These meetings and activities were held in different RDs.

Together with this group, rules and procedures for technical networks were developed. These rules and procedures were evaluated in some pilots by the textiles network.

These rules and procedures were assessed by the following people before they were accepted for the whole SENAI system: a) SENAI ND networks coordinators; b) regional directors from 6 RDs involved in textiles network; and c) regional directors of all the whole SENAI system.

6 Knowledge Management Facilitators and Policies into the SENAI System

In parallel to the work conducted over the technical networks, SENAI has launched a huge initiative in order to build (in all senses of the word) a network of innovation institutes across the country (25 of them have been planned so far, including embedded systems, mineral technology, electrochemistry, etc.) knowing in advance that SENAI institutes must be free to collaborate among themselves according to the business opportunities. As part of this work and in perfect harmony with the technical networks (now these networks involve not only RDs but also innovation institutes), an ongoing work focused on the use of Knowledge Management (KM) concepts and practices was started, in order to help creating a KM-oriented culture, a KM way of working, a KM environment. It is worth noticing that such a work was not targeting the development of “yet another KM tool”; rather, the idea was to put technology as the last bit of the work and to consider it only (and if only) deemed really necessary.

Fig. 3. KM facilitators at SENAI system

KM group, responsible for the KM angle in the SENAI system, is working supported in two major vectors: facilitators and policies. Facilitators (figure 3) represent the elements that play a relevant role as part of the creation and dissemination of a KM-oriented culture.

Therefore, figure 3 must be read bottom-up, as follows:

- Organization is the basic foundation supporting the whole work. In this case, organization represents the SENAI high administration level, which in this case, is firmly committed to the whole project.
- Culture represents the required change towards a KM culture. Actors involved in all SENAI networks must be *educated* to work collaboratively in an environment where knowledge exchange is vital. This means they must get the appropriate help to: give value to the knowledge created, provide a permanent knowledge memory, share, transfer, and reuse knowledge.
- Rules & Guidelines can be defined by the organization in order to help creating and promoting the KM environment. Few examples of rules & guidelines are the following: promoting collaborative work, pushing the creation and transfer of knowledge, providing access to the knowledge sources spread across the country.
- Operation represents the modus operandi of every single member of SENAI networks. Here is the stage where knowledge really takes form and action, during the activities performed by all members of SENAI system. How knowledge is created, stored, shared, and reused is effectively considered as part of the operational sphere of SENAI networks.
- Technology, as previously stated, may play a role but never the central one. KM platforms, if required, are tools intended to facilitate the technical procedures guiding the daily work of SENAI members, targeting the creation and dissemination of a KM environment. KM tools may help acquiring, storing, sharing, and reusing of knowledge as part of the collaborative work conducted by SENAI technical networks. It is important to say that technology is 100% dependent of the other levels and not the contrary.

Regarding KM policies, they are needed to guide the following subjects: a) knowledge sharing among SENAI institutes (what are the knowledge sources to be shared, how they are shared,); b) incentives to collaboration (why institutes must collaborate, from all perspectives); c) management of knowledge sources (responsibilities about the knowledge sources, their availability, quality, etc.); and d) interoperation among institutes at a national level, knowing that for the first time in

SENAI history one entity from a given RD will be able to conduct business with clients from other RDs. These 4 subjects were chosen due to their strong influence on knowledge management practices. The competences (from institutions and people) are the target in collaborative projects. The exchange of knowledge relies on collaboration channels, which by SENAI very nature, must be strongly promoted. Knowledge sources are the currency supporting successful collaborative (and sometimes innovative) processes. Finally, historical paradigms of SENAI behavior must be broken in order to give rise to a new culture of work, which must be collaborative and based on knowledge exchange, essentially. The success of SENAI networks will strongly rely on them.

7 Conclusions

The global stage competitive imposes organizations to change the way of work with their customers, suppliers, and even competitors. One strategy that is being implemented by these organizations is to work collaboratively or in networks. SENAI was created to attend Brazilian industry and in this context developed, in 2011, the SENAI Support program for industrial competitiveness. In this program there are challenges for the vocational and technological education areas as in the innovation and transfer technology to make industries more competitive. One strategy to achieve this program is to develop a new collaborative work culture in the SENAI system, leveraging the competences that exist in the 27 different RDs.

At the same time, launching the national network of innovation institutes set the challenge to a more complex level. Collaboration is a must to provide the power to SENAI networks to effectively attend industry demands, on one hand and, on the other hand, knowledge-based culture must be put in place in order to create the assets to fully provide an innovation-oriented environment for the Brazilian industry. After all, industry required a very clear help: a network of innovation institutes capable to push our potential forward and really gives birth to a new (and innovative) industry. We believe that this work is one of the most important for the maintenance of the SENAI system providing effectively and efficiently the Brazilian industry.

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Forms of Collaboration in Collaborative Enterprises: An Ontological Model

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Abstract. Reasoning techniques and their relations to cognition and reality gained significant momentum fueled by the advent of complex information systems which rely on robust and coherent, formal representations of their subject matter. In this sense, ontologies can provide models of different aspects of a business entity contributing to intra- and inter-enterprise information systems. This is particularly relevant for collaborative enterprises, which are entities far more complex than single enterprises. In particular, for the governance of collaborative enterprises it is essential to determine the relevant KPIs for the type of collaborative enterprise, taking into account several characteristics such as lifecycle and size. The main objective of this work is to develop an ontology of collaborative enterprises which enables the semi-automatic classification of instances. To this aim, we take into account the type of collaborative enterprise, its maturity (i.e., the lifecycle phase), size, territorial extension and other characteristics.

Keywords: Collaborative Enterprises, Ontologies, Enterprise Modeling, Business Rule.

1 Introduction

The transition from intra-organizational to inter-organizational relationships characterized the last twenty years of the evolution of enterprises. More recently the increasing importance of Collaborative Enterprises (CEs) and the growing impact of technologies on businesses drove the transition towards a new phase of trans-organizational relationship, characterized by an increased speed to create value [1, 2]. Indeed, CEs, defined as "*a number of autonomous organizations working together* […] *for mutual benefit*" [3], are often used as catalysts of competitive advantages.

However, it is known that globally 50%-70% of CEs fails, often due to the lack of a comprehensive analysis that combine strategic goals and KPIs [4, 5] with a possible negative impact on component firms. Indeed, CEs are heterogeneous clusters of partnerships among enterprises. CEs can be of different types (e.g., horizontal or vertical) and have different goals; therefore, they need for different KPIs [6]. In other words, firms and CEs have to understand which KPIs are relevant and what a KPI means in a

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 673–680, 2014.

given CE with defined set of goals. However, this kind of understanding is not immediate, especially in several SMEs, which lack of the know-how needed to perform this kind of analysis and often choose the more "known" KPI, instead of the more relevant, with possible negative effects on the CE equilibrium. In order to measure performance and to create governance tools for inter-organizational environments, it is essential to understand which KPIs are useful for which types of CE [7].

In this scenario, ontologies and reasoning techniques can help in the understanding of complex entities and in the development of specific Enterprise Information Systems for intra- and inter-organizational settings. By committing to the same ontological specification, different applications share a common vocabulary with a formal language and clear semantics. Also, by representing knowledge with a well-established formalism [8], internal consistency and compliance checking can be performed in order to determine content adequacy. The main objective of this work is to develop an ontology of CEs, starting from the taxonomy of Collaborative Networks (CNs) developed by [9], and to infer knowledge from a domain body. To this aim, we take into account the type of a CE, its maturity (i.e., the lifecycle phase), size and other characteristics. The work is structured as follows. In Section 2 we analyze related works on enterprise modeling. Section 3 is for the modeling methods and Section 4 for the representation of the ontology and the analysis of the case study. Finally, in Section 6 we discuss the ontology and draw conclusions.

2 Related Works

Ontologies can be very effective to represent shared conceptualizations of specific domains [10]. To this aim, ontologies can be useful, since they can be seen as repositories of concepts, intended as complex information structures tightly interconnected with each other, on which reasoning functionalities can be applied.

An ontology for CNs has been proposed in [11], where the organizational structure and the domain specific knowledge of Virtual Breeding Environments (VBEs) are represented. In particular, each VBE has some assets and have some participants. Each VBE participant has a VBE Role and to each role some tasks are associated. Also, a VBE has some business opportunities related to the development and commercialization of products and services. VBEs are defined as organizations, to which are connected competencies and processes. In turn, each Process uses some resources and produce or use as inputs other products and services. Although this ontology provides a general representation of CNOs and VBEs, it is possible to analyze the roles of participants but not to understand CEs types, since the ontology is focused on VBE. Therefore, the ontology is unable to provide a more comprehensive classification of CESs. The same considerations apply to the ontology for VBE capabilities and profiles [12]. Moreover, in [9], a taxonomy of Collaborative Networks (CNs) is provided. The authors start from a definition of CNs in order to classify 26 types of CNs, among which digital ecosystems. Although the study is quite interesting and takes into account criteria such as the time perspective, the analysis should be broadened. Also, the lack of a formal language doesn't allow the semi-automatic classification of instances (CEs). In [13] the IDEON ontology is proposed in order to support the design and the management of collaborative and distributed enterprises. To this aim, the authors take into account four views of the collaboration, namely, a) Enterprise Context View; b) Enterprise Organizational View; c) Process View; and d) Resource/Product View. Finally, in [14] a model for supply chain is presented with the aim of enabling the semantic integration of Information Systems. In order to do so, some basic concepts, such as the supply chain structure (SC_Structure), the participants (Party), their roles (Role), the purpose of the alliance (Purpose), the Activity, the Resource, the Performance and the Performance_Metric. However, not even in these two cases there is a classification of the types of CEs, although the basic concepts used in these ontology can be borrowed

3 Motivation and Requirements

This works is part of a wider project regarding performance measurement in CEs. This is a non-trivial task, which has not yet been addressed by current literature [15, 16]. In this context of high-complexity, enterprise modeling techniques can be helpful [17]. In more detail, in our proposal, the performance measurement is based on the definition of domain-specific KPIs with the aim of supporting the management of CEs. Domain-specific KPIs are derived starting from the analysis of the CEs and of the participants' goals and form the type of CE. Indeed, there are several kinds of CEs, which need different KPIs [3]. Therefore, it is particularly relevant to classify CEs in order to identify the peculiarities of each type and, consequently, to offer specific support for the measurement of performance. Using this scenario as a starting point, a set of competencies questions, subdivided in simple (SCQ) and complex (CCQ), were elicited. As an example, we provide the following:

[SCQ.1] which types of alliances are possible?
[SCQ.2] what characteristics should a CE satisfy in order to be a strategic horizontal alliance?
[SCQ.3] which organizational structures are possible?
[CCQ.1] how many firms should a CE be composed of, to have a dyadic structure?
[CCQ.2] what is the size of a collaborative enterprise with more than 10 firms?
[CCQ.3] what type of CE is the one that has a time perspective of more than 3 years and a vertical integration?

4 Modeling Methods

When dealing with ontologies, the first trade-off to be taken into account is between their level of semantic description and their level of decidability (i.e., the capability of specific software applications, the reasoners, to produce new knowledge by inferencing over the explicitly defined semantic relationships). Different ontology languages and flavors are available so that the modeler can tune its knowledge base properly. For such reasons we selected the OWL 2 DL language [18] since it is fully decidable.

In addition, OWL DL can be combined with SWRL, a language for the Semantic Web used to express rules as well as logic.

Moreover, knowledge resources can be represented as classes or instances depending on specific modeling requirements. We adopted a class-based approach to model the CE macro types and their characteristics, while we used business rules based on SWRL in order to infer the CE macro-types from the association of an instance of the class CE with some characteristics. In this way, end-users can easily populate the ontology by adding instances to CE classes, which inherit the semantic structure associated to the CE class they belong to. The ontology library named *"CE Ontology"* was developed with a modular architecture, as modularity is advantageous in terms of portability and reuse, domain decomposition and content categorization [19]. We modeled a core ontology (`ontoPM`) and a set of domain-dependent modules, namely `ontoKPI` for Key Performance Indicators, `ontoFirm` and `ontoCE`, which gather concepts describing firms and CEs respectively. The adoption of core and domain ontologies is a well-established custom in ontological engineering [20, 21]. CE ontology was developed by using the Protégé Desktop editor (v.4.3) [22], the de-facto freeware open-source ontology modeling tool. Ontology consistency, class expression satisfiability and finite reasoning time complexity were checked by using Pellet reasoner 2.2.0 [23]. The DL expressivity of the ontology is SHROIQ(D).

5 Collaborative Enterprise Ontology

This section provides some ontology fragments exemplifying our modeling approach.

The first excerpt illustrates `CollaborativeEnterprise`, the class describing a CE, its subclasses and associations with other classes. As depicted in Fig. 1, each CE has a `CELifecyclePhase`, an `OrganizationalStructure` and a `Size` (`small`, `medium`, `large`). This is codified by using existential (`owl:someValuesFrom`) or universal property restrictions (`owl:allValuesFrom`). Also, each CE is composed by at least 2 firms, which is codified with `owl:ObjectMinCardinality` and it has `Relation` and `Alliance` as subclasses. In turn, `Alliance` has an object property based semantic characterization, involving `integrationLevel` (`low`, `medium`, `high`), `timeHorizon` (`shortTerm`, `mediumTerm`, `longTerm`) and `integrationType` (`horizontalIntergration` or `verticalIntergration`. Finally, `Alliance` have as subclasses `StrategicAlliance` and `TacticAlliance`.

As show in Fig 2, the CE classification based on size, time horizon, type (strategic or tactic, horizontal or vertical) and organizational structure is performed with reasoning support [24], which enables to infer new knowledge from the original domain body. To do so, we used functional dependencies, represented by means of business rules, coded with Semantic Web Rule Language (SWRL) [25]. In particular, in order to determine the size of a CE, we use the datatype property `hasNumberOfFirms` and we define the following rule: `CollaborativeEnterprise(?x), hasNumberOfFirms(?x, ?integer), greaterThan(?integer, 4), lessThanOrEqual(?integer, 10) -> hasSize(?x, Medium)`. In this way, we assert that if a CE has a number of firms greater than 4 but less or equal to 10, then it has a medium size. Similar rules have been used in order to define the small and the large size. The `timeHorizon` has been determined by means of the datatype property `hasTimePerspective` and of the following rule: `Alliance(?x), hasTimePerspective(?x, ?integer), greaterThan(?integer, 3) -> hasTimeHorizon(?x, longTerm)`. Through this rule we assert that if an alliance has a time perspective greater than 3 years, then it has a long term horizon.

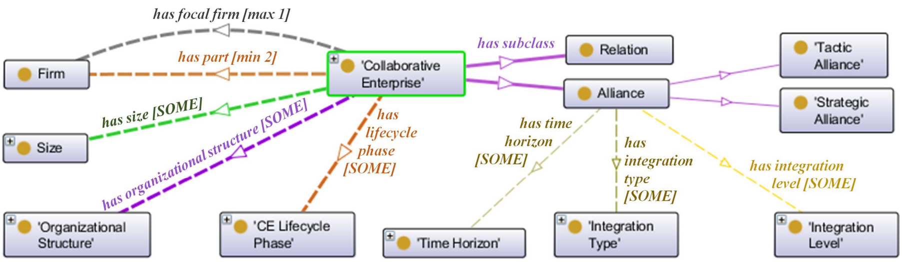

Fig. 1. Representation of a fragment of the ontology

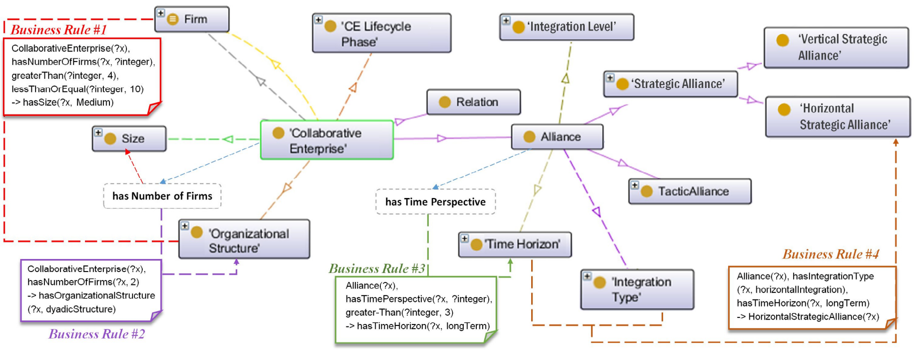

Fig. 2. Representation of the business rules

Moreover, the alliance type is defined by means of a business rule that takes into account the integration type and the time horizon. The last one is useful in order to distinguish between strategic alliances (medium and long term) and tactic alliances (short term), while the integration type helps in order to divide horizontal alliances from vertical ones. In more detail, with the rule "`Alliance(?x), hasIntegrationType(?x, horizontalIntegration), hasTimeHorizon(?x, longTerm) -> HorizontalStrategicAlliance(?x)`" we assert that if an alliance has a horizontal integration as well as a long-term time horizon, then it can be considered a horizontal strategic alliance. Also, the classification based on the `organizationalStructure` is based on the number of firms, the participation of firms to the CE, the existence of a focal firm and the presence of other forms of organizational structure. In more detail, the following rule "`CollaborativeEnterprise(?x), hasNumberOfFirms(?x, 2) -> hasOrganizationalStructure(?x,` `dyadicStructure)`" asserts that if a CE is composed by exactly two firms, then it has a dyadic structure. Moreover, the rule "`CollaborativeEnterprise(?x), hasFocalFirm(?x, ?y), hasPart(?x, ?y), hasNumberOfFirms(?x, ?integer), greaterThan(?integer, 2) -> hasOrganizationalStructure(?x, organizationWithFocalFirm)`" asserts that if CE is composed by more than two firms, has a focal firm and this focal firm is part of the CE, then the CE has an `organizationalStructureWithFocalFirm`. Finally, the rule "`CollaborativeEnterprise(?x), hasNumberOfFirms(?x, ?integer), greaterThan(?integer, 2), DifferentFrom (?y, organizationWithFocalFirm) -> hasOrganizationalStructure(?x, organizationWithoutFocalFirm)`" asserts that if a CE is composed by more than two firms and it can't be associated with the class `organizationalStructureWithFocalFirm`, then it has an `organizationalStructureWithoutFocalFirm`. The clause `DifferentFrom` was used in association with an `owl:allDifferents` axiom declaration to assess that the individual `organizationalStructureWithFocalFirm` is different from `organizationalStructureWithoutFocalFirm`. That clause was chosen because SWRL does not support negation as a failure, being a monotonic language.

5.1 Validation

In order to assess the quality of the proposed ontology, a way to evaluate how accurate is the encoded knowledge is needed. As a consequence, competency questions (CQs) were introduced in Section 3 in order to model our knowledge base accordingly. The ontology should contain enough information to be able to answer to CQs and these aspects have to be checked during validation. The importance of CQs during the entire ontology development and validation process was highlighted by Presutti et al. in [26]. According to them, CQs must be formalized into queries that have to be run against the ontology, so that query outcomes must be compared with the expected results. However, translating CQs into formal queries is not a straightforward task [27], since many aspects should be taken into account: presence of rules, necessity of considering inferred knowledge, etc. Some alternatives are available and the user should select the most suitable one according to its application scenario. SPARQL (Simple Protocol and RDF Query Language) [28] has high expressivity and allows to query and manipulate any RDF graph but considering inferences can be troublesome (unless SPARQL 1.1 entailment regimes are used). DL Queries [29] are more suitable to OWL class expressions and allow to capture inferences but cannot manage SWRL rules. SPARQL-DL [30] combines the best features of SPARQL and DL Queries but it is not a W3C standard and its future is still not very clear. Finally, SQWRL [31] is a SWRL-based language capable of querying OWL ontologies thanks to an ad hoc library of SWRL built-ins. Therefore, we used SPARQL to check SCQs and SQWRL to ascertain that CCQs can be answered as well (see Section 3). For the sake of brevity, an example from each of the two approaches is reported. The SCQ.2 was associated with the features of a CE: it can be translated into the following SPARQL query:

```
SELECT DISTINCT ?p ?o
WHERE { ontoCE:CollaborativeEnterprise ?p ?o
MINUS {ontoCE:CollaborativeEnterprise a ?o } }
```

that searches for both predicates and objects of any triple having the CE class as subject domain. In the same way, CCQ.3 aimed at classifying a CE having a time perspective of more than 3 years and a vertical integration. It can be rendered in SQWRL as in the following:

```
CollaborativeEnterprise(?x),
hasIntegrationType(?x, verticalIntegration),
hasTimeHorizon(?x, ?integer), greaterThan(?integer, 3)
-> sqwrl:select(?x)
```

Where all the CEs satisfying the conditions mentioned above are enlisted.

By adopting this methodology, we managed to verify that all the CQs can be answered by selecting a proper querying approach

6 Discussion and Conclusions

In this work, we introduce a semantic model for a large class of Collaborative Networks (CNs) defined as Collaborative Enterprises (CEs), in order to enable their understanding and analysis. The emphasis of the paper is on structuring the characteristics of CEs with respect to size, integration type and level, time horizon and so on. The classification of the instances is achieved by means of business rules. The development of the Collaborative Enterprise ontology, supported with business rules, enable the semi-automatic classification of CEs, which, if associated with a KPI Ontology brings to the development of an interpretative framework able to support both CEs and firm managers to understand which KPIs to use and how to integrate them in a performance framework.

Future works will include the online publication of the ontology in order to make the collection generally accessible to the community of researchers and practitioners interested in performance indicator modeling. For the purpose of our research, the ontology will be completed with a set of suitable software components with the aim of supporting users to effectively build, analyze and manage CEs.

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Health and Care Networks

Ontology-Based Workflow Design for the Coordination of Homecare Interventions

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Abstract. ICT are recognized as key opportunity to improve healthcare practices ,in the homecare domain particularly in relation to care interventions. However, despite all the advances accomplished in this field, a problem of coordination and continuity of personalized care remains. Given these needs, workflow management systems appear to be an appropriate tool for supporting the communication between the different stakeholders involved in the homecare ecosystem. Nevertheless, the specific characteristics of homecare processes make the design of such workflows a real challenge. In order to help with the conception of these workflows, we propose in this paper an approach based on ontology matching between homecare domain models and semantic representation of Business Process Modeling Notations (BPMN). This approach leads to the design of custom workflow coordinated interventions for a given patient according to his profile.

Keywords: Collaborative process, Homecare processes, Personalization, Workflow, Ontology, Model-Driven Engineering.

1 Introduction

Homecare interventions are complex processes, which represents the chain of various activities achieved by several stakeholders trades (i.e., nurse, physician, professional caregivers, etc.) to follow patient's progression and needs at their homes. Interventions often represent collaborative or cooperative processes with strong human components involvement. Such processes are usually long termed, distributed among several participants and composed of heterogeneous elements with various levels of autonomy, but are subject to dynamic changes [1]. As outlined in several research works [1–3], the delivery of homecare interventions faces many challenges, mainly in terms of coordination and continuity of care. In both cases, the problem

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seems to be related to how care activities are distributed and managed among the different participants involved in such processes. As a result, there is a need to improve the efficiency of the way in which information is exchanged and shared among care providers. One approach to overcome these challenges is to employ workflow systems, which appear to be appropriate tools for supporting the communication and coordination between the different stakeholders through managing a sequence of care workflow (careflow) activities. Indeed, the role of a workflow management system could be to coordinate the work to be done by transmitting the necessary information and tasks among different stakeholders, according to patient's needs and roles of the participants. For example, sending information about patient conditions to the right participant in real-time or notifying when a planned care activity is actually performed (or canceled) by a specified nurse.

The design of such intervention workflows is facing hurdles due to the complex characteristics of homecare processes, and this issue represents the framework of our research work presented in this paper. We present a new approach to assist in the conception of workflows apt to dynamically improve the coordination in homecare. The remainder of the paper is structured as follows. In Section 2, we give in the next section an overview of the coordination concerns in homecare, show how workflows can be used to tackle these concerns and point out some challenges for their design. Based on the latter, in the third section, we focus our endeavor on the presentation of our proposed approach to facilitate the design of personalized workflows that can be enacted to improve the coordination of homecare interventions. Our main contribution concerning this approach is described in this section. In Section 4 we discuss related work. Finally, we provide concluding remarks and future outlook.

2 Workflows-Based Coordination Challenges for Homecare Interventions

Homecare interventions occur in a mobile and dynamic environment that is continuously evolving during its execution, as new stakeholders can be integrated while others may leave depending on the outcomes of successive actions. The set of relationships and dependencies across intervention episodes requires for actors to share knowledge, expertise and experiences. Accordingly, care coordination is an essential component for quality healthcare delivery. A purposely-broad definition of care coordination has been proposed by [4], as “The deliberate organization of patient care activities between two or more participants (including the patient) involved in a patient’s care to facilitate the appropriate delivery of health care services”. The focus is on organizing care by systemizing personnel and other resources needed to carry out required patient activities through managing the exchange of carried interventions among the different actors responsible for the diverse aspects of care.

Within the homecare environment care coordination is considered as both crucial and timely for the efficient delivery of provided care services. Indeed, the homecare process represents a collaborative process which is a set of potentially interdependent services carried at patients’ homes by different stakeholders in a cooperative way. For such process, the need for coordination stands at two levels:

- **The Interventions Level:** where different providers of social and healthcare participants have to organize the delivery of homecare activities and the exchange of information with regards to performed interventions. This information is necessary to facilitate the appropriate delivery of health care services.
- **The Transitions over Time Level:** where the stakeholders must ensure continuity and consistency of provided care during the transition of different episodes of care and across the full spectrum of patient's care. For instance when moving from one care institution to another arises the need for responsibility shifts.

As shown in Figure 1, the coordination of home-based interventions at the first level is generally focused on monitoring the proper enactment of patient care plans, which represents duly personalized statements of planned healthcare activities encompassing all health care provider activities to be performed by one or several healthcare professionals.

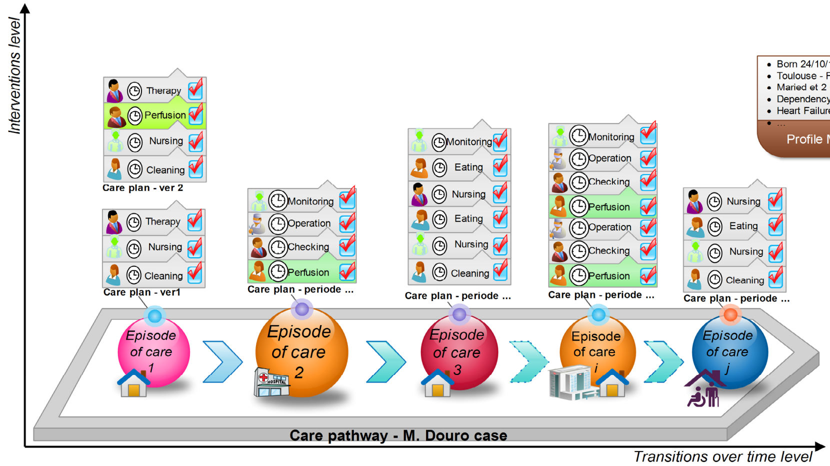

Fig. 1. Care coordination levels

The second level of coordination is mainly related the continuity of care over time through the integration, collaboration and sharing of information between different providers. Specifically, this level is focused on the anticipated care pathway, which is placed in an appropriate time frame, and agreed by a multidisciplinary team. In the home care domain, the coordination at this level simply consists of organizational shifting of care responsibilities and the transfer of current patient state condition and eventually the enactment of care history.

With regards to the above-mentioned levels we focus our endeavors on the first level of coordination since we consider it to be a fundamental step for homecare coordination. Given the needs at this level, workflow management systems appear to be an appropriate tool for supporting the communication and coordination between these different stakeholders through managing a sequence of care workflow activities.

2.1 Workflows Coordination for Homecare Process

Usually, workflow systems are process oriented, where a process represents a set of activities within a course-of-action that needs to be carried out in a prescribed sequence with the aim to achieve a determined outcome. In healthcare domain, such processes are known as care workflows (careflows), defined as the flow of care-related tasks to be carried out together with the timing and sequence of these tasks and the disciplines involved in completing them. Careflows tasks can either be diagnostic, therapeutic, administrative, or decision-making [5]. In the literature, there are several research works that have addressed the area of supporting healthcare process using workflow [6], mainly for the hospital domain.

However, fewer papers explore the design of workflow within the homecare domain. The mainstream of careflows in homecare context typically involves the coordinated provision of service care at patients' homes through monitoring sequences of interventions. Hence, these careflows, namely workflow coordination should be setup regarding a structured multidisciplinary care plans that detail essential tasks in the care for patients requiring specifically timed home services and offers structured means for developing and implementing local protocols of care based on planned clinical guidelines.

Fig. 2 shows a BPMN model process that represent a simple example of such a careflow in the homecare domain. It represents a sequence of interventions performed within a one-day timeframe for a specific patient, with the distribution of interventions amongst stakeholders (nurse, cleaning agent, etc.).

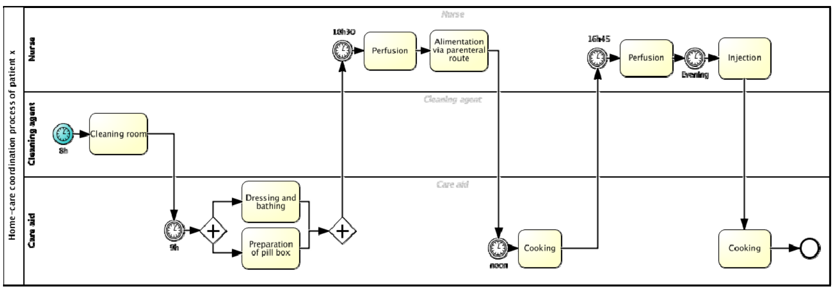

Fig. 2. An example of daily Home-care coordination workflow of a specific patient

This BPMN Model shows one pool representing a coordinated workflow, containing three lanes representing three different categories of actors involved in the homecare of a specific patient. In this case a cleaning agent should perform the first intervention at 8 o'clock, followed by two tasks (help with dressing and bathing and preparation of pill box) performed by a care aid agent. Followed by a third intervention that should be performed by a nurse at 10:30, etc.

In accordance with the patients' care plan, this careflow could be used to coordinate care interventions in real-time, thus allowing for the timely checking of planned care activities as to whether they were correctly executed by a specified actor or reported as cancelled. Notifications can be launched automatically by the system to advise when intervention is required, including the date and time of actions needed or alternatively to alert coordinators for any delays or cancellations. In addition, stakeholders could rely on careflows for sharing information with regards to care progression and patients' conditions [7]. Accordingly, we have developed an ontology-based approach for the coordination of homecare interventions to fulfill the above-mentioned requirements. This approach is presented in the following section.

3 Ontology-Based Careflow Design Approach

As noted in the previous section, a homecare plan can be considered as a rich temporal, process-centric, patient-specific representation of linked set of actions that need to be performed by several care providers at patient's home within agreed times. Based on the state-of-the-art, we have noticed that the knowledge management paradigm and more specifically the ontological approach are largely used in the field of medicine and health, especially to define careplans that are based on clinical guidelines. In addition they also seem to be a relevant means to cope with both flexibility and personalization needs.

Taking this into account and considering our goals, we propose to complement customized patient-centered workflows by using knowledge models. Specifically, according to the workflow architecture reference, ontologies are used to help in building workflow models in the design-time stage and to deal with the changing needs at run-time. In this work we have focused our endeavor on the design-time stage. Our approach consists of generating a "personalized care process" from a personalized careplan model. The resulting process model will be interpreted by a process definition tool in order to be enacted on a conventional workflow engine. This approach follows a Model-Driven Engineering approach, and is based on ontology matching between homecare domain conceptual models and a semantic representation of Business Process Modeling Notations. The result of the first step is an OWL model that conforms to a homecare ontology encompassing health objectives, subject of care profile, health and social conditions. Based on this intermediate personalized careplan model we generate a BPMN model by using the BPMN ontology [8] and SWRL (Semantic Web Rule Language) rules that define the mapping between the two ontologies. An important challenging step was to define a HomeCare Ontology (HCO).

3.1 Homecare Ontology: HCO

The use of ontologies has proven quite successful in the field of medicine and health in general, to describe diseases, their symptoms, and medical knowledge, e.g., CIM, UMLS and GALEN. A few ontologies have been built in the homecare area, however to our knowledge none is considered a standard in the field. Most ontologies of homecare remain at the stage of research projects, to address specific challenges of homecare [9–11].

In our work we adopted the APO (Actor Profile Ontology) and CPO (Case Profile Ontology) ontologies both implemented as part of the European K4Care project [2, 11]. APO deals with knowledge about actors and their skills involved in homecare domain and CPO is about illnesses and treatments. Though interesting, these ontologies on their own don't fit our needs Therefore we had to rebuild a new ontology that we called HCO. To build this ontology of homecare domain, we followed a synthesis of different methodologies in literature such as the ones proposed in [12, 13]. HCO focuses on the concepts of homecare coordination. This ontology contains global information about a structure and organization of homecare (actors, roles, etc.) as well as the knowledge for capturing the profile of patients, tasks required and actors needed for each disease. Our knowledge model is based on the reuse of some concepts from both APO and CPO such as Interventions, Actors and Actions. We also had to modify some other concepts such as patient and homecare semantic representation. We also introduced new concepts too, such as the duration and the frequency interventions. The proposed HCO is sketched in Fig 3. We use different colors, as specified in the figure legend, to clarify the origin of the concept: CPO, APO or others.

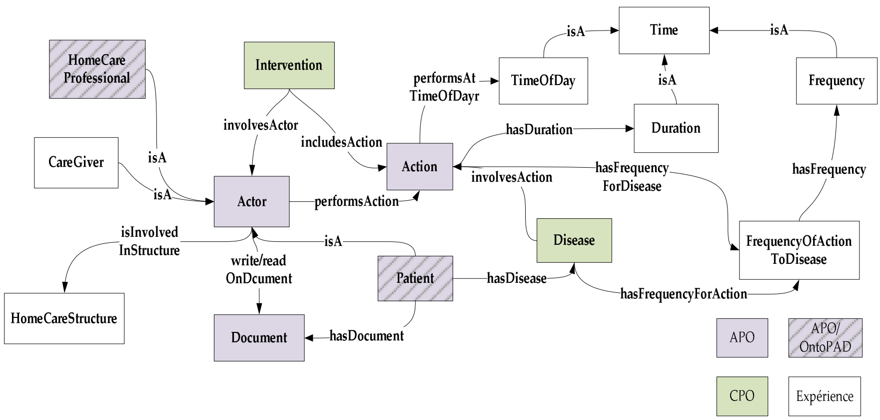

Fig. 3. Main classes and relations of HCO

This ontology could be queried to retrieve the elements that focus on which, when and by whom actions need to occur to treat a patient over a period of time.

With regard to the implementation of our approach, the software architecture is made of tree main components: a knowledge base, an inference engine that is able to query the knowledge base and the BPMN generator module that allows for generating BPMN files to be interpreted by a workflow modeler Tool.

4 Related Work

Numerous research efforts has focused on implementing computerized care pathway systems. Alexandrou *et al.* [14] proposed a semantic approach that supports the execution of treatment schemes based on clinical pathways to efficiently handle the application of healthcare business processes. The developed SEMantic PATHways (SEMPATH) system provisions for the constant monitoring of applied clinical pathways execution and automatically recognize any exceptional events. Abidi *et al.* [15] propose a patient care planning system that can automatically and proactively generates adaptive patient-specific healthcare procedures based on a semantic framework. They developed a careplan system that tries to combine heterogeneous healthcare knowledge sources with available patient information into personalized healthcare plans while utilizing the technology of web-services for the composition of integrated pathways. Yao *et al.* [16] propose a novel approach for integrating clinical pathways into clinical decision support systems. There work acknowledges the frequent deviation that clinical pathways involves and the need for significant flexibility to build successful clinical decision applications. This is achieved based on a better understanding of clinical context through using ontologies, and associating with rules to provide the knowledge required to allow in deciding the correct activities execution.

Most of these research works develop electronic clones of existing paper-based care plan management methods with a focus that is mainly related to hospital care. Contrariwise, in homecare the collaboration is asynchronous where the interventions are distributed in space and time. Accordingly, these approaches gave little consideration for the explicit modeling of intervention outcomes and related temporal relationships when formally defining the coordination of homecare process models. In our work, we are interested in the design of customized patient profile careflow models and monitoring their execution to improve the coordination of homecare interventions. To our knowledge there are no other works with the same goals.

5 Conclusion

Homecare interventions give rise to coordination and continuity of care. To ensure such continuity and to improve its quality, we proposed an ontology-based workflow design approach for homecare coordination of interventions with focus on organizing tasks among the numerous involved stakeholders. Our work differs from classical workflow based methods in that we incorporate considerable domain in addition to organizational and temporal knowledge. The fundamental proposition of our approach is its ability to assess a patient case, evaluate and implement workflow models for personalized patients' care interventions. We rely on ontologies to overcome workflow flexibility as the major identified obstacle and allow for the dynamic construction of careflows. Next step in our work is to promote a human in the loop approach in our transformation process, as indeed all necessary knowledge is not present in our ontology and we still need to give the users the means to complete the missing items during the transformation process.

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Healthcare Network Modeling and Analysis

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Abstract. A number of initiatives are nowadays in act to reorganize health systems and increase the interconnection of services offered to citizens to build a collaborative care network that maximizes service quality and minimizes costs. To achieve these purposes, a non standard quality assessment must be performed, as models for the analysis and evaluation of healthcare systems considered from the point of view of the entire network instead of single nodes have not been proposed yet. This paper aims at describing how to obtain a rigorous modeling and a meaningful analysis of the mass of data produced by a healthcare network. This analysis can be useful to inform the healthcare managers about the status of services under their responsibility and the degree of collaboration among entities of the network. The final outcome of these activities will be an improvement in the quality of service perceived by patients.

Keywords: Healthcare network, collaboration, performance indicators, UML.

1 Introduction

A promising trend in healthcare pushes the interconnection of the offered services to reduce diseconomies of scale. It implies the need for new analysis methods. Healthcare systems consist of a variety of providers (e.g., medical centers, hospital departments, emergency rooms) and prescribers (e.g., general and specialist physician). The entire network must be assessed, considering the relationships among these entities. Several works address the problem of analyzing single units by applying data/process mining and simulation [1,2]. However, the analysis of a single entity is limitative, because it cannot take into consideration the previous clinical history of the patient. For example, if a patient is addressed by the general practitioner to a specialist physician, and these in turn directs the patient to a specialist physician of another branch, it can be seen as an inefficiency of the system, because the general practitioner could have sent the patient directly to the second specialist. These anomalous behaviors are not detected by the analysis of individual service centers, but will be detected by analyzing patients' pathways through the network of services.

A first reason for which these analyses are not performed is the lack of a formal model to integrate information from different sources. Healthcare agencies maintain large administrative databases, which contain demographic information as well as clinical information such as diagnoses and medical procedures. While these data are

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 691–698, 2014.

collected for administrative data processing, taking advantage of them for other purposes would be highly desirable [3]. Furthermore, another reason of the incomplete analysis of data is the limited application to the healthcare of some ICT tools developed to perform data analysis in industrial environments. This paper aims at providing a methodology to fruitfully exploit data collected by healthcare networks. The first contribution is the definition of a metamodel of the healthcare network, then the analyses useful to extract information for the network evaluation are discussed. To make the methodology more concrete, real data collected by an Italian Healthcare Territorial Agency (HTA) are exploited as case study.

2 Related Works

Healthcare systems evolved from systems with few hospitals into integrated care delivery systems [4]. An integrated care system includes multiple structural functional aspects of healthcare organizations. The recent trend towards healthcare networks and integrated care even increases the need to effectively support interdisciplinary cooperation along with the patient treatment process [5]. In literature, significant attention has been devoted to the evaluation of the level of integration of healthcare services [6,7] and to the mining of the potential benefits of such integrated systems [8,9], such as a better quality of care, better services, more accessibility, more efficient operations, and reduced unit costs. On the other hand, severe problems were reported in applying advances in information technology to improve administrative and clinical processes [10], not only because of technical issues, but also due to the lack of cooperation among the healthcare network actors [11].

Despite its limitations, IT can provide positive effects to two kinds of processes: organizational processes (e.g., medical order entry and result reporting) and medical process (e.g., diagnostic and therapeutic procedures to be carried out for a particular patient) [5]. Since the effect on the first kind of process has been widely investigated (i.e., by reducing patient waiting times and costs), this work focuses on describing how IT solutions can be exploited to evaluate the medical processes in a healthcare network. Among data analysis methods, the use of data mining has taken great attention due to the large amount of generated data [12]. In [13], authors worked to identify the risk factors of a disease by using open source data mining tools, particularly association rule mining and classification techniques. A similar technique was proposed in [14] for mining association rules to identify possible side-effects of using multiple drugs during pregnancy. An approach of mining time dependency patterns is discussed in [15], where hospital paths are predicted for new patients. In [16], the authors proposed a temporal pattern mining framework to find predictive patterns for detecting and diagnosing adverse medical conditions associated with a disease. Pattern extraction techniques were already proposed in [17,18,19] to detect frequent medical treatments.

Present study advances previous works along two main dimensions: (i) it proposes a metamodel of the healthcare network to organize healthcare data in view of the following analyses, and (ii) since it considers the healthcare system as a network instead of single nodes, it proposes to extend the analysis also considering the interactions among nodes.

3 Methodology

The proposed approach to manage healthcare systems considered as a whole network instead of individual nodes is organized into three main phases, as shown in Figure 1. In "Data modeling" inputs come from the data collected by the healthcare control center. In "Data analysis", two kinds of analyses are proposed: a vertical analysis, i.e., fixed a node, analyzing the frequency of its children, and a horizontal analysis, i.e., fixed a level, extract the sequential pathways involving multiple nodes of that level. By combining the two kinds of analyses, an overview of the behavior of the network in terms of services accessed and pathways frequently followed by patients is provided. In the "Data evaluation" phase, the results emerged from the previous phase are evaluated with the help of domain experts.

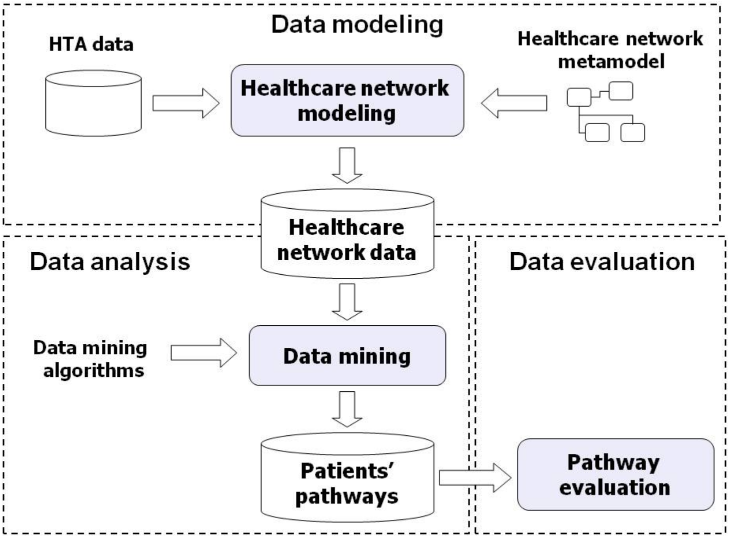

Fig. 1. Proposed approach to model, analyze and assess a healthcare network

4 Data Modeling

The metamodel of healthcare network was defined as a UML class diagram, as shown in Figure 2. In a healthcare system there are four main entities: Service, Prescriber, Provider, and User. A service is any kind of healthcare service provided to a citizen, from examinations to drugs to hospitalizations, while a user is any person who access the system. A prescriber is a physician who can do prescription of services to the users, while a provider is a structure that provides one or more services. For each provider, the list of services it provides is known. Two other entities are needed to represent the interaction and collaboration between these four elements, i.e., Prescription and Provision. A prescription contains the information of the specific services that a prescriber prescribes to a user, and a provision store the information of services provided by providers to the users. A user can be connected with a provision without any prescription, i.e. accessing an emergency room.

Once the entities and relationships in the metamodel have been defined, the model of a specific network is created as an instance of the metamodel. To this aim the case of a Italian healthcare territorial agency (HTA) is considered, which includes all users, providers and prescribers in a certain geographical area [20]. In a HTA, three types of providers can be identified, i.e., the medical structures without hospitalization capacities, the hospitalization structures and the drugstores. There are three services: (i) examination, (ii) the hospitalizations and (iii) the drugs distribution. Data regarding the prescriptions and provisions are routinely collected by the HTA.

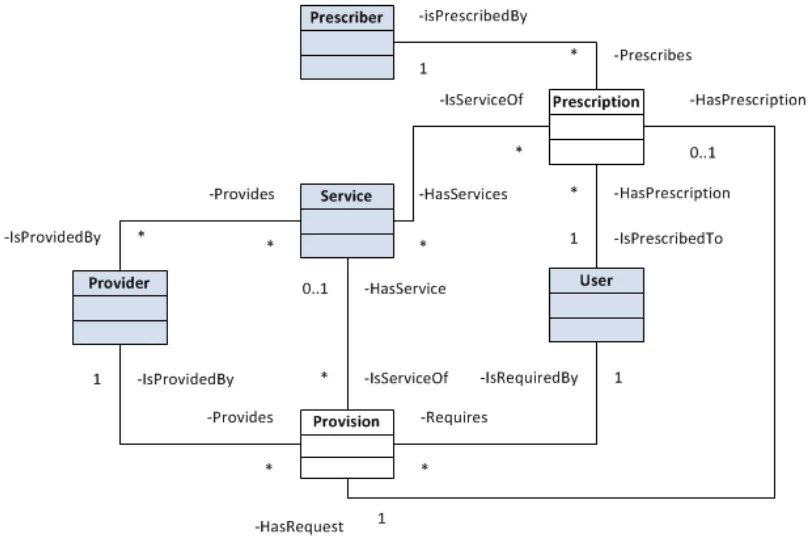

Fig. 2. Metamodel of the healthcare network

5 Data Analysis

Figure 3 shows an example of a hierarchy of service concepts. Starting from the most general concept of service, the first specialization is among the three types of services previously described, i.e., the examinations, the hospitalizations and the drugs. Then for each service type, other specializations can be done, e.g., the one based on the medical branch to which the examinations belong. In this way, a hierarchy of N levels is produced, where the N-th level is composed by the instances, i.e., the concrete services.

With respect to this data representation, two different analyses can be done. The first can be defined as a "vertical" analysis, i.e., fixed a node of the hierarchy, analyzing the frequency on which the patients access the services of its children. For example, if the healthcare manager is interested in analyzing the services most accessed in the network, he/she can perform a vertical analysis directly on the Service node. If he/she is interested in seeing how patients accessed the different medical branches of examinations, the vertical analysis can be performed on the Examination node. As a result, the number of patients that accessed each medical branch (e.g., Laboratory, Ophthalmology and Radiology in our example) is computed. This analysis can be useful to compare the behavior of different patients' groups in terms of services accessed, or to compare the accessibility of one service with respect to the others. The second kind of analysis, which is generally not performed by healthcare organizations, is a "horizontal" analysis, because it considers simultaneously different nodes at the same hierarchical level (e.g., level L1 in Figure 4). This analysis aims at computing the frequency of the movements of patients among the network entities through the extraction of sequential patterns. To accomplish this task, the data have to be transformed in a sequence dataset containing the temporally ordered activities of patients in the network.

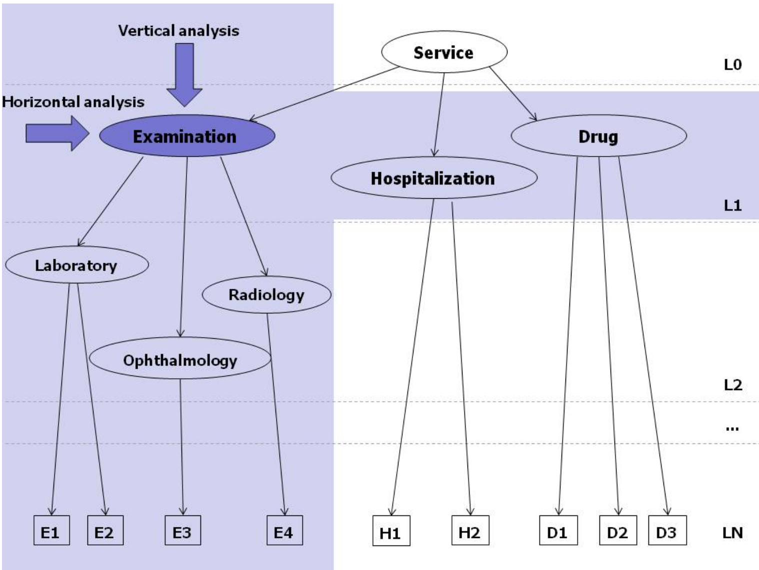

Fig. 3. Horizontal and vertical analysis on healthcare network data

More formally, a sequence dataset is a collection of tuples (Pid, S), where Pid is the patient identifier and S is the temporal list of sets of activities done by the patient. An activity set is a set of activities done in the same date, and it is indicated by curly brackets. Once the data were structured according to this format, data mining algorithms can be used to reconstruct the frequent pathways of patients in the network. The percentage of tuples (i.e., patients) that contain a sequence is called the support of the sequence and is indicated as sup(S). A sequence S is called frequent if its support is above a specified support threshold. To avoid the generation of redundant information and compactly represent the solution set, only the frequent sequences that are not subsequences of other sequences with the same frequency are extracted. Such sequences are named closed sequences [21]. The frequent closed sequences are extracted by means of the BIDE algorithm.

6 Data Evaluation

The dataset considered as a case study contains data collected by an Italian HTA all along one year. In the database, there is a number of 204,138 patients and a total of 341,373 provisions of services. Particularly, the percentage of services accessed are the following: 62.0% examinations, 30.3% drugs and 7.7% hospitalizations. The dataset was received in an anonymized form directly from the health territorial agency, and was stored and analysed on a dedicated machine not accessible from outside exclusively by authorized personnel.

The application of the vertical analysis to the Examination node in the L1 level identifies the number of patients which accessed examinations in each medical branch. This analysis can be useful to compare the behaviors of patients with different pathology. For example, by applying this analysis separately to patients who suffer from diabetes and who suffer from asthma, results show that the two groups of patients accessed different branches from each others. Patients who suffer from diabetes, access more frequently the branches of Laboratory, Ophthalmology, Cardiology, Radiology, Dietetics, Neurology and Vascular surgery. Instead, patients who suffered from asthma, access more frequently the Pneumology, the Laboratory, the Radiology, the Dermatology and the Allergology branches. The vertical analysis can also be done at a lower hierarchical level. For example, the application of the vertical analysis to the Laboratory branch (L2) shows the specific examinations most accessed by patients.

The horizontal analysis can reveal more interesting information because it considers the chronological order of activities performed by patients. If applied to nodes of level L1, it reveals the frequent patterns among types of services. From this analysis emerges that 100% of the diabetic patients accessed a medical center in the considered year, 79% accessed two times and 61% three times. The frequency of accesses to drugstores is a little bit low, in fact only 76% of patients accessed one time, 68% two times and 60% three times. The analysis at this level is useful to estimate the accessibility of patients to the different types of services, but it gives not details on treatments performed. Thus, the horizontal analysis was repeated at a lower level (i.e., LN). The analysis of extracted frequent patterns, reported in Table 1 for diabetic patients, reveals that most frequent examinations are the base tests repeated to monitor the concentration of sugar in the blood, such as Glucose, Venous blood sample, Capillary blood sample, and Urinalysis. After these, the most frequent examinations are the ones concerning cardiovascular complications and the ones for determining the liver health. Among sequences of length greater than 1, the most frequent sequences show that Glucose is repeated two times (58% of patients), three times (32%), or four times (15%) during the considered period. These patterns are coherent with the medical knowledge, but the frequency with which they are performed is lower than expected. The fact that around 15% of diabetic patients did not control the blood glucose level along a year can reveal some problem in patient management and need a further investigation of causes.

Table 1. Results of the horizontal analysis on the LN level of the Examination node (for diabetic patients)

Frequent sequences - length 1	***Support***
{Glucose}	85%
{Venous blood sample}	79%
{Capillary blood sample}	75%
{Urinalysis}	75%
…	
{Fundus oculi}	27%
Frequent sequences - length 2	***Support***
{Glucose}{Glucose}	58%
{Capillary blood sample}{Glucose}	54%
Frequent sequences - length 3	***Support***
{Glucose}{Glucose}{Glucose}	32%

7 Conclusion

The evaluation of a health network is a complex task because the patients have autonomy in the choice of which nodes (services) to visit. This paper aims at adapting tools and technologies derived from other research fields and using them firstly to obtain a model of a healthcare network, and secondly to perform a meaningful analysis of the mass of data produced by a healthcare network. The extracted knowledge represents a picture of the actual processes occurring in the healthcare network. The obtained results can be useful for healthcare managers to inform them clearly about the status of services under their responsibility, and to suggest improvements to system inefficiencies. It is also useful to evaluate the degree of collaboration among different entities of the network

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An AAL Collaborative System: The AAL4ALL and a Mobile Assistant Case Study

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Abstract. The areas of Ambient Assisted Living (AAL) and Intelligent Systems (IS) are in full development, but there are still some issues to be resolved. One issue is the myriad of user oriented solutions that are rarely built to interact or integrate with other systems available in the market. In this paper we present the AAL4ALL project and the UserAccess implementation, showing a novel approach towards virtual organizations, interoperability and certification. The aim of this project is to provide a collaborative network of services and devices that connect every user and product from other developers, building a heterogeneous ecosystem. Thus establishing an environment for collaborative care systems, which may be available to the users in from of safety services, comfort services and healthcare services.

Keywords: Ambient Assisted Living, Ambient Intelligence, AAL4ALL, Active Ageing, Artificial Intelligence, e-Health, Intelligent Environments, Collaborative Networks, Sensor Platform.

1 Introduction

Current United Nation (UN) population statistics [1] shows the evolution and growth trends changing rapidly, being expected in the near future a full reversion of the population distribution, age related. In fact, the UN states that the abrupt changes in the population evolution may become an international calamity if not dealt properly. The tendency occurring is the direct inversion of the teen-elderly ratio, being the tendency to greatly increase the number of elderly people. Furthermore, it is expected that in the year 2050 the elderly layer (60+) surpasses the young layer (0-15) [2].

This information stresses the investment on the services and products directed to the elderly. One issue is the shortage of specialized help, for instance, there is a lack of caregiving centres or domiciliary caregiving to all persons in need. The current demand of services greatly surpasses the offer available and in the future it is

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expected to be even more difficult to provide proper care. A different perspective is keeping people in their homes and providing them with specialized help.

That idea was the starting point of the Ambient Assisted Living (AAL) systems, being the aim providing people with technological resources that help them on their daily life. Currently there are numerous AAL projects [3] that provide help in many different ways, being services, devices or even humanoids, some being already available to the end-users.

A common issue with AAL projects, mainly due to the rapid development that is demanded, is that they are singular, meaning that they work by themselves and cannot be integrated with other systems [4–6]. Although it seems harmless, this issue quite serious. There are several implementation and operation issues that are resultant from it, and perhaps, a bigger issue that is user adoption of the technology.

Mostly what happens is that the AAL systems rely on their own knowledge, and the lack of established standards (from the community or organizations) constitutes a barrier to the interoperability. Furthermore, the AAL systems often rely on a panoply of concepts, ones in terms of software, others in terms of hardware to make everything work together, thus some compromises must be made.

Fagerberg et al. [4] presented an extensive overview about the latest developments of AAL projects, confirming that most of the developed projects stand alone in terms of interoperability. The authors affirm that there is more investment on the AAL area, being multiple projects addressing the same problems, without considering interoperability, due to several factors, such as development procedures, architectures and requirements guidelines.

Commercially, it is verified a large amount of services are interconnected, leading to a better usage and to information sharing between different platforms, enhancing the user profile of each service [7, 8]. Clearly there is an effort of the services providers to build an ecosystem that benefits all the participants.

This document is constituted by the following sections: section 2 presents the state of the art in terms of AAL ecosystems and previous attempts of building an ecosystem; section 3 presents the AAL4ALL project and the main lines of its architecture and structure; section 4 shows the UserAccess project, built to the AAL4ALL having as its aim the caregiver and relatives; finally, section 5 presents the conclusions and the future work.

2 AAL Ecosystems

As previously stated, what is occurring is the lack of viable business models that truly implement the needed interoperability [4–6]. In AAL projects interoperability comes in many forms, going from the sensor systems to the certification procedure. The following projects present a spectrum of approaches in terms of AAL ecosystems.

Norgall and Wichert [9] present an initial approach to the idea of an integrated environment. The universAAL project implemented an initial approach to interoperability, being the aim to provide an inexpensive platform so that users could benefit from low cost solutions. The initial approach was to implement conventional standards such as the IEEE 11073. This was the major issue with the universAAL project, as only one standard was insufficient to accommodate all features they proposed.

Memon et al. [10] presented the CareStore platform, being an AAL project the aim is to provide an system that is able to interact with all devices that are sold at their store. The authors provided a conceptual framework that is able to interact at different levels of communication between all the devices and services. This approach bridged the interoperability, integration, usability, security, and dependability features that an AAL platform must provide. This holistic perspective is built over the idea that several protocols have to be implemented, each one directed to the appropriate level of communication and security.

Lahteenmaki at al. [11] have presented an implementation that is not directly pointed to AAL but, with some level of adaptation, can serve as a starting point towards real communication protocols to medical environments. The ontologies created had the porpoise of establishing communication between medical services and external services that could be medical or not. Furthermore, the method of saving the data and the access procedures can be extrapolated to other systems as they are heterogeneous and can be ported to other solutions. The greatest contribution to the AAL was the implementation of this project on a real environment, thus proving that it is feasible to maintain communication between distinct spheres of action.

Walderhaug et al. [12] presents a discussion about the technological developments and the society needs, creating a dichotomy between the provision of quality technological services and the healthcare organizations standards. The authors emphasize the absence that a common system provokes, and how a group of singular services fail to present a useful or pleasant solution. Finally it is presented a framework with the aim of being a centralized system for information, resorting to ISO standards to comply with medical certification process.

These projects have provided information and technology to have a clear idea of what needs to be done to achieve an AAL ecosystem. It is easy to realize that the ecosystem must be based in ISO/IEEE standards and has to attend differently to each structure level, from the sensors to the logic reasoning.

3 AAL4ALL

The AAL4ALL [13] project is a Portuguese effort to construct an AAL ecosystem that shall serve as the standard for the future AAL projects. The project's consortium is constituted by academia and corporate partners, collaborating in ways that join the formal concepts with products that are already deployed in the market and adopted by people.

The AAL4ALL project has two main goals: to produce an AAL ecosystem and define a certification standard [14]. As it is expected, these two goals encompass various developments, going from the sensor systems to the high-level services, as seen in Figure 1. Therefore, the project must provide the design and architecture that structures and establishes a connection with every solution devised.

One of the AAL4ALL goals is to allow several distinct services to be connected to it. Not being limited to products developed internally, but to integrate all systems that bear an AAL4ALL certificate. Thus, other players, such as academia or industry, can build and integrate their devices to the system. Furthermore, one of the aims is to build a strong collaborative network. Virtual organizations (VO) and virtual environments (VE) are very interesting to this project, due to its own nature, of being fully ubiquitous and relying in external products providers to build solutions (whether hardware or software) to add value to the established systems.

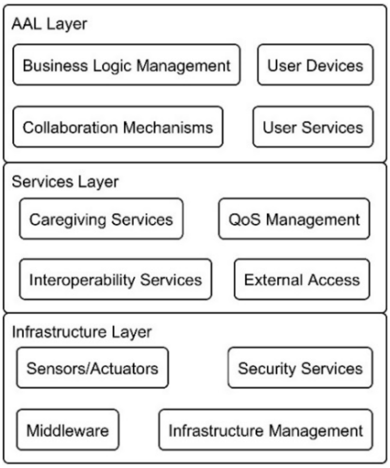

Fig. 1. Simplified diagram of the AAL4AAL layer architecture

The AAL4ALL relies in two types of virtual organizations: architecture collaborative network and users' collaborative network.

The architecture collaborative network is established using heterogeneous devices and services, resorting to a transversal architecture backbone that is common to all solutions (hardware and software), communicating with a central system that is responsible for the verification of the whole organization.

The users' collaborative network is the related to the panoply of the users connected and sharing information in the platform. The main system only works by having a large amount of information and having one's personal sphere of people that is also connected to the system. Therefore, with a large community using the system more information is generated thus, the system becomes more efficient. Each user can be on their own environment, for instance, users in their homes and physicians on the medical centre, and collaborate as if they were in the same space, being one positive aspect the resources savings and the natural environment monitoring.

AAL project's have spheres of action that are constituted by the actors (the distinct users) and the global actions. For instance, a typical project's user is an elderly person that is being monitored and has devices and services available to help at any given task, but the life of a person is also constituted with connection to other people, like friends, relatives and caregivers.

Moreover, these people need different solutions to the ones presented to the elderly user, thus there is a necessity to allow distinct levels of interaction, keeping the system homogeneous. The key to this issue is personalization of the devices/services to each sphere, which requires a high level of interoperability of each service involved.

As showed in Figure 2, the AAL4ALL platform connects the several spheres of each actor, providing interoperability and connection between them. A leading aspect is the collaboration between all actors, considering that the help of the technological systems have boundaries and are finite [15–18]. For instance, although we can witness technological revolutions almost every day, there are only few systems that can truly monitor one that is outside its home. So, a natural solution is to resort to a caregiver that is constantly available to attend the actor monitored, but this solution causes another issue that is selecting a person for the arduous task of being always in alert. It is clear that only one person is unable to perform such activity alone, thus it must be considered that external services, such as caregiving services, must be used accessing the AAL4ALL platform to retrieve the actors' information. Keeping the user and the caregiver in mind the UserAccess project was created.

UserAcces is a platform in form of a service built for the AAL4ALL project, aiming for the assistance of the caregiver and the relatives of the user.

Fig. 2. Interaction of the different spheres

4 User Access

The AAL4ALL ecosystem is composed of various services and devices, being most of them platforms on their own. The idea of such architecture was to provide an integrated service, which one could contract the solutions that sees fit, being assured that any product chosen works perfectly with all others. Therefore, several scopes were projected responding to the various user spheres, ones regarding the user and its direct monitoring, others monitoring the home, and others providing information. As presented before, the UserAccess [19, 20] platform was developed within the scope of the AAL4ALL project and, in simplified terms, consists in a platform that provides information about the actor being monitored. Corresponding to the information sphere, the UserAccess focuses the user monitored but it is not designed to be used by him/her, but by others that directly interact with them. Therefore, the UserAccess is a complementary service, in the perspective of the AAL4ALL, but plays an important role, as it relives the caregiver of arduous tasks, such as constant monitoring, allowing he/she to do other tasks of even monitor other users at the same time, providing a harmonious work schedule. One of the high-level goals is to create a collaborative platform here the actors can directly interact with each other by relaying information, send text and video messages, and schedule activities remotely. Therefore, conveying all information in only one place, thus the actor only has to interact with one service. This collaborative sphere is somewhat similar to a social network, although it lacks support to out-of-scope interaction, meaning that only discussions and interactions that are within the scope of the AAL4ALL theme are allowed. Currently the available information consists in health reports from the sensor system, current location and future activities.

In terms of interaction, the UserAccess has an ongoing development for deployment via web and mobile devices. The information consumption dictates the constant internet connection thus justifying the user method of access, as offline information soon becomes dated and invalid.

4.1 Architecture

In terms of architecture, the UserAccess is a server based platform, were all information passes. This procedure was opted due to the high volume of information that needs to be processed and the connectivity between all users, being the most effective way to overcome connection problems and devices overloading. Moreover, with the use of mobile devices, such as smartphones, their internal services can be retained and used to directly connect with other actors (by telephony or messaging).

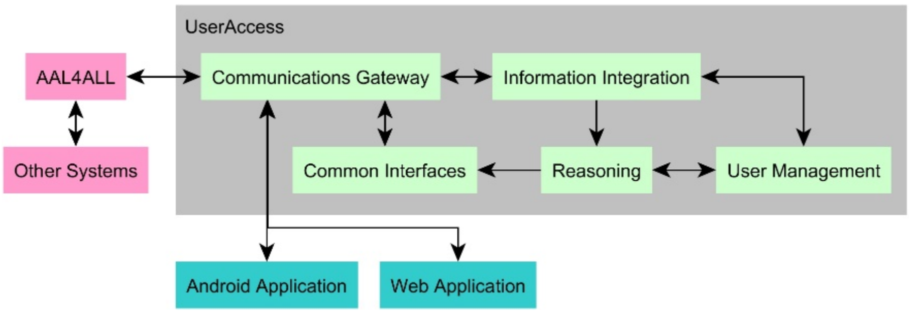

Fig. 3. UserAccess architecture overview

This architecture also allows the development of the expected collaborative platform, being the information always accessible and distributed between all actors involved in a decision or task.

Figure 3 is the overview of the architecture, it is composed of five modules plus two user visual interfaces. The architecture is based on a multi-agent system, where every module has several agents in charge of different aspects of the module. This approach helps in terms of scalability and availability, making simpler to change options at the local level and update without downtime of the system.

The communication gateway provides the means to receive information from the AAL4ALL (more exactly from the AAL4ALL Node) and relay it to the next modules, using internal protocols based on XML and JSON formats.

Information integration module takes care of verifying the source of the information and checking it with the one present in the relational models. The UserAccess is open to any communication that follows its ontologies there is the necessity of knowing if the system possess the means to understand it. Also, the information that arrives is very distinct (in format and content) of the one that is present internally, thus it must be integrated in the system.

The reasoning is a vital part of the system, as it provide complex decisions in secure actions. For instance in terms of scheduling, if the user has already a task scheduled at a time that other user wanted to reserve the system can automatically respond that that time slot is occupied, or if it's the user physician scheduling, the system can reserve that time and notify all people involve in the previous task that it is not happening. Thereon, the information is relayed to the user management module that updates that information on the AAL4ALL platform.

User management module treats the actor personal information, keeping updated his/hers likings and medical condition modulating the reasoning and providing extra information to the reasoning so that module can make better decisions.

Common interfaces module holds the information to be relayed back to the AAL4ALL platform. The reason why this module is separated from the information integration module is to keep the sent and receive procedures linear and non-blocked.

Finally, the android application and web application are the typical way of keeping the actors informed. Depending which actor is using (resorting to the user management module) the type of information and the content is changed.

4.2 Case Study

The UserAccess must be thoroughly tested before any real usage of the platform, as any information or action can result in unforeseeable results. The UserAccess is unable to change critical systems or choices, but the information delivered to the user can change the way that he/she acts, thus it is imperative that all systems are at least error free, and in the worst case scenario no information is showed.

With the current implementation of the UserAccess has already produced results, being the correct capture of information by the server and presenting it on a webpage and relaying it to the Android application, as showed in Figure 4. The ubiquitous nature of the system requires some features to be implemented differently from the common procedures, being scalability a theme that should be carefully considered.

The initial tests are very promising and it validates the work done until now, being the next steps to integrate other platforms. Furthermore, the information about the state of the sensor platform was correctly displayed, presenting warnings if the user exited his home and left something open, or if it pressed the panic button.

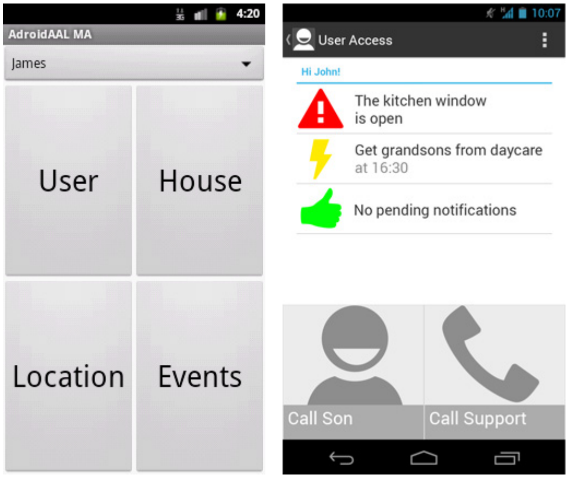

Fig. 4. UserAccess Android Interface

The scheduling is also a challenging theme, because of the inherent social interaction. We can safely assume that a great part of the tasks anyone does involves other people, and that make the process of scheduling much more complex due to the assumption of constraints of each party involved in the task. Let's assume the following scenario:

- Mario wants to play bridge with his friends Roger, Maria and Jack;
- To Mario Friday afternoon would be great;
- Roger can play Friday after 4 pm;
- Maria can play Friday until 5 pm;
- Jack can play Friday but only after 4:30 pm.

Thus there is a problem with the schedule that Mario suggested, as they cannot combine their tasks to play Friday.

This scenario shows how a simple task can be difficult to synchronize between all actors. Furthermore, we must consider the fact that each person has more than four friends and each one must be managed. We are used to schedule different tasks with different persons easily but we mind only our own schedule.

Another situation is the fact that some activities are more important than others, for instance, a medical appointment is more important than a game of bridge, and most of the time most of those tasks are not neatly scheduled. So, one issue that must be considered is the arrival of important tasks that overlap others that are already scheduled. There are two approaches to resolve this problem that can be used combined: actor hierarchy or actor preference.

The actor hierarchy consists in ranking the person that schedules the task according to the importance in the user's life, being task scheduled and others eliminated or reallocated. The problem with this approach is that it is quite inflexible, as the most used action is to schedule the one with priority and delete the others with least priority.

The actor preference is a modulated approach where the reasoning module can learn from the user's interactions and provide a hierarchy values that are more real. Furthermore, it allows interactive reallocation of the tasks that are overlapping and suggest times where all parties involved are in accordance.

Finally, the next step will be taken in a living lab that in the AAL4ALL project means collaboration with the Santa Casa da Misericórdia, which is a retirement home. The test will be proceeded with a small group (3 to 5) persons where it will be evaluated their reaction to the system and the reliability and usability. It is expected a large amount of results due to the time (1 month) and the exigency of the environment.

5 Conclusions

In this paper it was presented the AAL4ALL project and the UserAccess case study. The UserAccess is still in development, being most of the modules in the final stage, being the reasoning module the one that requires more effort and time, due to the its complexity. The system has also the web application and a basic Android application and is, currently, able to receive information from a sensor platform and generate valid information as well as warnings when a threshold is achieved. It is also able to receive multiple application connection and successfully connect users and share information about them, being in an initial stage of a collaborative environment.

In terms of future work, we are focusing in the reasoning module and provide visual interfaces' features so the users are allowed to direct communicate with the others. Furthermore, we plan to provide an easy way of integrating other devices with the UserAccess, by allowing the information integration module receive remote updates. Being the next step the deployment in a retirement home, and testing it in a controlled real scenario, testing the features and usability of the system. After this test the results obtained will be used to provide real information of the performance and the errors or shortcomings, being a final test planned to use all people in that retirement home, leading to the final stage of the project and the certification procedure of all services and devices.

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Mobility and Logistics

Collaborative Management of Intermodal Mobility

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Abstract. Throughout the world societies are changing, so is mobility behavior. People are increasingly using multiple modes of transport; not only different modes for different trips but also combined use of different modes within one trip can be observed. Furthermore decisions for certain modes on specific trip stages depend on situational context (e.g. current traffic) and individual preferences. This trend can be supported by collaboration of mobility and service providers. Therefore information systems need to provide real-time data about traffic, provider status (of several mobility providers) and possible transfer points to enact context sensitive route adjustment. Alongside with customer preferences traffic flow can be optimized on individual and public level. In this article we strive to highlight challenges associated to this scenario. In addition we will present an architecture for intermodal information systems that offers services for individual planning, real-time route adjustment and provider cooperation.

Keywords: Intermodal Information Systems, Mobility, Public Transport, Collaborative Management.

1 Introduction

Throughout the world societies are changing, especially in urban regions mobility behavior of people is affected. In metropolitan areas individual motor car traffic is causing problems, e.g. traffic jam, overloaded parking space and air pollution. Therefore people are increasingly using multiple modes of transport, in order to accomplish mobility requirements. Not only different modes for different trips but also combined use of different modes within one trip can be observed. Furthermore decisions for certain modes on specific trip stages depend on situational context (e.g. current traffic) and individual preferences. In order to support and promote this development provider cooperation has to be strengthened. In addition new collaboration services are needed in order to cope with extended requirements,

L.M. Camarinha-Matos and H. Afsarmanesh (Eds.): PRO-VE 2014, IFIP AICT 434, pp. 713–721, 2014.

especially high load on demand side and dynamic reactions in real time (e.g. request for different kind of service or transport mode) based on a current situation. Thus providers have to offer services based on seamless ad-hoc collaboration, therefore two main adjustments have to be made to fulfill customer requirements. First of all a conceptual model that allows dynamic provider collaboration (including accounting) has to be developed. Secondly IT systems of providers have to exchange information regarding current state of operating vehicles as well as data to allow billing of performed services.

Alongside with given customer preferences traffic flow can be optimized on individual and public level. At customer level this means information systems have to provide real-time data about traffic, vehicle status and possible transfer points to enact context sensitive route adjustment. Additionally all mobility providers that collaborate to offer seamless mobility services have to offer information to allow billing of utilized services. In this article we strive to highlight challenges associated to this scenario. In addition we will present an architecture for intermodal information systems that offers services for individual planning, real-time route adjustment and provider collaboration.

2 Mobility Patterns

The travel behavior of the people is getting more and more heterogeneous. People use modes of transport which are convenient for them in specific situations. Contrary to some decades ago, people are less captive of one mode. Also, as displayed in **Fig. 1**, people use increasingly all modes during a longer period [1]. People reveal a multimodal travel behavior when they switch their main modes of transport for different trips in a longer period (e.g. in the course of one week). Just as the multimodal travel behavior the intermodal travel behavior is increasing. We define an intermodal trip as the usage of several transport modes during one trip, e.g. a trip with public transport in combination with bike or private car.

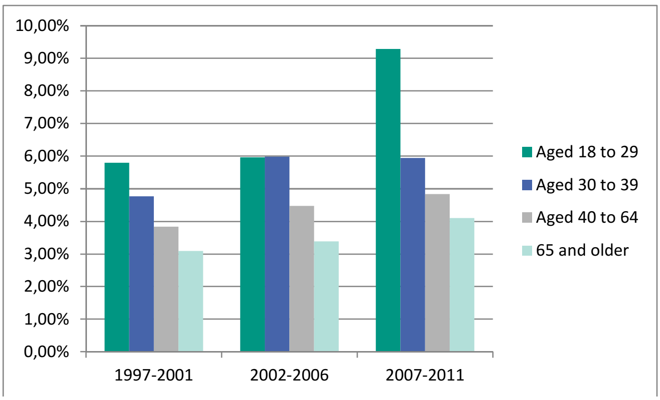

Fig. 1. Share of people with multimodal transport behavior [1]

This work aims on developing and evaluating innovative intermodal vehicle concepts and flexible vehicle sharing services in combination with public transport. Successful implementation of new mobility services in a certain region is driven by mobility needs of people. Therefore we analyzed the Rhine-Neckar-Region in order to get information about travel behavior and intermodal trip patterns of the inhabitants. A pre-existing study of this region was missing knowledge about the sequence of stages and their duration. Therefore we carried out a combined revealed preference (RP) and stated preference (SP) survey to collect intermodal trip information. The RP survey analyzed the revealed travel behavior including different stages, different modes and transfer points. In the SP survey participants could choose between several hypothetical but realistic mode choice situations based on reported trips including electric driven vehicles for the so called last mile (e.g. from public transport stop to work place). The SP survey is the empirical base to analyze acceptance of different electric vehicle concepts with a travel demand model which is under development. Both surveys together result in a model that reveals information about where and when a switch in transport mode is made or would be valuable. This can be utilized by providers to offer new services and extend collaboration to other providers.

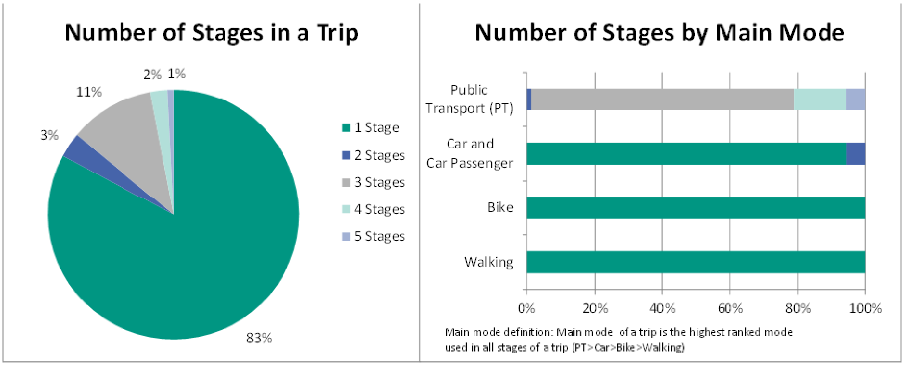

Fig. 2. Numbers of stages in a trip and by main mode in Rhine-Neckar-Region

As one result the RP survey the intermodal trip patterns of inhabitants including all stages are input for the design of information systems utilized by mobility providers. 17% of all trips include more than one stage (see **Fig. 2**). Almost all intermodal trips include at least one stage covered by public transport. Our results also reveal that there is a need for improved information on intermodal trips. Customers are especially seeking for real-time data and in certain situations information about backup services (including those of other service providers). Such enriched information will lead to profound knowledge of transfer possibilities for changing modes and to an increasing number of intermodal trips.

3 Mobility Management

As mentioned one reason for changing mobility behavior is the rising number of inhabitants of urban and metropolitan areas. In turn urban travel management is becoming more and more complex and has to respond to new challenges within high traffic density, lack of parking space and pollution. Furthermore urban inhabitants are more likely open to use environment-friendly mobility concepts, younger people also tend to prefer concepts of sharing over ownership (e.g. the rate of younger people not owning a car is growing). Taken together these trends can foster new intermodal mobility concepts. To turn the challenges mentioned above into opportunities, mobility providers have to cooperate and implement new business models including shared service concepts. However, mobility services in urban cities are currently far from fulfilling these requirements. State of the art services for intermodal mobility suffer from significant shortcomings. Expected real-time information during the trip as well as accurate route planning before and during the trip is currently unavailable or characterized by several media breaks. Especially planning and integrated ticketing of intermodal trips is still a major hurdle for customers, who have to cope with several provider specific information systems, applications and payment systems.

Mobility providers have realized that collaboration and networking are the key factors to solve these shortcomings. Hence first cooperation efforts between mobility providers can be observed in many German cities today. Three major types of cooperation can be observed:

- *Joint fee packages with special rates to each other's customers:* For example some car-sharing providers offer starting package deals over the first couple of months with special rates for public transport. Others offer general discounts for tickets of local public transport.
- *Integrated mobility offers through so called "Mobility cards"*: In some public funded pilot projects so called integrated mobility cards are being developed. The key idea is to combine various mobility and leisure services by a debit card. Thus customers can utilize one card as ticket different services (such as public transport or car sharing). The HANNOVERmobil-Card can serve as an example [2].
- *Joint sales and marketing activities:* A well-known and widely spread kind of cooperation is the establishment of joint sales and marketing activities. Cooperating partners advertise each other in own publications, point customers to partner offers or even negotiate contracts for partners.

These types of cooperation are first steps to improve support of intermodal trips, they, however, do not meet the needs and demands of today's mobility developments. On customers side only few aspects (primarily ticketing) to diminish the hurdle of intermodal trip planning are tackled. Regarding efficient provider collaboration all solutions suffer main drawbacks. Generally current approaches are operating on local level with pre-defined providers, which create rigid structures that are not designed to integrate new providers or new mobility services. Additionally on a technical level solutions focus information systems utilized by local providers and often neglect standards; thus further development of standards (e.g. VDV 452 [3] that cannot cope anymore with above mentioned requirements is also not promoted. Hence Intermodal Transport Control Systems (ITCS) that would enable efficient collaboration of providers and implement integrated mobility services with simple access for customers are still not established.

4 Intermodal Information Management

As elaborated, collaboration networks on business and IT level are required to implement ITCS. Thus information systems, interfaces, business processes and business models of the collaborating mobility providers have to be analyzed, aligned and integrated. This includes integration of pre-existing information systems of all participating partners; particularly the establishment of a collaborative integration platform is a major issue. To enable ad-hoc collaboration and integration of new services as well as providers, extendable open standards have to be developed and used. The most crucial nonfunctional requirement is, that the technical platform has to react in real-time under a high load (number of customers and status data delivered by mobility providers). In a public funded joint project we developed a four step approach to tackle these challenges:

1. Discover services and business processes offered by providers
2. Identify possible future services alongside intermodal trip support
3. Design platform architecture
4. Development of platform prototype with provider integration

At first we conducted several workshops with the participating mobility providers (Stadtmobil and RNV). Herein we identified, grouped and aggregated current use cases to derive relevant business process models. By process and interface analysis we identified interoperability opportunities and shortcomings. During this analysis we included several domain models such as [4] and a set of key performance indicators. As output an overall process map covering the relevant, aligned business processes of public transport and car sharing was generated. In a second step we went through further workshops to identify relevant target use cases for future intermodal mobility services. Taken together with identified mobility patterns (result of our surveys, see section 2) we could identify regional mobility demand and specify a set of service concepts prosperous to be implemented within provider business models. As stated a provider collaboration platform, that seamlessly links information and accounting systems, is essential to implement an overall and collaborative ITCS. The general architecture of such a platform is given in **Fig. 3**. The architecture is based on a mediator component, which acts as integrator for the collaborating partners. As collaboration participants **Fig. 3** displays a car-sharing provider, a public transport provider as well as a service provider (e.g. provider of routing and navigation technology). Routing and navigation technology is important to enable intermodal trip planning; the mediator can forward information of possible mobility related services. Further services and providers may be integrated in order to optimize planning of suggested intermodal trips. Furthermore the platform is designed with open interfaces to enact simple entry for further providers (mobility as well as additional services of other domains).

In our joint project all providers committed themselves to deliver real-time information (e.g. regarding state of vehicles, traffic situation, ticketing) to the mediator, which forwards them to customers. Customers can get access to information and ticketing by various clients (e.g. web-frontend, applications for desktop and smartphone). The data interface is currently based on standards utilized by providers. In this context standards such as VDV 452, 453 and 454 as well as CEN SIRI (see [3, 5]) are important, for enhanced provider collaboration. However, standard extensions are necessary, especially because their current main focus is providers of public transport. Thus we intend to suggest a meta-format that is flexible enough to integrate and extend several data standards and services beyond mobility. Therefore data transformation and coordination of interaction between all collaboration partners is a major task for the mediator component. Direct vehicle communication is out of scope of this architecture, since it has to be covered by collaborating mobility providers (e.g. car status is delivered from its on-board unit (OBU) to the car-sharing provider which forwards this information to the mediator if relevant). Thereby a load balancing mechanism is implemented implicitly.

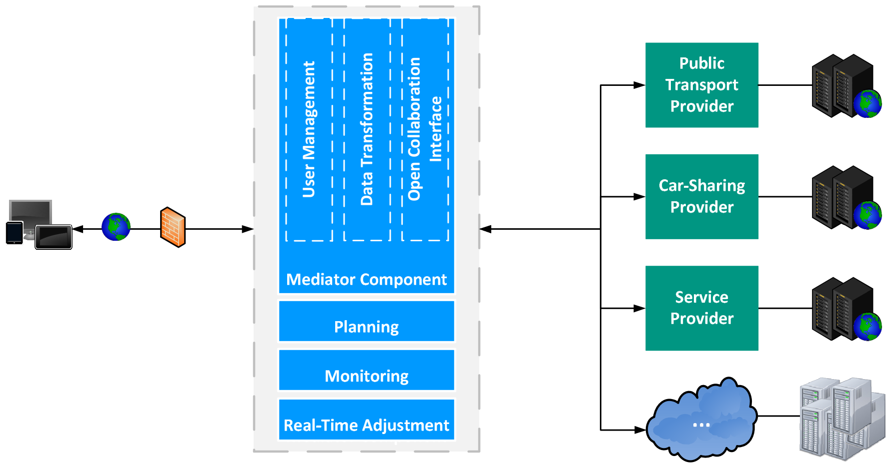

Fig. 3. General platform architecture to enact ITCS

The suggested architecture is implemented by an iterative approach. In a first stage we are implementing services for pre-trip planning and context based adaption of planned trips. Additionally to planning in general, we offer services to specify individual preferences in a user profile. This profile can also automatically be updated through the mobile app, if the user enables tracking of decisions and requests for mobility services. In order to create an interoperable implementation on customer level, we decided to offer these services by a web-based mobile application and a web-frontend. On provider level we integrated pre-existing information services based on their current API. Our implementation is based on extension and integration of systems of two mobility providers (RNV and Stadtmobil) and one service provider (PTV). Once a user requested a route, the mediator component communicates with PTV's xServer to get the results of the route calculation, additionally it coordinates interaction with the information systems of RNV and Stadtmobil. By integration of all results and customer preferences, the mediating component calculates an intermodal route which best fits to user and the current traffic situation. The current situation is retrieved through sensors of mobile devices and can be extended by third-party services (further collaboration partners of other domains such as weather forecasting). Results of this tactical route planning are presented to the customer.

As second iteration monitoring of the current situation will be implemented. This includes processing of incoming real-time information (traffic and provider related) in order to adapt trip stages, again this involve the planning steps described above. We plan to create push messages to keep the customer informed and suggest optimal mode switching (e.g. because an accident or a delayed tram). In a third iteration of implementation, the mediator will forward ticketing information to all affected providers in order to enable seamless ticketing based on booking through the known mobile app (thereby an additional debit card can be avoided).

5 Related Work

Only few research efforts have been taken on the coordination and cooperation of independent mobility and service providers in inter- and multimodal traffic. Some articles concerning intermodal freight transportation have been published, these mainly focus on methods derived from operations research in order to adjust planning along transport modes and handling of cargo [6–10]. Research regarding individual traffic is often not focused on intermodal traffic [11, 12]. Examples of cooperation between mobility providers can be found in Germany and Europe. In Barcelona, for instance, bike-sharing stations can easily be found nearby metro stations [4]. Holders of the "Mobil in Düsseldorf" season ticket can use public transportation as well as bike-sharing (240 minutes per day) and car-sharing (90 minutes per month). Comparable services are available in Hannover, Freiburg and Bremen [13]. Several research projects like Stuttgart Services [14] or BeMobility [15] deal with questions around integration and management of mobility concepts like car sharing, electrical vehicles and public transport in order to meet today's mobility needs. These projects consider implementing new intermodal mobility concepts with debit cards and specialized access points. However, initiatives are mainly local, based on rigid rate and cooperation concepts. Thus flexible integration of additional services is not covered conceptually. Furthermore optimization of route planning and adjustment is usually out of scope.

Also prosperous is development driven by automotive manufacturers that increase creation of new services, mobility concepts and investment in start-up companies with innovative mobility concepts. Daimler for instance is working on a consolidation of car-sharing services car2go and moovel supplemented by search services for parking space or load stations. Corresponding efforts can also be observed by other manufacturers such as BMW or Volkswagen. This strengthens the observation of increased importance of intermodal traffic and the combination of mobility and additional services. Nevertheless, currently an open integration platform across mobility providers which supports pre- and on-trip planning (including dynamical route adaption and real-time information across mobility providers) is still missing.

6 Conclusion

Traffic issues in larger cities require intelligent traffic control and lead to changed mobility behavior of people. Therefore demand for intermodal traffic and context-driven route adaption is increasing. The need for new services can be identified based on analysis of mobility patterns (as outlined in section 2). Implementation of these services can be supported by new forms of provider collaboration, which can be derived by analysis of pre-existing information systems, business processes and interfaces (as described in section 4). It should be noted that nowadays ad-hoc collaboration in general is not possible for providers because of two reasons: first of all common standard formats that allow exchange of real-time and accounting data are still not utilized, missing or under development; secondly a common architecture that enacts plug-n-play of providers is missing.

Throughout the article we presented a solution architecture that will enable mobility providers to create ad-hoc collaboration in order to fulfill customer demands based on individual preferences, route planning and current traffic situation. The architecture includes mechanisms for integration of supplementary services and providers. Currently we are implementing services within the proposed architecture to enact collaboration of providers of local public transport and car-sharing. To evaluate the proposed platform we are in cooperation with two major local providers. The implementation is driven be pre-existing systems and their extension. As a next step we plan to elaborate extension of current data standards to exchange provider and accounting information. Thereby we intend to widen the range of possible collaboration providers and lower the hurdle for integration (also of service providers of other domains). We are also planning to abstract general mobility patterns that might be relevant for all urban regions. The latter could be used to identify required services fast and easily.

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A Collaborative IT Network for Three Adriatic Maritime Ports

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Abstract. Collaborative IT networks are suitable to model and represent the interconnected maritime ports that in nowadays globalized world are poised for tremendous growth. Actually, there are already such strongly connected collaborative networks mainly serving national purposes. Although, there are almost no collaborative networks for maritime port B2B platforms for cross border services. Here, we present a pilot collaborative network that was built to serve in Adriatic Sea among three heterogeneous and autonomous maritime port community systems (PCS). Their integration was based on a cross border platform that dealt with several challenges and met all the key requirements set by the stakeholders. In this paper we present the design details of this innovative platform, the experimental results of the prototype and the potential for wide use.

Keywords: Maritime Ports, data exchange, web services, business2bussiness, cross border IT, port stakeholders, EDI exchange, port community systems.

1 Introduction

European Union has effectively undertaken actions in the field of maritime security and transportation services that led European ports to work towards creating cross border alliances. This is the case of a project named Adriatic Port Community (APC) [1] aiming to enhance the collaboration of port process of the participating ports (Venice, Igoumenitsa and Ploče) through the establishment of a common information interchange electronic platform. Almost all modern ports have developed Port Community Systems (PCS exploiting Information Technology to provide better passenger and maritime services. Interactions, exchanging, and collaborations among PCS are fast becoming a necessity in today's international freighting and transportation industries. Sophisticated logistics chains require an accurate flow of information for tracking, planning and control. Many sectors of the shipping and containerization industries already used Electronic Data Interchange (EDI) [2] as a natural technology for the communication of much of this vital information. Since the first efforts for data interchange in international trade the contributions of such applications, to governments and corporations, are primarily to provide models of

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successful applications to existing international processes, such as transportation and trade [3]. Port Community Systems have played a major role in facilitating and increasing the efficiency in movement of goods and passengers while allowing Customs and all the other interesting government departments to organize effective inspections [4]. This study revealed a great variety of existing port community systems in terms of features and implementations. While the needs of different ports vary, also PCSs usually differ quite a lot from each other. There is no golden rule or guidelines between them except the wide use of EDI for the paperwork similar to the IMO FAL forms [5].

Today's trend is Single Window for implementation of modern PCS that significantly help to organize and improve the efficiency of a collaborative network of PCSs. Admissible European directives and development frameworks and methodologies were examined [6] towards the efficient implementation of cross border service models. The APC project successfully recorded and described all the in-port stakeholder's needs but also the "cross border needs" to achieve quality of travelling services for passengers, security and goods transportation. In this paper we present the main outputs regarding the APC collaborative network named hereafter Global Single Window (GSW). Key points of the paper refers to the approaches regarding data restriction, data sharing, and user moderation.

2 The Needs and Requirements of a Cross Border Collaborative Network for PCSs

In Port Community Systems the required IT services are usually maintained and handled by the local port authorities covering all the needs and features that ensure a smooth working environment between the port stakeholders. Any PCS has to be aligned with all the national laws, European directives and obligations. Within APC project we expanded their functionality by creating special supplementary modules to the PCS to implement data exchange interfaces. The aim was to strengthen the relationship between ports, to make the procedures more efficient, harmonized and to reduce the time for administrative procedures linked to ship's arrival and departure. The analysis of the main process among the three port authorities, identified the key actors, the cases and the existing port procedures that could benefit from cross border data. In early stages of the analysis it was mandatory to create a new common web platform, based on the principle of "single window", for all the stakeholders and cross border processes. Each PCS had only to create a new software module for data exchange and there was not acceptable to perform significant modifications to the existing processes and data handling. There was identified a set of practical and useful processes, a universal communication protocol, the exchanged data format, a pairing of terms in four languages and an innovative process to moderate and handle the users and the data in the proposed collaborative network of port community systems.

3 Innovation / Contribution

3.1 Actor Identification

The port community processes and the role of port authorities have a direct impact in the way port communities are using ICT technologies. Consequently it is worth to enlist the main roles of all actors being part of a port community system that were identified for the APC ports: shipping agent, forwarding agent, port authority, harbor master, mooring services, terminal operator, waste treatment, vessel supplies, customs brokers, customs authority, police, security of port area, inspection services, fire department, gate control and haulers.

At the next stage we narrowed them down the roles that were interested and allowed to access cross border maritime port data: 1) Shipping agent, 2) Port authority, 3) Coast Guard, 4) Police, 5) Security of port area, 6) Customs Authority. There was also identified two global moderated roles named: 7) global administrator and 8) local port moderator. The global administrator was a special role to be used only for moderating the users with local port moderator, no other permission was allowed. Global administrator had no authority to perform moderation on attributes and parameters handled by the local authorities. Such actions were performed only by the local port moderators.

3.2 Data Sharing and Collaborative Operations in Maritime Ports

The inspiration to create collaboration network between maritime ports was born from four key areas. These key areas mainly use the data collected in the local port community systems which can be improved by enriching ship data retrieved from the other participating ports of the collaborative network.

For example a ship, carrying dangerous goods, which left from Venice with direction to Igoumenitsa must be declared at the departure in Venice (IMO FAL document 7). This information (data at Venice) may be used in Igoumenitsa (as extra input to OLIG PCS) in order to perform on time activities to handle safer and better the expected to ship's arrival dangerous goods.

First key area was related to the ship arrival and departure management. This manages port processes related to a ship's arrival and departure in/from the port up to the announcement, up to obtainment of the inward/outward clearance. It coordinates the exchange of documents, port information and decisions between the different public and private parties that interact with a member of the port community.

The second area was related to custom export clearance applications. This represents an up-to-date tool capable to provide the customs clearing readiness for export goods functionality and to set up the departure cargo manifest.

The third area was custom import clearance applications. This activity was designed to reinforce and speed up the import of cargo customs clearing operations at the port premises as early as possible. To achieve the expected result the implemented modules allowed to prepare the statement of incoming cargo manifest when it was certain that the ship called at the port of reference for the arrival, even when the ship was still be under way.

Last area was the parking space booking and in port traffic. The collaborative network can deliver extra information to help in port traffic and parking space automated estimators to perform better on congestion avoidance in port facilities and services. For example we the PCS can predict to have more personnel at the gates when a passenger ship unloads and loads thousands passengers and vehicles in a short period of time.

During the implementation step, APC created a set of on demand operations where port community users could fetch data from foreign port authorities on the collaborative network. Thus, the system provided authorized and analytical communication information among all the participating ports. The exchanged messaging and data was in XML format as described in [7] and the data was a superset of information based on IMO FAL documents and stakeholder requirement analysis.

3.3 Data Restriction and User Management of the Collaborative Network

The user authentication, role management and user profiling was based on the commonly used Lightweight Directory Access Protocol (LDAP) services. Each user in order to use the GSW should be authenticated based on the profile stored to the APC LDAP service. Moreover each participating port can dynamically moderate the privileges assigned to the roles of other collaborative ports based on the location of the user and the role. For example a port moderator of port A can restrict or permit the shipping agents of port B to access a subset of data belonging to port A. These set of privileges were also included accordingly to the LDAP schema.

The data restriction was a process triggered whenever a user tried to start a data retrieval operation. This restriction performed in two logical authentication levels.

- The first level of authentication takes place on the GSW platform and does not allow the user to create any data retrieval to the port.
- The second level of authentication was handled by the new implemented module in the local port community system. In this case the PCS through the module performs the second restriction data according to the parameters provided from the GSW and restrictions stored to the local PCS. With this feature the port authorities have the option to know who the recipient of the requested data is and perform extra restrictions actions accordingly.

The main objective for this innovative approach was to create cross border "teams". It was asked, by the stakeholders, to design an extra feature that the data submitted from a shipping agent user to a PCS A can be restricted and be available only to shipping agent users belonging to the same working company in port B. Without this extra feature it was possible, unintentionally to permit competitors to reach sensitive company data. With the second authentication level now we could separate the shipping agent roles based on their companies and create any motif of cross border – multinational trusted teams.

Summarizing all the above we present the two level of authentication in a short example of how we can have a cross border team between the user X@ppa (user from Ploce Port Authority) and user Y@vpa (user from Venice Port Authority).

step1: The user X@ppa will use the GSW to search for dangerous goods in a ship that comes from Venice.
step2: The GSW will use the PPA's role/privileges matrix to see if the dangerous goods service at VPA is available for the shipping agents of PPA.
step3: If step2 permits the access the GSW starts the appropriate service of VPA including all the details related to the profile X@ppa (team tag, team members etc.).
step4: the PCS module of VPA PCS will evaluate the team parameter and accordingly it decides if the related data was submitted from a user (in VPA) of the same team.
step5: Accordingly the returned data are plotted to the screen of user X@ppa.

Implementing the First Level of Authentication the GSW LDAP service stores a logical two dimensional matrix for each port where the operations of the prototype were correlated with the eight (8) different user types as were described in paragraph 3.1. According to the privileges given on this matrix the GSW platform enable's or disable's for each user the available operations.

The flow of processes related to the second level of authentication includes a matching mechanism, by port authority, in order to map the teams with users on the local port community system. This functionality was applicable only for local port community systems where the submitted data were linked with GSW users or with the cross border "teams".

3.4 The Architecture of the Collaborative Network

The architecture was a web based platform enabling intelligent and secure exchange of information between port stakeholders of the three Adriatic port community systems. The architecture challenges were set to be able to update information and maintenance system that supports per year more than 10000 sea going ship calls, create innovative efforts for safely and trusted data, increase productivity and quality for maritime services, semi-automated acquisition of master data, single window implementation. In Figure 1 the most important modules were depicted in order to create a representation of the used approach. The GSW platform consists of: GSW Application Services, GSW Web Service (client), GSW Application, GSW Web Interface, GSW Application layer, Open LDAP (server) and a Database Server. The three participating PCS implemented a web service that followed the APC protocol. A thorough description of the communication protocols, LDAP and database schemas can be found at [1].

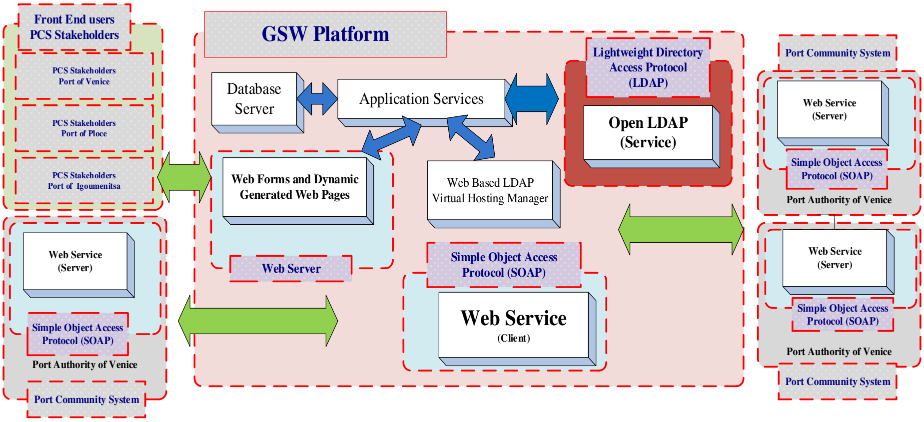

Fig. 1. The overall architecture of the collaborative maritime network

4 Experimental Results of the Collaborative Network

The most common communication method for daily port processes were, as anticipated, the port community system, telephone and fax, as well as e-mail. For the shipping companies the main volume of data exchange and internal communication was served via their corporate information systems. In very rare occasions for port to port communications were performed by formal communication procedures. Such processes usually involved other public sector services like customs authorities. Within APC prototype was performed quantitative and qualitative evaluation. The quantitative evaluation benchmarked the prototype under low and high stress. The qualitative analysis was based on evaluating questionnaires filled by the port stakeholders.

4.1 The Quantitative Analysis of the Collaborative Network

To generate test cases the methodology was based on a three-step procedure from a fully detailed use case. The first phase created a set of use case scenarios randomly generated by identifying combinations of main and alternate flows on the basis of the use case description. Once the full sets of scenarios were identified, the next step was to describe test cases with a variety of conditions and data elements required to run the scenarios. Since all test cases were identified, there were reviewed and validated thoroughly to ensure accuracy and search for redundant or missing test cases. Once they were approved by the stakeholders, the final step was to substitute actual data values. However, some of the interactions with the system did not included data input, but user actions such as clicking with the mouse in a specific area of the screen or scrolling. The test bed was based on a tool named SOAPUI and we run a complete set of tests to each participating PCS. The stress test was performed as a debug tool and as evaluation tool to estimate the traffic and limitations of the different implementations. Moreover the stress test was an indicator of the scalability of the system. Details of the results are out of the scope of this paper and can be found at [1] but the potential of generalization was based on these tests.

4.2 The Qualitative Analysis

Local stakeholders evaluated the system. Evaluation procedure included presentations and training of the GSW during bilateral meetings between APC team members and port-related stakeholders. During demonstrations there was presented the usage of both systems to stakeholders, and they had the opportunity to discuss about related issues and to suggest changes and future improvements. The developed GSW system would be used every day by the customs and harbor master officers, but only in special occasions by the shipping companies. The overall assessment of the Global Single Window application, based on the demonstration and discussion sessions with the representatives of each stakeholder, led to the following output that:

- 20% certain modifications required to be made
- 50% suitable for their needs as is
- 30% minor improvements were required

Overall, the GSW application was positively evaluated with the following key benefits for the customs operations:

- Faster and more reliable exchange of information.
- Estimation of anticipated workloads.
- Redundant channel of updating delays in ship arrivals.
- Statistical record of arrivals/departures for ships, trucks, private vehicles.
- Complementary tool to the existing one.

Custom officers stressed that documents exchange and communication from and towards the customs authority is legally restricted and usually confidential. Due to this attribute, the customs employees will normally be able to receive and utilize the information from the GSW system, but only provide limited amount of data to other users only through the port community system. The Coast Guard representatives were highly positive about the functionalities of the features presented, because they would have fast and systematic access to well-structured data allowing them to crosscheck passenger or vehicle movements and to improve other everyday operations.

5 Potential Generalization and Conclusions

The success of the developed IT collaboration network was multidimensional. The project consortium successfully identified all the necessary non-functional requirements for designing and implementing the cross border data exchange system. The test of the developed system proved that the data, related to departure of a ship, stored in a maritime port community system is very useful to the destination port. In order to implement this collaborative network, there were a lot of difficulties such as different interpretation of data, national laws, added effort and requirements to the existing port community systems. The qualitative and quantitative evaluation of the prototype showed that between two ports with direct ship transportations connections should perform direct or in-direct data exchange and so to raise the provided port services and reduce their load. The benchmarking tests of the pilot showed that the scalability of the network was quite impressive and even a network of 100 ports could be handled by the proposed collaborative architecture. The feedback gathered, from the three PCS, showed that all port authorities with often direct ship connections, either at national level or international level, should make efforts on establish PCS data exchange.

Results of the pilot suggest the following improvements for similar applications: Existing port community systems should create more complex data sharing modules in order to enrich their available data presented to the stakeholders. Certified users could use directly the port community system user interface to access cross border available port data. Secondly the directory services that were handled by the GSW LDAP server and the proposed two levels of authentication were highly connected to the efficiency of the modules implemented by the port community systems. For future implementations, it is suggested to create a distributed LDAP service over the centralized one, used in APC collaborative network, which would offer better flexibility and data control.

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Integration of Social Concerns in Collaborative Logistics and Transportation Networks

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Abstract. Freight transport optimization, long based solely on an economic approach, happen today through the integration of environmental and/or social concerns, in line with the objectives of sustainable development. In the case of Small and Very Small Enterprises, these objectives cannot be reached individually, and these companies have to join their efforts to find collective solutions. Therefore, the Fleet Size and Mix Vehicle Routing Problem (FSMVRP) was adapted to take into account social objectives, and results are compared to Vehicle Routing Problem with homogeneous fleet. An exact mathematical formulation of the extended problem was developed. Computational experiments for the problem formulation are performed using CPLEX and give a solution of a small instance to illustrate the problem. The model is tested on a case study of optimal parcel pickup, from many manufacturers to a common depot in the agri-food sector.

Keywords: Sustainable logistics network, collaborative network, Social concerns, Products pickup optimization, agri-food sector.

1 Introduction

The topic of Sustainable Collaborative Networks has been of great interest for the last decade both from academics and practitioners. In this context, logistics systems must now meet the requirements of sustainable development, namely: economic; environmental and social issues. These requirements are more difficult to reach for SMEs, because their logistics performance does not allow them to engage in a sustainable approach [1] [2]. Furthermore, Just in Time-JIT policy has been implemented in most sectors: to deliver faster, more frequently, and in small quantities. These changes in flow management explode the logistics' costs for SMEs, which endangers the entire implementation of a sustainable development approach. For this reason, collaboration has become one of the key issues in supply chain efficiency, in which optimization approaches are expected to play a crucial role [3]. In the French agri-food sector, transportation costs represent about 20% of the final cost which then emphasizes the importance of the Vehicle Routing Problem-VRP [4].

The objective of this research is to optimize the upstream logistic cost of a common depot of a set of SMEs in the agri-food sector. Depending on the sum of products to be picked up from these manufacturers, the fleet of vehicles has to be

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adapted in order to reduce the total costs. In addition, these agri-food manufacturers want to include sustainability into their logistics performance, as this would enable them to enhance their brand in the current market, and meet upcoming regulations. Thus, the problem considered in this paper is a Fleet Size and Mix Vehicle Routing Problem (FSMVRP) that is adapted to take into account the social objectives, while focusing on the picking up of products from several manufacturers, within logistics network collaboration.

2 FSMVRP Problem: Definition and Overview

To enhance an effective collaboration in a logistics network of products pickup or deliveries, the use of vehicles routing remains among the least costly scenarios of collaboration [4]. Most of the time, VRP is based on a combination of “fleet acquisition”, “depreciation costs” and “transportation costs” for the routing plan [5]. Logistics planning is a multifaceted field with an increasing complexity in the decision-making process [6]. The traditional VRP is usually based on a homogeneous fleet size problem and many researchers have used these assumptions [7]. However, VRP becomes more complex when the vehicle fleet is heterogeneous, i.e., vehicles differ in their equipment, capacity, and cost [8]. In real life, this configuration has multiple advantages. Indeed, the fleet composition can be revised to better suit customer needs [9]. Therefore, vehicles of different carrying capacities provide capacity according to the customers’ varying demand, in a more cost effective way [10]. Moreover, it is possible that customers on efficient route may require smaller vehicles to access urban areas, avoid physical restrictions on vehicle size and weight. The reverse may be true in some case for larger vehicles [11]. This field of research is still in full swing because of the large growth in vehicle types and the implementation of new types of constraints on this type of problems [6].

A thorough analysis of the literature shows that almost all papers have addressed the problem only considering the objective of minimizing the economic cost, with the main parameters considered has fixed or variable cost [6]. Few recent scientific studies have also considered the FSMVRP with environmental objective by minimizing the fuel consumption and/or CO2 emissions of vehicle routing [12]. However, social considerations are often neglected and it seems that no scientific work addresses the social dimension in modeling FSMVRP. For this reason, there is a real need to integrate social issue, which will be stated in the following sections. An adequate mathematical decision model will be proposed, tested and validated within a collect pickup case study.

3 Modeling of Fleet Size and Mix Sustainable Routing Problem

This section presents a new version of the traditional approach for the FSMVRP. This new model reduces social costs by enhancing the use of different vehicles types.

3.1 Social Concerns to Integrate in Routing Problems

The secondary effects associated to transport in a logistics network, include accidents, noise, air quality and traffic congestion. Therefore, the adverse social impacts on various stakeholders have to be considered when evaluating sustainable routing systems. Two sorts of stakeholders are mostly involved: carriers and residents. Carriers and especially the drivers involved are the main actors of transport, and their needs and expectations should be taken into account. Any reduction in the number of kilometers traveled, helps reducing the accidental risks. Decreasing congestion by reducing the number of vehicles involved in transport also plays a role in reducing the risk of accidents. For our purpose, we chose to use the traveling distance for the accident risk assessment.

The second type of stakeholders is the residents, who are not directly involved in goods transportation, but share the same transport network. Vehicles Congestion, noise as well as blocking access because of parked or blocked trucks, and other situations, are negatively considered by most inhabitants. Thus, a transport system that reduces congestions, or limits the use of large vehicles in transportation grids can be considered as a sustainable solution. Note that all of these indicators are difficult to quantify empirically, because they are linked to more sociological aspects. For this reason, we consider the number and the size (type) of used vehicles as an estimation of other less quantifiable indicators of the social pillar of sustainable development.

3.2 General Assumptions and Format Definition

As in normal VRPs, we assume that there is only one depot in our system. The schedules are one-time plans and the time horizon is assumed to be a single period e.g. one day. It is assumed that all goods are conditioned in parcels with different volumes and weights. The fleet consists of vehicles of multiple types with differing curb weights and load capacities. All vehicles start their routes at time zero. Vehicles are assumed to travel with a constant speed that depends on the destination (urban or regional). Each vehicle returns to the depot once completed its respective trips. All waiting times are assumed to be equal to zero and all sorts of unexpected delays are disregarded, that is, a vehicle never becomes inactive until it returns to the depot. At each stop, the vehicle has a loading time which is relative to the vehicle type. Note that we are dealing with a problem of products pickup from manufacturers to a common depot. After loading, vehicles immediately go to their next stop which can either be a new manufacturer or a return trip to the depot.

There is a restriction on the total duration of each route: Vehicles tours have a strict deadline (4 hours in our case), and the arrival time at the depot cannot exceed this deadline. There is limitation on the vehicle speeds, for regional delivery only average vehicle speeds above 45 km/h are considered.

Our problem is defined as complete graph $G(N, A)$ where $N=\{0\}U\{1,\dots,n\}U\{n+1\}$ defines the set of different nodes and $\{0\}$ and $\{n+1\}$ represent the depot and A is the set of arcs between each pair of nodes. The set of manufacturers is represented by $N_c = \{1,\dots,n\}$. For every arc (i,j) in A, the distance between nodes i and j is defined as d_{ij}.

For all $i \in N_c$, there is a positive demand of q_i to be satisfied. For each manufacturer, there is an associated loading time which is directly proportional to the vehicle type but not to the demand of that manufacturer, because we are dealing with very small demands which are delivered in parcels. The demand at the depot is considered to be zero ($q_0 = 0$; $q_{n+1} = 0$).An unlimited heterogeneous fleet of vehicles is available. This fleet is composed of $V = \{1,..., K\}$ different vehicle types, each with a different capacity. The following are the constraints used for traditional FSMVRP:

i. Each manufacturer should be visited once by one vehicle.
ii. Routes must start and finish in the depot.
iii. Vehicle capacity should not be exceeded.

3.3 Modeling FSMVRP under Social Objectives

Based on the literature, we adopted the formulation of FSMVRP to be consistent with the problem addressed. The following notations are used:

$\boldsymbol{n}$ = number of manufacturers (nodes) ; $\boldsymbol{K}$ = number of vehicle types;
$\boldsymbol{Q_k}$ = total authorized weight of a type k vehicle $(Q_1 < \ldots < Q_K)$;
$\boldsymbol{f_k}$ = fixed cost of a type k vehicle $(f_1 <\ldots < f_k)$; $\boldsymbol{\beta_k}$ = cost /km of a type k vehicle;
$\boldsymbol{\alpha_k}$ = cost /ton.km of a type k vehicle ; $\boldsymbol{\delta_k}$ = cost /ton of a type k vehicle;
$\boldsymbol{C_k^P}$ = capacity (useful load) of a type k vehicle ; $\boldsymbol{q_i}$ = demand for customer i;
$\boldsymbol{E_{empty}^k}$ = CO_2 emission of an empty vehicle of type k; $\boldsymbol{d_{ij}}$= distance of the arc ij;
$\boldsymbol{E_{full}^k}$= CO_2 emission of full truckload of type k vehicle;
$\boldsymbol{E_{manufacturing}(k)}$ = CO_2 emission of manufacturing type k vehicle;
$\boldsymbol{D(k)}$= Lifetime in km of type k vehicle;
$\boldsymbol{T}$= Vehicle routes deadline ; $\boldsymbol{t^k}$ = Unloading time of type k *vehicle*;

In addition, the following decision variables are used:

$\boldsymbol{y_{ij}^k}$: flows on arcs (i, j) loaded on type k vehicle;
$\boldsymbol{Z_j^k}$: 1 if type k vehicle visit j, and 0 otherwise; $\boldsymbol{t_{ij}}$: Time runs on (i, j);
$\boldsymbol{x_{ij}^k}$: 1 if type k vehicle is assigned to (i, j), and 0 otherwise;

An infinite set of each vehicle type is assumed. The sum $\sum_{j=1}^{N} x_{0j}^{k}$ represents the number of vehicles of type k used. Generally, to incorporate sustainable aspects, we concentrate on these fours factors: the type and the number of vehicles used, cargo load and the distance traveled. Then the objective function (1) is defined as follow:

$$Minimize \sum_{j=1}^{N} Q_k\, x_{0j}^k \; * \; \sum_{k\in V} \; \sum_{(i,j)\in A} \; d_{ij}\, x_{ij}^k$$

To assess economic and environmental costs of social optimization solutions, we adopted these equations:

- Environmental function (CO_2 emissions):

$$\boldsymbol{\varepsilon}(g) = \sum_{k\in V} \sum_{(i,j)\in A} d_{ij} * \left[(\boldsymbol{E}^k_{full} - \boldsymbol{E}^k_{empty}) * \frac{y^k_{ij}}{\boldsymbol{C}^P_k} + \boldsymbol{E}^k_{empty} + \frac{\boldsymbol{E}_{manufacturing}(k)}{\boldsymbol{D}\,(\mathrm{k})} \right] \quad (2)$$

- Economic function:

$$Cost(€) = \sum_{k\in V} \sum_{j\in N} f_k x^k_{0j} + \sum_{k\in V} \sum_{(i,j)\in A} \alpha_k\, d_{ij}\, y^k_{ij} + \sum_{k\in V} \sum_{(i,j)\in A} \beta_k\, d_{ij}\, x^k_{ij} + \sum_{k\in V} \sum_{(i,j)\in A} \delta_k\, y^k_{ij} \quad (3)$$

From literature, all constraints related to a FSMVRP were adapted, and a time constraint was added for routes (constraint 11). So, the constraints brought to our model are as follows:

$$\sum_{i=0}^{n} x^k_{ij} = \sum_{i=0}^{n} x^k_{ji}, \forall k \in V, \forall j \in N \ (4) \quad ; \quad \sum_{i=0}^{n} x^k_{ij} = Z^k_j, \forall k \in V, \forall j \in N \ (5)$$

$$\sum_{k=1}^{m} Z^k_j = 1, \forall j \in Nc \quad (6); \quad ; \quad \sum_{j\in N} y^k_{0j} = 0 \quad (7)$$

$$\sum_{k\in V} \sum_{j\in N} y^k_{j0} = \sum_{i\in N} q_i \quad (8) \quad ; \quad y^k_{ij} \le \sum_{k\in V} Q_k x^k_{ij}, \ \forall (i,j) \in A \ (9)$$

$$\sum_{i=0}^{n} y^k_{ij} + q_j * Z^k_j = \sum_{i=0}^{n} y^k_{ji} \quad \forall k \in V, \forall j \in Nc \ (10)$$

$$t^k \sum_{(i,j)\in A}^{n} x^k_{ij} + \sum_{(i,j)\in A}^{n} t_{ji}\, x^k_{ji} \le T \quad , \forall k \in V \quad (11)$$

$$y^k_{ij} \ge 0; \ t_{ij} \ge 0 \ \forall (i,j) \in A\, \forall k \in V \ (12) \quad ; \quad y^k_{ii} = 0, \ \forall i \in N, \forall k \in V \quad (13)$$

$$x^k_{ij} \in \{0,1\}, \ \forall (i,j) \in A, \forall k \in K \quad (14) \quad ; \quad Z^k_i \in \{0,1\}, \ \forall i \in A, \forall k \in K \quad (15)$$

Constraint (4) ensure that a vehicle that arrives at a manufacturer will also be the same type that leaves, while constraints (5) and (6) state that each manufacturer is visited exactly once, so the type of vehicle arriving and leaving one particular manufacturer has to be the same. Constraints (7) and (8) indicate that vehicles are empty when they leave the depot and must return loaded. In (9), the total load on a trip is constrained not to exceed the capacity of the vehicle assigned to that trip and equation (10) represents the movement of goods assuming that all manufacturer demands must be satisfied. The constraint of max time of a route is represented in (11). Constraints (12) ensures that the flow and time are non-negative and (13) means that there is no flow from a manufacturers to itself; finally constraints (14) and (15) define that each arc has the value 1 if it is used and 0 if it is not used by a vehicle of type *k*.

4 Case Study

In order to test the model, one of our professional collaborators (3PL) gave us the following case study. A common platform (depot) located in Saint-Etienne processes every day parcels pickup from different manufacturers. In a given day, 10 addresses are serviced in the Loire region in France. The demand vector is given by table 1:

Table 1. Manufacturer's demand

Manufacturer	1	2	3	4	5	6	7	8	9	10
Demand (Ton)	0.09	0.11	0.07	0.5	0.7	0.03	0.11	0.06	0.05	0.6

4.1 Optimization Approach

First, our mathematical model was programmed in CPLEX. Then, MAPPOINT software is used to represent manufacturers and depot locations geographically. Then, the software provides a distance matrix between the various locations according to their address. Then, this distance matrix with other data from the case study is introduced in our model via the optimization software CPLEX. The execution of our optimization program provides the optimal delivery routes depending on selected objective (economic, environmental or social). After that, all scenarios can be represented geographically in MAPPOINT software. To operate our case study, we used a set of parameters, summarized in the table 2.

Table 2. Parameters of optimization (adapted from [13] and [14])

Category	Type of vehicles	Total authorized weight (ton)	Useful load (ton)	Cost/km	Cost/ton	Fixed Cost	E^k_{Empty} (g/CO$_2$)	E^k_{full}(g/CO$_2$)	$E_{manufacturing}$ /km	Loading time (min)
LDV*	**1**	**1.5-2.5**	**0.7**	**0.15**	**0.04**	**104.84**	**68.4**	**68.4**	**8.3**	**7**
HDV**	**2**	**3.5**	**1.4**	**0.23**	**0.05**	**111.58**	**100.9**	**101**	**10.5**	**10**
HDV**	**3**	**5-6**	**2.84**	**0.25**	**0.07**	**111.58**	**107**	**154**	**14.2**	**17**

LDV:** light duty vehicles * HDV:** heavy duty vehicles

4.2 Results

In this case study and depending on fleet composition, the social optimization model presents the following results for direct pickup scenario (DC) and for social VRP:

Table 3. Summary of results

		DC	***Social VRP***			
	Fleet	**Type 1 (Best fleet)**	**Heterogeneous**	**Homogeneous**		
			Type (1; 2; 3)	**Type 1**	**Type 2**	**Type 3**
Assessment	**Economic**	262.2	105.8	129.55	*91.158*	117.38
	Environmental	17106	12132	*11252*	13680	14297
	Social	4460.6	*452.05*	1173.6	859.39	1225.9
	Distance	223.03	*111.45*	146.7	122.77	*111.45*
	Number of routes	**10**	**2** : 1 of type 1 and 1 of type 3	**4**	**2**	**2**

Routes relevant to the use of different fleets are summarized in the following table:

Table 4. Routes of various scenarios

Fleet	*Composition*	*Routes*
Homoge-neous	**Type 1**	Route 1: (0,5,0); Route 2: (0,10,0); Route 3: (0,1,4,3,0); Route 4: (0,9,2,8,6,7,0);
	Type 2	Route 1: (0,2,7,6,8,5,0); Route 2: (0,9,3,1,4,10,0)
	Type 3	Route 1: (0,9,3,1,4,10,5,0); Route 2: (0,2,8,7,6,0)
Hetero-geneous	**Type (1; 2; 3)**	Type 1: Route 1 (0,2,6,7,8,0)
		Type 2: No Route (Type not used)
		Type 3: Route 1: (0,9,3,1,4,10,5,0)

For the discussed case study, the model gives different results depending on the fleet composition. First, the basic scenario with direct pickup (DC) from the manufacturers to the depot has to be assessed. In direct pickup scenario, the use of a homogeneous fleet of type 1 vehicles gives better results than homogeneous fleets that consist sequentially of type 2 and type 3 vehicles.

The second finding is that social optimization for vehicle routing gives best results than direct pickup scenario, whatever the composition of the fleet used and whatever the assessment criterion. This is explained by the fact that direct pickup scenario requires more vehicles (10 vehicles) and travels longer distances.

The third important point with this model is that the use of a heterogeneous fleet gives the best social results and a good compromise of economic and environmental cost than the use of homogeneous fleet. Indeed, the use of a homogeneous fleet of type 2 vehicles significantly decreases the economic cost, but explodes at the same time the environmental and social costs. And in the same way, using a fleet of type 1 vehicles reduces the environmental cost but not the economic and social costs. While the scenario using a homogeneous fleet of type 3 vehicles, dramatically increase all costs (economic, environmental and social) because it uses 2 large vehicles, despite the fact that it travels the same distance as the scenario with a heterogeneous fleet. Using a heterogeneous fleet can sometimes substitute a large truck with a low fill rate, by a full small truck. Thus minimizes the economic cost while generating fewer $CO2$ emissions, less noise and less congestion.

Another observation concerning social optimization is that the routes to follow depend on the fleet composition. Thus, the use of a fleet with type 2 vehicles or with type 3 vehicles requires 2 routes, but in the first case, travels are 122.77 km long while in the second cases, travels are only 111.45 km long. This is explained by the fact that routes depend on the vehicles capacity of the fleet used.

5 Conclusion

The optimization of freight distribution for SMEs needs an improved shared logistics network to meet the requirements of sustainable development and therefore, the performance of their upstream logistics are not in line with the social objectives.

In this paper, the pickup network was designed with a single platform (collect center) and the routing problem was solved taking into consideration the social pillar of sustainable development. Due to the constraints of low volume and limited time for delivery, the Fleet Size and Mix Vehicle Routing Problem (FSMVRP) was studied. Starting from the literature on this topic, new social objective functions were developed to minimize the traveled distance and the number and the size of the vehicles used to reduce the risk of accidents, congestion and noise.

The aim of this paper is to demonstrate the importance of the choice of the type and number of vehicles in social optimization, and that routes depend on fleet composition. A linear multi-objective programming optimization model was developed that compare optimal social solutions depending on the fleet composition. Unfortunately, due to long computational delays, this model can support only small instances. Clearly, this difficulty should be dealt with in future work. Our work, as presented, represents the first step to designing shared logistics schemes that fulfill the requirements of sustainable development.

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Infomobility for "Car-Driver" Systems: Reference Model and Case Study

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Abstract. The proposed approach to infomobility is based on the concepts of cyber physical system and context-aware decision support. The "car-driver" system is considered as a collaborative cyber-physical system. Its dynamic nature is addressed via the context management technology. The context is modeled as a "problem situation." It specifies domain knowledge describing the situation and problems to be solved in this situation. An application of these ideas is illustrated by an example of decision support for tourists travelling by car. In this example, the proposed system generates ad hoc travel plans and assists tourists in planning their attraction attending times depending on the context information about the current situation in the region and its foreseen development.

Keywords: cyber-physical system, infomobility, context-aware decision support, tourist trip planning & scheduling.

1 Introduction

Infomobility infrastructure plays an important role in attaining higher traffic and transport efficiency as well as higher quality levels in travel experience by the users. It can be defined as operation and service provision scheme whereby dynamic multi-modal information is selected, used and distributed to the users both pre-trip and, more importantly, on-trip [1]. The proposed approach to infomobility is based on the concepts of cyber physical system and context-aware decision support.

The application of the concept of cyber-physical system (CPS) could enable higher flexibility and sustainability of transportation systems. CPS tightly integrate physical systems and cyber (IT) systems based on interaction between these systems in real time. This is a relatively new research field demanding for new approaches and techniques. CPS rely on communication, computation and control infrastructures commonly consisting of several levels for both the physical and the IT-part with sensors, actuators, computational resources, services or communication facilities.

CPS are oriented to domain independent architectures and technologies for supporting cyber-physical artefacts and networks [2]. CPSs open the avenue towards

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new kinds of information services by exploiting the ability of physical systems to provide context information in a quality so far not available [3].

A good recent state-of-the-art review of different CPS approaches and supporting technologies can be found in [4]. Among the other conclusions, Horvath and Gerritsen conclude that “the next-generation of CPSs will not emerge by aggregating many un-coordinated ideas and technologies in an incremental fashion. Instead, they will require a more organized and coordinated attack on the synergy problem, driven by an overarching view of what the future outcome should be”.

Sharing information and services between different devices independently of their physical location is achieved via usage of the ubiquitous environment technology.

Current developments of in-vehicle information systems (e.g., Ford’s AppLink, Chrysler’s UConnect, Honda’s HomeLink, etc.) make it possible to benefit from integration of new decision support methodologies into cars to provide richer driving experience and seamless integration of information from various sources.

Context-aware decision support is required in situations happening in dynamic, rapidly changing, and often unpredictable distributed environments such as, for example, roads. Such situations can be characterized by highly decentralized, up-to-date data sets coming from various information sources. The goals of context-aware support to operational decision making are to timely provide the decisions maker with up-to-date information, to assess the relevance of information & knowledge to a decision, and to gain insight in seeking and evaluating possible decision alternatives.

Context is any information that can be used to characterize the situation of the considered entity where an entity is a person, place, or object that is considered relevant to the interaction between a user (driver) and a system (service network), including the user and system themselves (adapted from [5]). The context is purposed to represent only relevant information and knowledge from the large amount of those. Relevance of information and knowledge is evaluated on a basis how they are related to a modelling of an ad hoc problem.

The theoretical fundamentals of the approach are built around ontologies. The ontologies are a widely accepted tool for modeling context information. They provide efficient facilities to represent application knowledge, and to make objects of the dynamic environments context-aware and interoperable.

The proposed fundamentals are supported by advanced intelligent technologies with their application to Web. The developed context-aware CPS has a service-oriented architecture. Such architecture facilitates the interactions of collaborating service components and the integration of new ones [6, 7, 8].

The rest of the paper is structured as follows. Section 2 proposes the reference model of the proposed CPS. Section 3 illustrates the application of the reference model in the area of tourism. Main research results are summarized in the conclusion.

2 Reference Model

As it was mentioned, the developed reference model relies on the Web-service technology. In this framework, the resources of the CPS are represented by

Web-services. Each resource is characterized by a profile describing its capabilities. Due to the representation used a service network comprises Web-services representing resources which provide informational and computational services for information support.

Interaction between services requires interoperability at different levels. The interoperability at technical and syntactic levels is achieved via usage of the common enterprise service bus (e.g. OpenESB, fig. 1). The interoperability at the level of semantics is addressed via an ontology-driven approach. It assumes usage of common semantics and terminology described via ontologies. It is proposed to have one common high-level application ontology. It generalises knowledge from internal ontologies of participating services. The context is also represented in terms of the application ontology. It is updated depending on the information from the environment and as a result of services' activities in the community.

The ontology slice that describes a service at a certain point of time is its abstract context. It is formed automatically (or reused) applying ontology slicing and merging techniques [9] and updated depending on the information from the environment and as a result of the service's activity in the community. The purpose of the abstract context formation is to collect and integrate knowledge relevant to the current task (situation). The information sources defined in the abstract context provide the information that instantiates the context and forms the operational context. The operational context updates defines the behaviour of the service. The ability of a system (service network) to describe, use and adapt its behaviour to its context is referred to as self-contextualization [10]. The presented approach exploits the idea of self-contextualization to autonomously adapt behaviours of multiple services to the context of the car-driver system in order to provide support according to this context and to propose context-based decisions.

A concrete description of the current situation is formed, and the problem at hand is augmented with additional data. On the knowledge representation level, the operational context is a set of RDF triples to be added to the smart space by an appropriate service. Therefore, other services can discover these RDF triples and understand the current problem.

In [11] service *i* queries up-to-date information from the operational context through smart space in accordance with the task specified in the service's ontology. Services *j* and *n* are involved in solving a particular task. They form the operational context related to this task and based on the abstract contexts of the services. This operational context is described by the smart space service ontology, which also corresponds to the current task and integrates abstract contexts of the involved services.

The embedded Web-services generate a set of feasible solutions (plans) for the current situation. The set of plans is generated using the constraint satisfaction technology. A plan is a scheduled set of actions for the driver and services of CPS. An efficient plan is selected from the set and proposed to the driver for approval. If the plan is approved by the driver, the corresponding service community is organized to support the plan. Otherwise, another plan is taken up. The process of re-planning is an iterative process repeated until a plan that suits the driver's needs and preferences is found. The approved plan is thought to be the guide to actions of the driver and services of CPS.

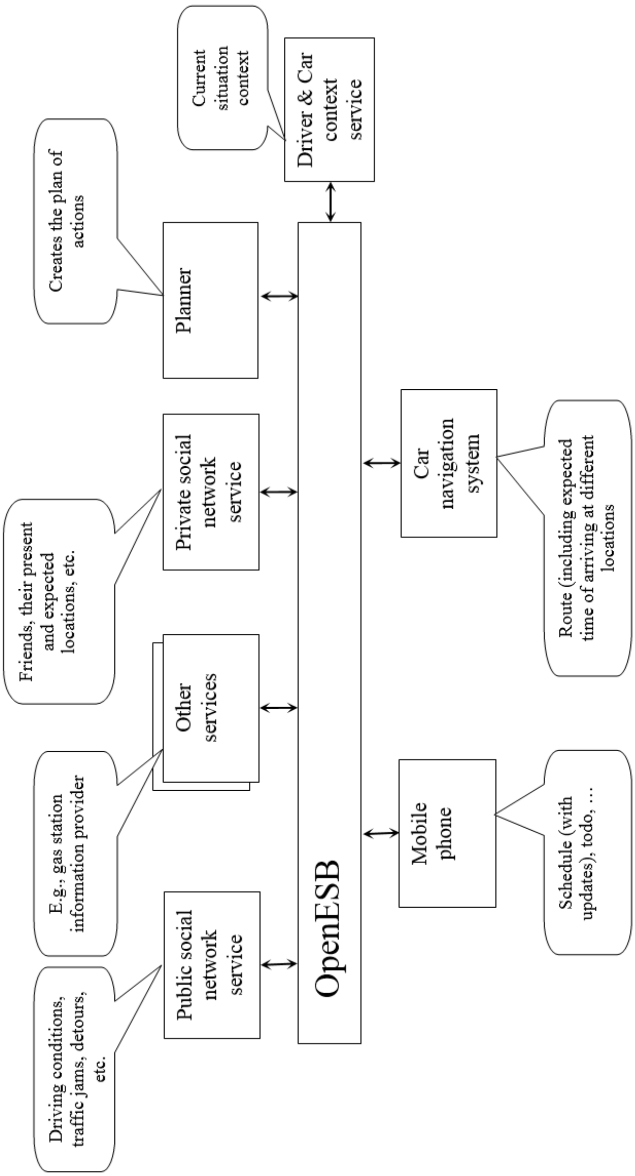

Fig. 1. Example services integrated via OpenESB

The option of rejection is provided for two reasons. Firstly, the situation on a road is a rapidly changing one – something may happen between the moment when a plan is selected and time when the driver is making the decision. Secondly, not all driver's preferences could be taken into account correctly. In this case, when the driver rejects the plan, his/her preferences are re-calculated accordingly.

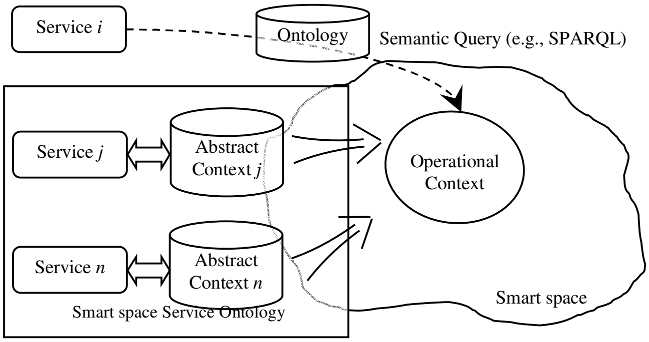

Fig. 2. Reference model of smart space-based service interaction for infomobility

In order for such system to operate efficiently, a number of issues are to be resolved. The proposed approach is aimed at coordinated design and run-time configuration of cyber physical human system integrating the car, driver and services, and incorporates some techniques and models in order to achieve this.

3 Case Study "Tourist Information Support"

Recently, the tourism business is getting more and more popular. People travel around the world and visit museums and other places of interests. They have a restricted amount of time and usually would like to see many museums. In this regard a system is needed, which would allow assisting visitors (using their mobile devices), in planning their museum attending time depending on the context information about the current situation in the museums (amount of visitors around exhibits, closed exhibits, reconstructions and other), traffic situation, and visitor's preferences.

Mobile devices interact with each other through a smart space [11, 12] (a virtual space enabling devices to share information independntly of their locations) implemented via an open source software platform (Smart-M3) [13] that aims at providing a Semantic Web information sharing infrastructure between software entities and devices in the form of blackboard. In this platform, the ontology is represented via RDF triples (more than 1000 triples). Every visitor installs a smart space client to his/her mobile device. This client shares needed information with other mobile devices in the smart space. As a result, each mobile device can acquire only shared information from other mobile devices. When the visitor registers in the environment, his/her mobile device creates the visitor's profile (which is stored in a cloud and contains long-term context information of the visitor such as his/her preferences). The information storage cloud (not computing, which is distributed among the services of the smart space) might belong to the system or be a public cloud. The only requirement is providing for the security of the stored personal data. The profile allows specifying visitor requirements in the smart space and personalizing the information and knowledge flow from the service to the visitor.

The tourist downloads software for getting intelligent tourist support. Installation of this software takes a few minutes depending on operating system of mobile device. When the tourist runs the system for the first time, the profile has to be completed. This procedure takes not more than 10 minutes. The visitor can fill the profile or can use a default profile. In case of default profile, the system cannot propose preferred exhibitions to the visitor.

The in-vehicle information system is also connected to the smart space (SS in Fig. 3) for a higher interaction level of decision support. For example, let us consider Ford's AppLink system. The AppLink provides the current user location and other car information to the operational context of the smart space automatically. Based on the operational context complemented with information from other sources, the attraction information service together with the recommendation service [14, 15] propose an attraction visiting plan and put it into the AppLink's in-car navigation system (Fig. 3).

Other services contributing to the creation of the operational context and involved in the scenario include: attraction information system (AIS) providing textual and multimedia information about the attractions, attraction recommendation service (RS) analysing appropriateness of attractions and points of interests to user preferences, croud sourcing service (CroudS) analysing feedback of other users with similar interests related to corresponding attractions and points of interests, motorway related information services (MSA), and car dealer service (CarS) monitoring the car condition, reminding about required servicing, etc. Any other services can also be connected to the smart space to enrich the decision support possibilities. For example, the car diagnostic system can perform firmware update while the user is visiting a museum if the expected museum vistitng time is longer than time required for the update.

The overall scenario of the case study is shown in Fig. 4. Though the scenario is shown as linear, in fact, it can be interactive and iterative if the user wishes to adjust generated solution via adding additional constraints or preferences.

Before the trip, the tourist configures the preliminary plan consisting of the list of attractions he/she would prefer to visit, and gets information about specifics of the country/region of the trip. During the trip the tourists gets updates of the actual trip plan and driving directions (including re-fueling, eating, etc.). The current situation information includes current attraction occupancies, traffic, car gas level, etc. After the trip, the tourist can leave his/her feedback and comments regarding the trip in social networks.

An example of the attraction visiting plan is presented in Fig. 5. The tourist starts from the Astoria hotel at 11:52, visits the State Hermitage, the Museum of History of Karl May Gymnasium (with a guided tour starting at 17:00), and finally returns back to the Astoria hotel. The expected travel time from Astoria to the State Hermitage based on the current traffic (provided by Yandex.Traffic service of Yandex.ru, the biggest Russian Internet company) is about 5 minutes. Since the guided tour at the Museum of History of Karl May Gymnasium starts at 17:00, and the expected travel time from the State Hermitage to the Museum of History of Karl May Gymnasium based on accumulated traffic statistics is 15 minutes, the driver is suggested to leave the State Hermitage at 16:35.

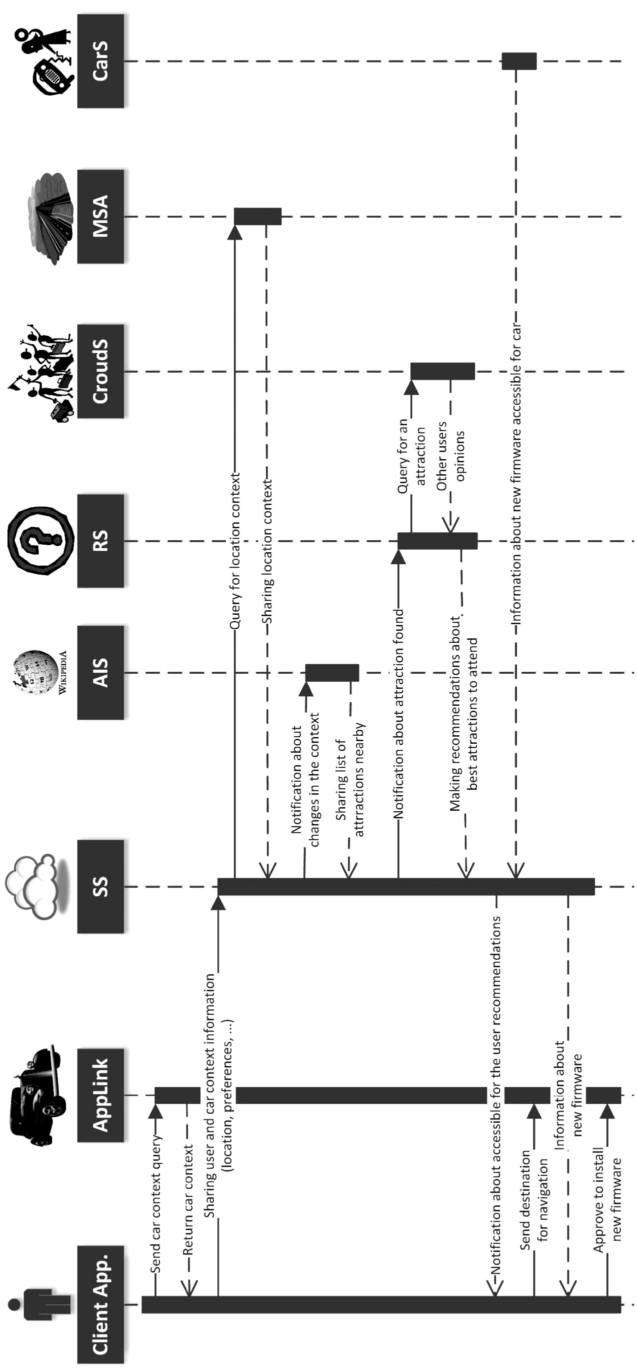

Fig. 3. Service interaction

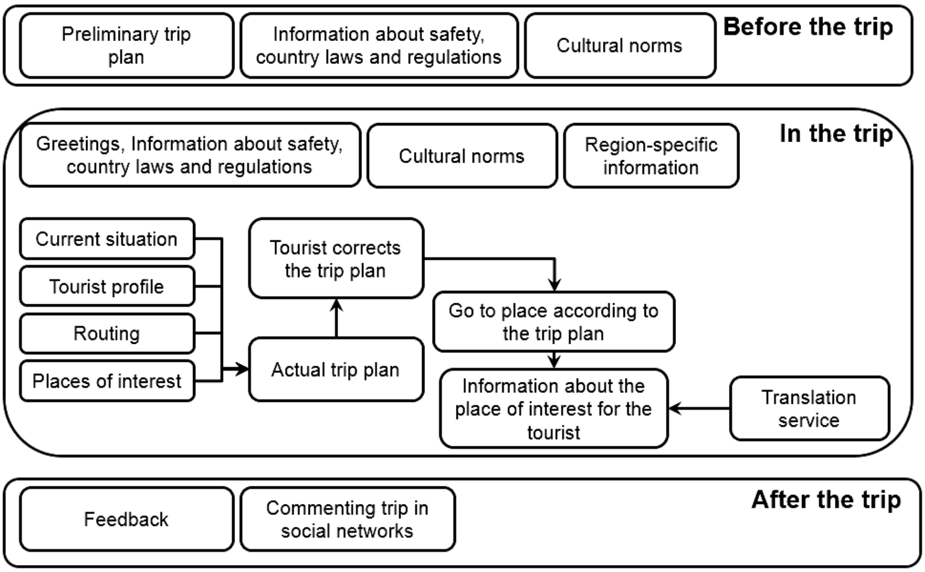

Fig. 4. Overall case study scenario

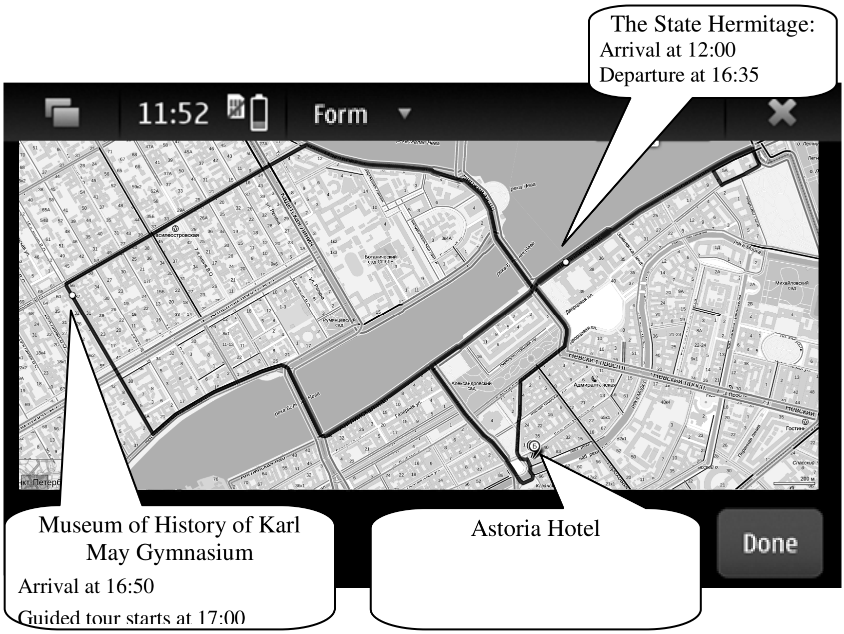

Fig. 5. A sample of attraction visiting plan at the center of St. Petersburg

4 Conclusion

The paper presents the concept, main supporting technologies and an illustrative case study for CPS enabling infomobility. Unlike existing navigation or trip planning applications the developed system implements usage of context information from different sources (Internet resources, car information, user mobile device), integrates with car on-board information system, doesn’t transfer private information into a public cloud. The key idea is to implement context-aware service-based CPS, which could provide a new, previously unavailable level of personalized on-board information support via finding decisions taking into account the context of the current situation and driver’s preferences. The users of the system will have up-to-date personalized support of their trip based on the current situation and taking into account its various aspects from traffic jams and attraction occupancies to gas level in the car and required car servicing.

For illustrative purposes, the methodology is implemented in a decision support system for tourists visiting attractions by car. The system helps tourists to plan their attraction attending time depending on the context information about the current situation in the region, its foreseen development and tourists’ preferences, using their mobile devices and in-car information systems.

At the moment, if the user wishes to adjust generated solutions via adding additional constraints or preferences the solutions will have to be generated from scratch (only the context is reused). Future work will address incremental solution adaptation via iterative interaction with the user based on planning models (e.g., opportunistic planning [16]).

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Erratum: Applying Platform Design to Improve Product-Service Systems Collaborative Development

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Author Index