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# Deduction of inter-organizational collaborative business processes within an enterprise social network

Aurelie Montarnal

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# THÈSE

En vue de l'obtention du

## DOCTORAT DE L'UNIVERSITÉ DE TOULOUSE

Délivré par :

École Nationale Supérieure des Mines d'Albi-Carmaux conjointement avec l'INSA de Toulouse

---

**Présentée et soutenue par :**

**Aurélié Montarnal**

**le** Jeudi 8 Octobre 2015

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Deduction of inter-organizational collaborative business processes within an enterprise social network

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# General Introduction

“Begin at the beginning,” the King said, gravely, “and go on till you come to an end; then stop.”

— Lewis Carroll, Alice in Wonderland

In the last years, inter-organizational collaborations have become a necessity, rather than a strategy, for a company to remain competitive in its environment. Hence, it becomes harder and harder for an isolated enterprise to stay competitive and survive in the current economic context.

Moreover, the advances made in IT and Management sciences have allowed enterprises to become more agile and reactive when sharing their resources and know-hows, and are thus more prepared to face new challenges and market opportunities. Another explanation is that the recent advances in information technologies always allow faster and easier ways to communicate. Working with distant partners and heterogeneous information systems becomes easier for companies, thanks to research works on interoperability. Hence, for a company located in France, working with other companies, whichever their IT devices, software environment or even languages, turns out to be more and more feasible. The emergence of several types of inter-organizational collaborations, such as Virtual Organizations, Virtual Enterprises or Virtual Supply Chains, clearly shows the advantages of such tools.

In general, organizations choose between various degrees of sharing such as information exchange (i.e. communication) or activity sharing (i.e. coordination) when setting new collaborations. The term *collaboration* can be used to describe the generic behavior of organizations working together. However, from a technical point of view, this terminology rather stands for goal sharing, in which the organizations join their forces to achieve common objectives. Here, the notion of collaborative business process comes as a cornerstone of collaborations. It defines and orders the different activities that need to be executed to reach the common goals. Nowadays, for the broker of a collaboration, setting up the collaborative network - i.e. the design-time of the collaboration - is achieved in three phases: (i) defining the objectives of the collaboration, (ii) finding the partners of the collaboration to achieve them, and (iii) establishing the adapted inter-organizational business process that will further be orchestrated during the

## General Introduction

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run-time of the collaboration. These steps are generally carried out based on human resources, and are thus laborious since they are both time- and resource-consuming.

The automation of the design-time of inter-organizational collaborations is a rich topic, since it raises complex issues, which could be classified in *what/who/when* questions:

1. Which business services should be performed in order to fulfill the objectives? (*What?*)
2. Who could provide these business services to achieve the best results (in terms of criteria such as time of completion, or cost)? (*Who?*)
3. When should each organization execute its business services? (*When?*)

Within this research, these three questions have led to think about the relevant ways to *represent and acquire the relevant knowledge* that allow characterizing the context of the collaboration, so that the objectives of the collaboration could then be fulfilled by *exploiting this knowledge* into an optimized collaborative business process.

These research works find their roots in two projects: the MISE (Mediation Information System Engineering) project and the French FUI project OpenPaaS. This PhD thesis is part of the MISE project, which was initiated in 2004 and has now gone through three iterations. MISE is led by the Interoperability of Organizations axis of the Industrial Engineering Research Center of Mines Albi and aims at supporting inter-organizational collaborations from the design-time to the run-time, and also adds an agility-step that comes as a feedback loop to dynamically adapt collaboration from run-time to run-time or run-time to design-time. This PhD thesis comes as a successor of several other PhD theses focused on the automation of the design-time. Each iteration of MISE comes along with new assumptions to raise. After MISE 2.0 research works, this PhD thesis aims at raising the assumptions that the partners of the collaboration are already known: which adds deep complexity to the problem to solve.

The OpenPaaS French project aims at implementing a Platform as a Service in an Enterprise Social Network (ESN) that supports inter-organizational collaborations by providing tools to facilitate the collaborations. The ESN comes as a mean to associate plenty of enterprises so that they could work together: either by exchanging information as would be done on any social network, or by exploiting dedicated services to set up new collaborations and supports. The information gathered by the ESN can be integrated as knowledge so that these research works can take advantages of it to characterize the context of the collaborations.

Hence, the context of realization of this PhD thesis is wide: located at the intersection of Management Science and Computer Science. Chapter 1 aims at providing a large point of view on this rich context, by detailing the *whys and wherefores* of these PhD research works.

Once the problematic of this PhD thesis will be defined as well as its context of application, Chapter 2 will provide a first step to answer the previous question *Who?* by providing a

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literature review on the non-functional requirements usually taken into account when selecting partners. This Chapter will result in a non-functional framework particularly adapted to the context of ESNs.

Then, Chapter 3 will focus on how to acquire knowledge on the collaboration in order to be able to further deduce an inter-organizational collaborative network. This approach can be detailed in two steps: (i) designing the knowledge bases structure and (ii) populate them either by extracting knowledge from other existing knowledge bases or (ii) by acquiring it directly from the users of the ESN.

Chapter 4 details how the results of Chapter 2 and Chapter 3 can be exploited together in order to answer the questions *what/who/when* simultaneously. Finally, a quasi-optimal collaborative process is obtained, from (i) the description of the collaborative situation, by the users (using Chapter 2 and Chapter 3 results) and (ii) the already existing knowledge on collaboration, acquired in Chapter 3.

Finally, Chapter 5 focuses on the implementation of this system and proposes a use case that details the tools that have been developed within this PhD thesis and their use in the example of the automation of a bidding process.



# Introduction Générale

Ces dernières années, la capacité à établir des collaborations inter-organisationnelles est devenue, plus qu'une stratégie, une vraie nécessité pour les entreprises désireuses de rester compétitives. Effectivement, pour une entreprise isolée, il devient de plus en plus difficile de survivre dans le contexte économique actuel.

Les récents progrès réalisés, à la fois dans les technologies de l'information et dans le domaine du génie industriel, ont amené plus d'agilité et de réactivité aux entreprises partageant leurs ressources et leurs savoir-faire. Ainsi, elles sont mieux préparées à relever de nouveaux défis et à répondre à de nouvelles opportunités de marché. Les avancées réalisées en informatique permettent de communiquer de plus en plus facilement et de plus en plus rapidement, ce qui favorise ce récent essor pour les collaboration inter-organisationnelles. Travailler avec des collaborateurs éloignés géographiquement, ou dont les systèmes d'information sont hétérogènes est plus aisé grâce aux travaux de recherche et industriels réalisés sur l'interopérabilité des systèmes. Ainsi, pour une entreprise localisée en France, travailler avec d'autres entreprises, quelque soit leurs systèmes d'information, leurs environnements logiciel, ou même leurs langages, se révèle de plus en plus envisageable. L'émergence de nombreux types de collaborations inter-organisationnelles comme les *organisations virtuelles*, les *entreprises virtuelles* ou les *chaînes logistiques virtuelles* démontre les avantages de tels outils.

Généralement, lorsque les organisations créent de nouvelles collaborations, elles choisissent parmi différents degrés de partage, comme le partage d'information (i.e. communication) ou le partage d'activités (i.e. coordination). Le terme *collaboration* peut en fait être utilisé pour décrire le comportement générique des organisations lorsqu'elles travaillent ensemble, mais, d'un point de vue technique, il s'applique plutôt au partage d'objectifs communs, pour lesquels les organisations unissent leurs forces. Dans ce cas, la notion de processus collaboratif est une pierre angulaire des collaborations inter-organisationnelles: cela définit l'ordre des différentes activités devant être réalisées afin d'atteindre les buts communs. De nos jours, pour l'organisation désireuse de créer une nouvelle collaboration, l'étape de création de la collaboration - le *design-time* de la collaboration - est souvent partagé en trois phases: (i) la définition des objectifs de la collaboration, (ii) la recherche des partenaires permettant de les remplir et (iii) l'établissement d'un processus métier inter-organisationnel - qui permet par la suite d'orchestrer cette collaboration pendant le *run-time*. Or, ces étapes sont souvent réalisées

## Introduction Générale

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de façon humaine, et sont donc laborieuses, chronophages et gourmandes en ressources.

L'automatisation du *design-time* des collaborations inter-organisationnelles est un sujet riche, qui soulève des problèmes complexes que l'on peut définir selon trois questions *quoi/qui/quand*:

1. Quels sont les services métier devant être mis en place pour atteindre les objectifs de collaboration? (*Quoi?*)
2. Quelles organisations peuvent fournir ces services métier pour obtenir les meilleurs résultats (selon des critères non-fonctionnels comme le temps de réalisation ou le coût)? (*Qui?*)
3. Quand les organisations doivent-elles réaliser ces services métiers? (*Quand?*)

Dans le cadre de cette thèse, ces trois questions ont amené à réfléchir sur les façons pertinentes de *représenter et acquérir les connaissances* permettant de caractériser le contexte de la collaboration, puis, d'*exploiter ces connaissances* afin de déduire un processus métier collaboratif optimisé répondant aux objectifs de collaboration.

Ces travaux de recherche ont été menés dans le cadre de deux projets: le projet MISE (Mediation Information System Engineering) et le projet FUI OpenPaaS.

D'une part, le projet MISE a été initié en 2004 et a, depuis, subi trois itérations. Réalisé au sein de l'axe Intéropérabilité des Organisations, au Centre Génie Industriel de l'Ecole des Mines d'Albi-Carmaux, MISE a pour but de supporter les collaborations inter-organisationnelles du *design-time* jusqu'au *run-time*, en y ajoutant une étape d'agilité intervenant comme une boucle de rétroaction pour adapter dynamiquement les collaborations aux changements (du *run-time* sur le *run-time* ou du *run-time* sur le *design-time*). Cette thèse succède à plusieurs autres thèses centrées sur l'automatisation du *design-time*. En effet, à chaque itération du projet, MISE ambitionne de lever de nouvelles hypothèses. Après les travaux réalisés dans le cadre du projet MISE 2.0, cette thèse vise à lever l'hypothèse faite que les partenaires de la collaboration sont déjà connus lors du *design-time*, ce qui amène une forte complexité lors de la déduction de processus collaboratifs.

D'autre part, le projet OpenPaaS est un projet français visant à implémenter un Réseau Social d'Entreprises (RSE) sur une plate-forme en tant que service, pour supporter et faciliter les collaborations inter-organisationnelles. Le RSE est un moyen de regrouper de nombreuses entreprises afin qu'elles puissent travailler ensemble: soit en échangeant des informations comme sur n'importe quel autre RSE, soit en exploitant des services dédiés à la mise en place de nouvelles collaborations ou au support des collaborations déjà créées. Les informations collectées par le RSE sont intégrées sous la forme de connaissances, afin que les travaux de recherche menés au cours de cette thèse puissent en tirer parti pour caractériser les contextes collaboratifs.

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Ainsi, cette thèse s'est déroulée dans un environnement scientifique très riche, à l'intersection entre le génie industriel et le domaine des systèmes d'information.

Le Chapitre 1 vise à fournir un large point de vue sur ce vaste contexte, en détaillant les tenants et aboutissants des travaux de recherche menés dans cette thèse.

Une fois cernées les problématiques et le contexte de mise en oeuvre de cette thèse, le Chapitre 2 permettra de faire un premier pas vers la réponse à la question précédente *Qui?* en établissant une revue de littérature sur les facteurs non-fonctionnels habituellement pris en compte dans la sélection de partenaires. Ce chapitre résultera en un cadre structuré sur les facteurs non-fonctionnels, particulièrement adapté au contexte des RSEs.

Puis, le Chapitre 3 sera centré sur l'acquisition des connaissances sur les collaboration inter-organisationnelles, dans le but de permettre une future déduction de nouveaux réseaux collaboratifs. Pour cela, l'approche menée peut être décrite en deux étapes: (i) concevoir la structure des bases de connaissances et (ii) peupler ces dernières avec des connaissances extraites d'autres bases déjà existantes ou acquises directement auprès des utilisateurs du RSE.

Le Chapitre 4 détaillera comment les résultats obtenus aux Chapitres 2 et 3 peuvent être exploités dans le but de répondre simultanément aux question *quoi/qui/quand*. Finalement, un processus métier collaboratif quasi-optimal est obtenu à partir (i) de la description de la situation collaborative, par les utilisateurs et (ii) des connaissances déjà existantes, injectées dans le système d'information, comme décrit dans le Chapitre 3.

Finalement, le Chapitre 5 s'intéresse à la mise en oeuvre de ce système et propose aux lecteurs un cas d'illustration décrivant les outils informatiques qui ont été développés dans le cadre de cette thèse, et leur utilisation dans un exemple de réponse automatisée à un appel d'offres.





# 1 Context and Problem Statement

“Every step is a first step if it’s a step in the right direction.”

– Terry Pratchett, *I Shall Wear Midnight*

## 1.1 Introduction

A short return to the past shows that, in 1776, Adam Smith (1723-1790) wrote his economy treaty entitled *An Inquiry Into the Nature and Causes of the Wealth of Nations* [1]. Within this broad synthesis of ideas and observations on his contemporary economy, A. Smith remains particularly famous for his thoughts about the division of labor. The specialization of the workers in each different operations lets them improve their efficiency and consequently the factory gains in productivity. However this specialization naturally leads to two facts: the need of a deep degree of cooperation between the workers but also a form of outsourcing so that anyone can exchange his products to obtain the other products he wants (even though the term “outsourcing” was first used as a business strategy a couple of centuries later). Decades after the industrial revolution, Frederick Taylor (1856-1915) developed his new theory on scientific management - referred as Taylorism - with *The Principles of Scientific Management* [2], and improved the productivity by establishing and analyzing workflows, and Henry Ford (1863-1947) developed the first mass production lines for the T-Fords.

Then, around the 50’s, the digital revolution appeared with the first computers and brought the society to a next level. About this, van der Aalst [3] mentions a continuous improvement of the productivity through technical innovations, new ways to organize work and finally new digital infrastructures. According to Lummus and Vokurka [4], the 80’s constitute the beginning of the era of supply chain management: collaborative relationships within and beyond the organizations becomes a major concern. In 1993, Wortmann et al. [5] published a prospective report on the manufacturing systems for the Commission of the European Communities.

## Chapter 1. Context and Problem Statement

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According to this report, three pressures (globalization, environmental concerns in production and the evolution of business and organization structures) would lead to the *inter-enterprise integration*. Retrospectively, the evolution over the last twenty years proves them right, with the emergence of new paradigms both in computer science and management science to support inter-organizational collaborations.

This chapter aims at providing the reader a large scope on these two disciplines and situating this thesis and its challenges in such a context. Therefore, Section 1.2 is dedicated to the different types of Collaborative Networks of Organizations (CNO): their structure, their behavior and their specific properties. As an application case, the virtual supply chain will be described. IT systems are able to provide the interoperability required by such collaborative networks, hence, the Section 1.3 focuses on the IT tools that allow supporting Business Process Management (BPM) approaches. These two parts will help the reader position the French OpenPaaS project at the junction of two main thematics and also situate this PhD thesis works within the MISE (Mediation Information System Engineering) project, in Section 1.4. Finally, from this large scope will emerge the challenges and the main issues these research works aim at answering.

## 1.2 Collaborative Networks of Organizations

### 1.2.1 Framework for characterizing the collaborative networks

This Section focuses on the different types of networks of organizations that are commonly used in order to provide a large vision of their characteristics and usage contexts. Based on a literature review oriented on three axes of study, a new framework is proposed for characterizing these collaborative networks according to (i) the degree of sharing between the partners, (ii) the topology and (iii) the perspective of the network.

#### 3 axes of study

Camarinha-Matos et al. [6] have analyzed the evolution of CNOs across the time. They characterize a CNO through 4 terms:

- Duration: long or short term;
- Geometry: internal behaviour, exclusivity or many alliances for a partner and fixed (*e.g.* little variation among the partners) or dynamic structure;
- Visibility: which partners can be seen by another partner;
- Coordination: which structure is used between the partners;

Rajsiri [7] introduces the collaboration by detailing different types and levels of collaboration, and then focuses on the network configuration factors broken down into three topics:

## 1.2. Collaborative Networks of Organizations

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- The inter-enterprise relationships: deal with the specific roles of enterprises within CNOs.
- The topologies of networks: concern the structure of networks.
- The dependencies and coordination mechanisms: the possible interactions within a CNO.

Here, a three dimensional framework is proposed to characterize CNOs according to:

1. The intensity or *degree of sharing* between the partners, that deals with the coordination [6] and the levels of collaboration in the works of Rajsiri [7].
2. The *network management topology* refers to the geometry and the visibility in the works of Camarinha-Matos et al. [6] and the topologies studied in Rajsiri [7].
3. The *perspective of the CNO*, that not only focuses on the duration of the collaboration [6], but also on the goals pursued by the collaboration.

**Degree of sharing** The degree of sharing in a CNO is what the partners decide to have in common when working together. In the literature, four inclusive degrees of sharing, as illustrated in Figure 1.1, are usually mentioned:

- Communication: Touzi [8] defines communication as a simple data exchange.
- Coordination: Camarinha-Matos et al. [9] describe a coordinated network, whose activities are executed in a predefined order to reach a specific goal. In the same vision, Dameron [10] refers to coordination as a way “to order parts according to a logical plan”. Dameron [10] insists on the fact that the coordination is static and does not take place as an action. Touzi [8] writes that it is “sharing and synchronizing tasks”.
- Cooperation: Camarinha-Matos et al. [9] mention an autonomous work from each partner of the CNO, which have their own objectives. There is a leading entity, but also a sharing of the resources, in order to create a final product or service.
- Collaboration: it is hardly distinguishable from cooperation and authors have generally different point of view. On the one hand, Touzi [8] does not make any difference between the two terms, and already mentions a sharing of the objectives between the participants of the cooperation. On the other hand, Camarinha-Matos et al. [9] make a clear difference and the objectives are only shared in a collaboration. Dillenbourg [11] considers that collaboration comes along with the permanent interaction between partners, but is not totally independent of cooperation in the sense that two partners working with the same resources will instinctively distribute sub tasks in order to work more effectively.
- Fusion: Touzi [8] mentions *integration*, whilst Bénaben [12] uses the term *fusion* as “the affiliation of the partners to the same entity”. Including the previous levels, it also adds

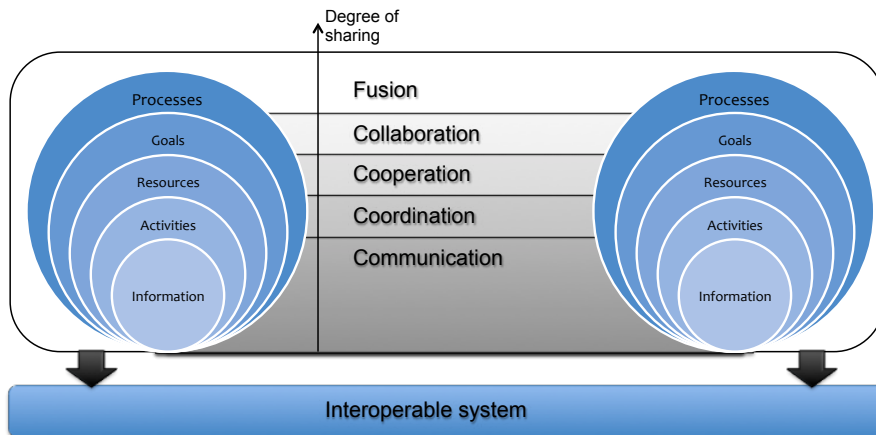


Figure 1.1 – Degree of sharing within collaborative networks, based on [12].

a common structure and leads to the term of interoperability by enabling interactions within the CNO.

**Network management topology** The evolution of such communities of organizations has led to the establishment of specific types of management. CNOs can respect different types of architectures (*i.e.* topologies), which enable specific relationships between partners. Here, an organization is considered as a node and a network as a graph. The power of decision is studied along two axes: the integration decision - on the overall *static* organization of the CNO - and the coordination decision - related to the *dynamic* management of the network. These axes come from the works of Stadler [13], explained in Part 1.2.2.

- Peer-to-peer (cf *a* in Figure 1.2): Each node can interact with the others without any hierarchy. The power of decision is equally shared between the nodes and there is no particular forms of *integration decision* or *coordination decision* in the network and the responsibilities are distributed. Peer-to-peer (P2P) networks are considered to be rare because they often emerge spontaneously and do not require a global management : each node knows its own tasks to achieve [14–16].
- Chain-like (cf *b* in Figure 1.2): Croom et al. [17] have analyzed the literature on supply chain: the chain-like topology can be associated to the supply chain management, a coordinated system in which partners are ordered depending on information, service or materials transfers, to the end customer (*e.g.* to achieve a specific final goal) [18–21]. Consequently the *coordination decision* process exists to define the order of appearance of the organizations during the collaboration but no organization takes a global decision: coordinated parts are managed by each organization for its own needs and finally constitute a global chronological chain of tasks.

## 1.2. Collaborative Networks of Organizations

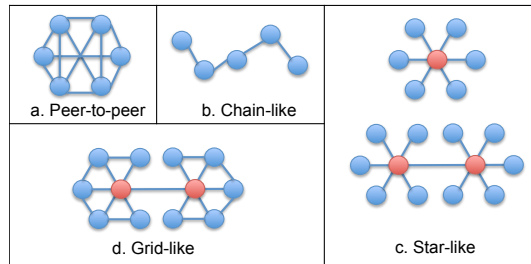


Figure 1.2 – Topologies of collaborative networks.

- Star-like (cf c in Figure 1.2): An organization is at the center of the collaboration and sets the exchange standards and rules to comply. This topology is rather used in a fixed structure with long term customer/supplier relationships in which the collaborative project requires a strong *coordination decision*. Interactions are exclusively established between the supervisor and the partners. Both *integration decision* and *coordination decision* are managed by the central entity.
- Grid-like (cf d in Figure 1.2): Zhu [22] defines this topology as follows: each node can interact with its neighbor nodes, moreover nodes are gathered into groups that are supervised by a facilitator and a node can only be part of one group. If a node needs to interact with another node that is not its neighbor, it should pass through its facilitator. For each group the facilitator makes the *coordination decisions*, it is up to all the facilitators to take *integration decisions* and global *coordination decisions*.

**Perspective of the network** When choosing the type of CNO it is important to know its perspective. More than the duration, this characteristic also depends on the goal of the CNO. It can be developed along three levels:

- One project goal: Camarinha-Matos et al. [6] depict short-term alliances established for a project. These one-shot CNOs are “made for single business opportunity” and “dissolved at the end of such process”. Camarinha-Matos and Afsarmanesh [23] mention the term “Grasping-opportunity driven CNOs”: the collaborative system offers an answer to a specific and unique business opportunity. Consequently, the network is designed once for the entire project life.
- Program goal: Camarinha-Matos and Afsarmanesh [23] use “Goal-oriented networks” to describe a mid-term CNO where partners have clearly defined roles. The CNO is dedicated to the program, which can be product-oriented or project-oriented. The program life consists of a repeated loop of a pre-established project structure with a known end.
- Program flow: Camarinha-Matos and Afsarmanesh [23] depict long-term agreements between potential partners, that can be quickly configured, as soon as a new type of

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opportunity emerges. It results in series of projects or programs, each adapted to a type of opportunity. In line with this type of perspective, Andres and Poler [24] mention the issues encountered by heterogeneous CNOs, in which organizations have different strategies. They deal with the alignment of the partners' strategies to find a relevant strategy to activate for positive results for all the partners. According to Andres and Poler [24], such approach helps leading to a more stable collaborative network, which could benefit to small and medium enterprises.

Figure 1.3 summarizes the consequent three-dimensional framework proposed here.

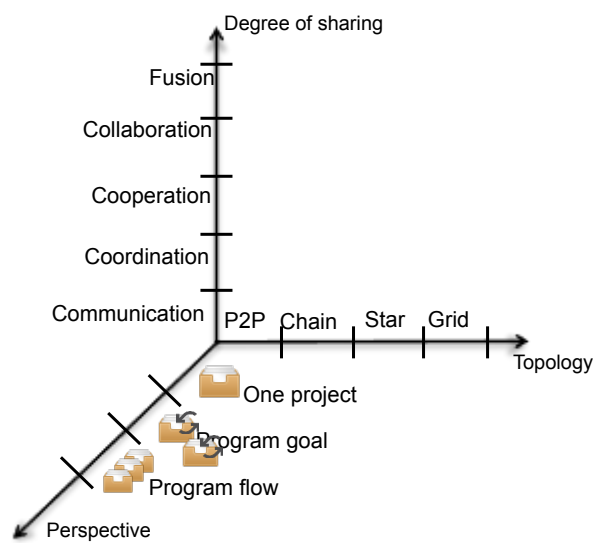


Figure 1.3 – Three-dimensional framework for characterizing collaborative networks.

### Classification of the CNO regarding the proposed framework

It is interesting to list and study the typical kinds of CNOs and to try to confront them to the proposed framework.

**Extended Enterprise (EE)** Davis and Spekman [25] consider that an EE is an enterprise network composed by each enterprise that takes part at least one time during the whole process of production: “from the raw material to the end-use consumption”. Davis and Spekman [25] consider an EE as a long term relationship between partners established in a supply chain structure.

Camarinha-Matos and Afsarmanesh [26] describe an EE as follows:

“ A dominant enterprise extends its boundaries to all or some of its suppliers. ”

An EE typically allows the dominant organization to quickly establish a network to answer to the needs of a customer.

Martinez et al. [27] depict the same star topology with one or more hierarchic leader firm(s) surrounded by partners. An EE is depicted as a long-term partnership on a mature market, in which the actors achieve a common process. According to Martinez et al. [27], complex EE can include more than one leader firm but a leader systematically globalizes the exchanges and therefore one non-leader partner cannot communicate with another (as proposed in the grid topology).

**Virtual Enterprise (VE)** According to Camarinha-Matos et al. [6], the difference between a VE and an EE lies in the fact that it has a more democratic structure, following a peer-to-peer topology. The duration can be variable and fits as well a *one project* as a *program goal* perspective. The VE is considered as a way to share skills but not necessarily goals. Martinez et al. [27] bring a different point of view on VE and do not make a frank difference between a VE and an EE, which is considered as a type of VE. According to the authors “the success of the project depends on all co-operating as a single unit” and every organization provides its own competences to the network. There are short-term and “consortium” VE to answer either to a particular bid for a unique product or to a new market for customized or semi-standardized products. Therefore Martinez et al. depict a *one project* or *program goal* perspective.

In terms of hierarchy, Martinez et al. [27] consider a non-hierarchical relationship with “probability of leadership”, which reminds of a grid-like or a peer-to-peer structure. Zhang and Li [28] mentions a “master company”. Binder and Clegg [29] propose a new framework where a VE presents a “loose [...] collaborative venture” with a “low degree of integration” and Pollalis and Dimitriou [30] depict an evolution from hierarchical structures to “network forms of organizations, such as the VE”.

If the collaboration is important, for Binder and Clegg [29] the VE has to present “a unified face to externals” but it doesn’t mean that partners share process together. Indeed, they keep their autonomous behaviors and can be part of many VEs for example. Zhang and Li [28] base their definition on Rolstadås [31] where a VE is managed as “one total unit” but Pollalis and Dimitriou [30] rather mention common resources utilization.

Zhang and Li [28], Pollalis and Dimitriou [30] agree on a short relationship particularly dynamic with a certain turnover among the partners. The aim of a VE is to quickly establish a network that can answer to opportunities emerging from a new market for example. Zhang and Li [28] define a product-oriented structure around a master company as a program goal structure.



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**Virtual organization (VO)** Camarinha-Matos and Afsarmanesh [32] consider a VE as a particular VO, in that a VO concerns any kind of partners either enterprises or any other kind of organizations, but both share the same characteristics. Karvonen et al. [15], based on Kürümlüoğlu et al. [33], define a VO as a short-term consortium that is created to answer a punctual demand of a customer, with a precise lifecycle. Since it is established for a unique request, the structure should be adapted to the case. Any of the star chain or peer-to-peer topologies could be adopted, depending on two factors: “the level of dependencies” between the partners and “the risk involved in the VO objective”. There is a coordination of the VO and the partners share resources that are part of the VO management. Although there is no specific need to share goals or processes, and it seems that its degree of sharing also should be adapted to the objective of the VO.

Abuelmaatti and Rezgui [34] agree with Camarinha-Matos and Afsarmanesh [32] and give a very general picture of the concept of VO that seems to include any type of CN. It can adopt a chain, star-like or peer-to-peer topology and basically requires establishing a coordination level. The authors relates that lately there is a need of higher performance, especially for SMEs networks and the exchanges between partners are attempted to evolve, which could be understood as an eventuality to reach a “fusion” level if needed.

**Clusters** A cluster of organizations is an interesting type of CNO to study: it is described as one of the earliest form of CNO by Camarinha-Matos et al. [9]. An industrial cluster brings together a group of companies, usually within the same geographic area, to share “some buyer–supplier relationships, common technologies and tools, common buyers, distribution channels or common labor pools, all contributing to some form of cooperation or collaboration when business opportunities arise”. It can therefore be classified as a *program flow* perspective collaboration. As it aims at responding rapidly to opportunities, it is important that the partners share the same infrastructures. No particular hierarchy is mentioned and it seems to be close to a peer-to-peer relationship. Morosini [35] gives a precise definition of an industrial cluster where:

“ A significant part of both the social community and the economic agents work together in economically linked activities, sharing and nurturing a common stock of product, technology and organizational knowledge in order to generate superior products and services in the marketplace. ”

Moreover, Morosini [35] considers that a group of individuals have a leadership and facilitate cooperation or knowledge sharing between the partners, for example. The cluster is a long-term relationship in which a common knowledge capital is kept.

### 1.2.2 The Virtual Supply Chain specific case

#### Short history of logistics

Baron Antoine-Henri de Jomini (1779 - 1869) analyzed war tactics from Caesar's military campaigns to his contemporary Napoleonic wars. In his book *The Art of War* [36], he particularly formalized the importance of the logistics (also called "the art of moving armies"): first used for the basic management of the military camp, the word evolved with the "art of the war" and, at the beginning of the nineteenth century, it became a strategic role assigned to the chief of staff. As underlined by Lauras [37], the latter military officers had henceforth to deal with the whole supplying of provisions, munitions and materials with the associated responsibilities from the decision making to the coordination and the monitoring.

After World War II, the concept has naturally been extended to the enterprises in the 50's in the United States. Although the notion of logistics has always existed since at least the Egyptian pyramids, it has only been perceived as a key success factor of companies in recent decades. According to the French Associations for Standards (AFNOR - Standard X 50-600), logistics can be seen as the methods and means which goal is to optimally manage product, financial and information flows. Thus, the concept of supply chain is inherent in it and can now be expanded.

#### Supply Chain Management

The term of "Supply Chain Management" (SCM) is commonly accredited to the British Booz Allen consultant and logistician Keith Oliver, during an interview from the Financial Times. Laseter and Oliver [38] explain that, in 1982, the SCM first referred to the whole supply chain as a single entity by breaking the silo perception within companies and integrating production, marketing distribution, sales and finance altogether. Besides, moving towards cross-functional business processes became a motto for Hammer and Champy [39] in their famous work *Reengineering the Corporation: A Manifesto for Business Revolution*. After some years, SCM is no more about intra-enterprise process but rather about cross-organizational collaborations, as mentioned by Mangan et al. [40] as the *integrated supply chain* (cf. Figure 1.4). Christopher [41] also claims that SCM is about relationships between buyers and suppliers: "The focus of supply chain management is on co-operation and trust and the recognition that, properly managed, the 'whole can be greater than the sum of its parts'", and argues the fact that it is more about a *network* than a *chain* of suppliers and customers. In our application of the SCM within the works of this thesis, the definition of Aitken [42] is adopted:

“ A network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users. ”

It is interesting to have a look on Stadler's research works on SCM: in particular, his SCM

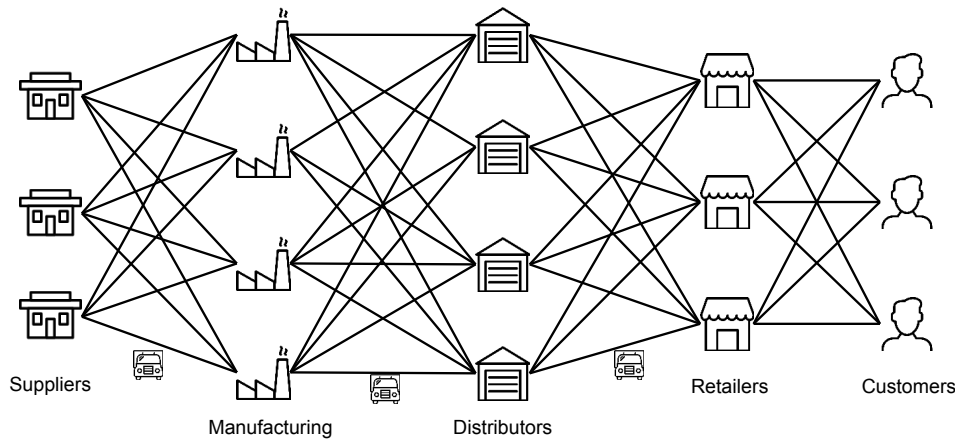


Figure 1.4 – Integrated supply chain overview.

house [13] illustrated in Figure 1.5 gives a very comprehensive and exhaustive perception of what actually involves the SCM definition.

The roof of the SCM house is composed by the *competitiveness* and the *customer service* tiles, which are defined by Stadler as the ultimate objective: simultaneously improve the efficiency of the SCM and also fulfill the customer expectations. In order to obtain such result, the SCM lies on two main pillars: *integration of organizational units* and *coordination of flows*. Let's briefly recall the hidden concepts behind those two expressions:

- Integration of organizational units brings together the “choice of partners”, “network organization and inter-organizational collaboration” and “leadership”, which are rather *static* concerns. The first topic aims at selecting the best partners in order to set up a new supply chain (SC). SC are generally created for medium-term partnerships, in opposition with the virtual company which rather fulfills single orders. The second topic is all about controlling a somehow “non-hierarchical” network of independent organizations that are only linked through the common goal of the current supply chain (*i.e.* strong risk of separation as soon as the collaboration is no longer a priority for one of the partners). Finally, the last topic concerns the presence of a leading partner or committee to align the partners' decisions.
- Coordination of flows goes through three other aspects “information and communication technology”, “process orientation” and “advanced planning”, which are rather *dynamic* concerns. The information technologies enable to easily exchange data between the partners and facilitate the decision making processes. Besides, the establishment of not only cross-functional but also cross-organizational processes allows improving the supply chains. As a third point, Stadler [13] explains that SCM also requires an advanced planning system that enables both a high level and a very detailed level scheduling (intra- and inter-organization point of view is adopted here).

## 1.2. Collaborative Networks of Organizations

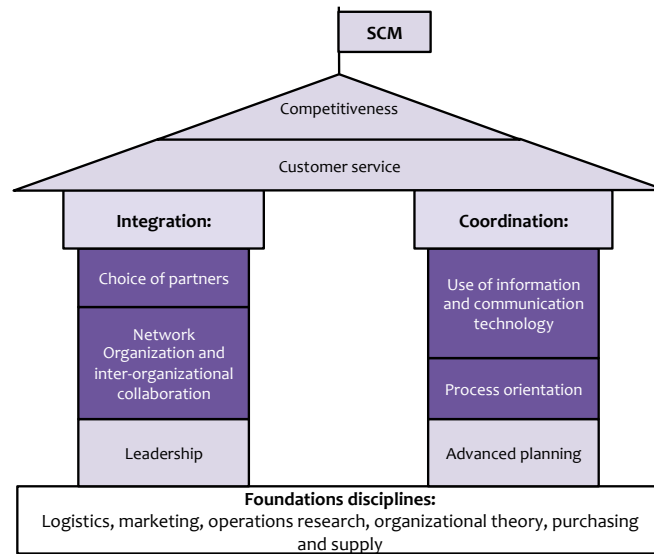


Figure 1.5 – House of Supply Chain Management, [13].

These research works are most interested in the four bricks: “choice of partners”, “network organization and inter-organization collaboration”, “use of information and communication technology” and “process orientation”, as highlighted in Figure 1.5. Besides, SCM has evolved these last years, and is now in line with the IT progress: it has led to Virtual Supply Chain (VSC).

### Virtual Supply Chain

According to Christopher [41], Gunasekaran and Ngai [43], the advances of information systems and the apparition of e-commerce has naturally led to the electronic supply chain. For Christopher [41], the concept of VSC underpins the extended enterprise by enabling to diffuse and share information among the partners of the collaboration: “Even more importantly it is information shared between partners in the supply chain that makes possible the responsive flow of product from one end of the pipeline to another”. In other words, the definition of the VSC can be based on a sentence from Gunasekaran and Ngai [43]:

“ In VSCs, a network of firms provides different products or services so that a complete service can be performed by the virtual organization. ”

Rayport and Sviokla [44] study the two parallel worlds of resource-management and information, and ask the question: how to integrate the information point of view on the value chain? They propose the *marketspace* concept, which idea is to create value from information through five main activities: *gathering*, *organizing*, *selecting*, *synthesizing* and *distributing* information. The authors develop many ideas around the marketspace with knowledge gathering and exploitation

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e.g. enhance the efficiency and the responsiveness of the production depending on customers' demand. Using IT systems enables *visibility* (i.e. coordinate and monitor the activities within a company), *mirroring capability* (i.e. create new full virtual value chains) and *establish new customer relationships*.

A further step to these possibilities is considered here: gathering and exploiting knowledge to automatically establish new VSCs.

### 1.2.3 Interoperability, towards Mediation Information Systems

Interoperability concept has first been applied to computer science in the early 90's and then has been generalized to products and systems study. The concept relies on establishing tools that enable facilitated collaborations between heterogeneous systems. In fact, all the previous types of networks are trying to achieve interoperability at different levels. But what is exactly *interoperability*? In 1991, IEEE [45] gives the following definition: "Ability of a system or a product to work with other systems or products without special effort on the part of the customer. Interoperability is made possible by the implementation of standards.". Pingaud [46] extends the definition to any systems willing to work together:

“ Interoperability is the ability of systems, natively independent, to interact in order to build harmonious and intentional collaborative behaviors without modifying deeply their individual structure or behavior. ”

According to the ISO14258 [47] standard , interoperability can happen on three different levels:

- *The integrated approach* consists in systems that use the same standard format to communicate.
- *The unified approach* deals with the establishment of a common metamodel to allow semantic equivalence of the systems.
- *The federated approach* enables a on-the-fly matching between models of systems using different metamodels.

These degrees of interoperability can be reached by crossing the syntactic interoperability and semantic interoperability barriers [48]. According to Jain and Singh [49], syntactic interoperability "means that applications must be able to read data and present information", whereas semantic interoperability "defines that data that is exchanged should be understandable". Syntax and semantic are two barriers that should be raised to enable the collaboration between several systems. A way to break the underlying technological frontiers between heterogeneous systems is to implement mediation information systems, according to the works of Bénaben et al. [50]. Such type of mediation information system has been and is still developed under the MISE project umbrella, which will be further detailed in Part 1.4.1.

### 1.3 Business Process Management

#### 1.3.1 Definitions

As mentioned in Part 1.1, the establishment, the analysis and the monitoring of workflows have become key success factors for enterprises when enhancing their productivity. According to van der Aalst et al. [51], workflows are commonly considered as only a part of BPM. Basically, van der Aalst et al. [51] extend the definition of BPM given by Weske [52]:

“ Supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information. ”

But, what exactly is a business process? Weske [52] provides a somewhat limited definition in that it states that “Each business process is enacted by a single organization, but it may interact with business process performed by other organizations”, which does not take into account inter-organizational business processes. While, Vernadat [53] defines a process as a set of activities executed in order to achieve at least one objective, Davenport and Short [54] give this close definition:

“ We define business processes as a set of logically related tasks performed to achieve a defined business outcome. ”

They also emphasize two characteristics of business processes:

- “They have customers; that is, processes have defined business outcomes, and there are recipients of the outcomes. Customers may be either internal or external to the firm.”
- “They cross organizational boundaries; that is, they normally occur across or between organizational subunits. Processes are generally independent of formal organizational structure.”

#### 1.3.2 Business process lifecycle

The BPM approach can be fulfilled through several tools applied in the different states of the studied system. Several BPM lifecycles have been defined in the literature, some are rather oriented towards a business perspective and others also take into account the technical level *i.e.* the level that involves IT engineers to implement and execute the process. Wetzstein et al. [55] propose a decomposition through four phases:

1. Process Modeling is about “drawing” the business process according to modeling languages and by using specific graphical modeling tools.

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2. Process Implementation consists in transforming and enriching this business process model into an executable model. In the context of Service Oriented Architecture (SOA) the executable model could be a Business Process Execution Language (BPEL) model that states for each task of the business process which web service should be invoked.
3. Process Execution deals with the execution of the process with a process execution engine.
4. Process Analysis, which goal is to monitor it as it is running: an analysis of the business process through specifically chosen key performance indicators allows to evaluate and to enhance it.

van der Aalst [3], Weske [52], Jung et al. [56] agree on a rather high-level decomposition of BPM phases, that could be summarized through four steps:

1. *model* that is related to the previous process modeling step [55].
2. *enact* that rather includes the previous implementation and execution steps [55].
3. *analyze* embedded in previous analysis step [55].
4. *manage* rather also included in previous analysis step [55].

In order to keep the business/IT level consideration, Benaben et al. [57] split the cycle into two overall parts: the *design-time* (when the process is modeled) and the *run-time* (when the process is executed). In addition, Jung et al. [56] mention the semantic BPM and propose an integration of knowledge management within the BPM lifecycle, which brings a clearly interesting third point of view on BPM. The Figure 1.6 summarizes all these perception of BPM and thus also includes the use of knowledge.

These research works will only focus on the design-time step which relates to the creation of business processes. However the current part shows that BPM is a whole cycle, and the choices made within the design-time cannot be uncorrelated of the run-time.

### 1.3.3 Business Process Modeling tools

With the growing interest of the industrial and academic worlds for BPM, many tools and languages have been established to support for this approach. This part aims at giving an overview of them and arguing the choices made in this thesis. Ko et al. [58] offer a wide literature review on the different business process modeling standards and specifications that exist. They propose to study them according to three types:

- The graphical standards: used to “draw” the business processes. They allow a more human perception, and they are therefore adapted for illustrating and reengineering for example.

### 1.3. Business Process Management

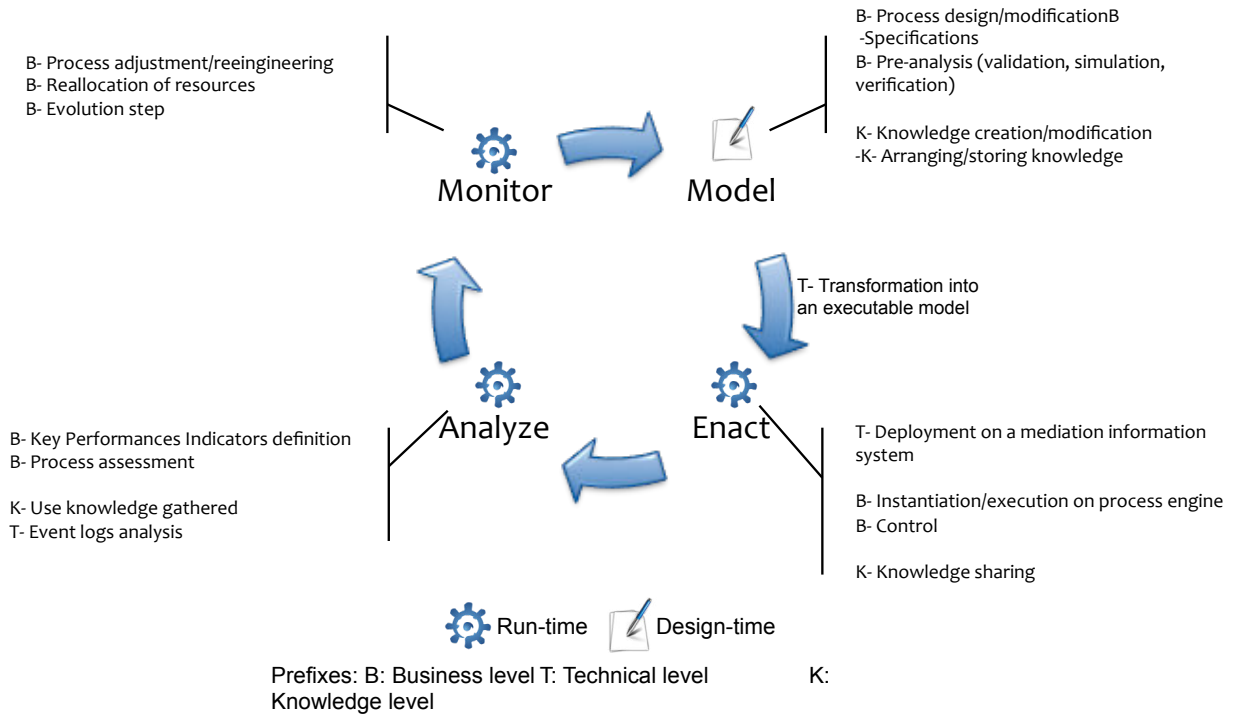


Figure 1.6 – BPM lifecycle, inspired from [3, 52, 56, 57].

- The execution standards: are computer compliant and offer a way to automate business processes on run-time.
- the interchange standards: to facilitate data portability between different graphical standards for example.

The same authors provide a diagram to guide the users on the type of BPM standard to choose depending on the use they have. This diagram can be found in Appendix A. According to it, either graphical of execution standards could be chosen to fit the process design step of the BPM lifecycle.

Malekan and Afsarmanesh [59] focus their survey on the BPM standards to describe specifically collaborative networks. They conducted a study on what are the main critical success factors depending on the objectives of the collaboration, and what are the key requirement indicators to choose a BPM standard. Their evaluation of the various BPM types based on these criteria shows that the graphical standards are the most understandable and available, and are good compromise for expressibility, enactibility and flexibility. Executional languages are rather good for enactibility, though they also provide good compromises on all other dimensions. According to them ontological languages could also be used as good compromise on understandability and excellent expressibility.



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According to Malekan and Afsarmanesh [59] and Ko et al. [58], graphical languages usually include: Business Process Model and Notation (BPMN), Unified Modeling Language (UML), Event-driven Process Chains (EPC), Yet Another Workflow Language (YAWL), Business Process Definition Metamodel (BPDM), Integrated DEFinition (IDEF). And execution languages could be: Business Process Execution Language (BPEL), Business Process Modeling Language (BPML), Calculus [60], Web Service Choreography Interface (WSCI), Web Service Conversation Language (WSCL), Web Service Choreography Description Language (WS-CDL), Web Services FLOW Language (WSFL), XML Process Definition Language (XPDL).

Patig et al. [61] have conducted a wide survey on the BPM tools used by major companies to describe their processes. As a result, it appears that most of them use text or tables to express their business processes. About the specific languages they use BPMN first, then UML, EPC, BPEL and the various IDEF methodologies.

Thus, plenty of BPM representations are available, and the specific use here should be expanded. This thesis focuses on automating the design-time of BPM (as explained later in Part 1.4.1), and more precisely on establishing new business processes based on business opportunities that the users would like to fulfill. In such a context, there are some constraints that the chosen BPM standard should offer:

- The design-time and run-time cannot be thought independently. The design-time modeling language must at least enable a transformation from it to an executable model, or be directly executable.
- Even if generated automatically, these business processes should be understandable by the users so that they can adapt them easily, if they do not fit entirely their expectations. If not, this business process would not facilitate their collaborations anymore.

Consequently a graphical language has been chosen. Besides, in its second version, BPMN 2.0 [62] now offers a standard notation supporting workflow orchestration, as underlined by Poizat and Salaün [63].

### 1.4 Context of the PhD thesis

These research works were achieved within both a French FUI project, OpenPaaS, and an internal program MISE (Mediation Information System Engineering).

#### 1.4.1 MISE: Mediation Information System Engineering

The MISE program gathers several works of former or actual PhD students of the axis *Interoperability of the Organizations* at the *Industrial Engineering research center* of Mines Albi. The evolution of these works for the last ten years has led to a complete cycle for supporting

inter-organizational collaboration in various fields of application. A detailed explanation of MISE allows to better understand the position of this thesis within OpenPaaS, but first the system is entirely based on the Model Driven Architecture (MDA) paradigm which should thus be introduced.

### Introduction to the model driven architecture paradigm

The BPM approach enables to build collaborative business process models that describe the dynamic of the collaboration. However, obtaining a business process model and deploying and orchestrating it on a MIS are not trivial steps. The Model Driven Engineering (MDE) and especially the Model Driven Architecture (MDA) provide a set of tools which particularly suits these steps, by allowing abstract descriptions of systems in order to help at designing IT systems. The MDE approach appeared in the late 80's with the Computer-Aided Software Engineering (CASE) that proposed a kind of Integrated Development Environment (IDE) according to the description made by Merbeth [64], whilst the development of software products became more and more complex. Yet, the US Air Force commissioned the developers of the well known Structured Analysis and Design Technique (SADT) to develop a new modeling method that would rather focus on the functional perspective of a system: the IDEF0(Integrated Computer-Aided Manufacturing - ICAM - now famous as Integrated DEfinition) [65], which would then be followed by a series of 16 extensions offering different points of view to describe systems. In 2001, the Object Management Group (OMG)<sup>1</sup> published its first version of the MDA specification [66] - which is now an OMG's trademark. OMG [67] states that:

“ MDA provides an approach for deriving value from models and architecture in support of the full life cycle of physical, organizational and IT systems. ”

This approach is composed of several models that can be basically positioned within a "Y" structure (cf. Figure 1.7):

- The Computer Independent Model (CIM) allows to describe the requirements for the system. It is independent of the implementation and, thus, is often called the *business model*, and helps both at understanding the problem to solve and at gathering vocabulary and knowledge.
- The Platform Independent Model (PIM) brings a solution to the requirements defined in the CIM, but does not address the IT constraints.
- The Platform Model (PM) describes the IT technologies used for the system.
- The Platform Specific Model (PSM) is situated at the junction of the PM and the PIM: it is the concrete IT solution to the CIM's requirements.

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<sup>1</sup>OMG MDA web page: <http://www.omg.org/mda/>

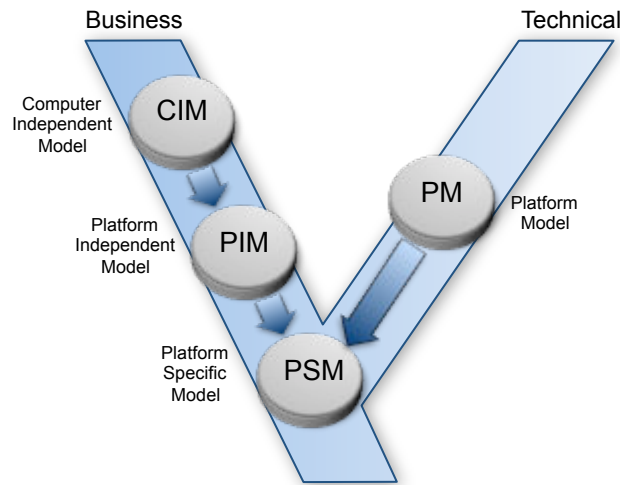


Figure 1.7 – Overall structure of the MDA, [12].

According to Bénaben [12], two main principles of MDE have emerged from this MDA decomposition: (i) MDA relies on the various models describing different perceptions (*i.e.* level of abstraction) of the system and (ii) model transformation mechanisms can be developed in order to obtain the models (*e.g.* from CIM to PIM). Such MDA approach has been adopted within the MISE program which therefore deserves to be explained in details.

### MISE overview and positioning

Launched in 2004 by Frédéric Bénaben, the MISE program aims at providing a MIS to address the interoperability issues [68] and provides a support for collaborative situations, whatever the field of the collaboration (crisis situation, virtual enterprise environment, etc.). Actually, the first observation was that setting up collaborations (design and run-time) was really time-consuming. It indeed required (i) to know the coalition of organizations willing to work together, (ii) for all the organizations, to establish how they would collaborate (who is doing what and when, *i.e.* the inter-organizational collaborative process), and (iii) to involve IT engineers to eventually deploy the latter process on a IT platform. The requirements of such a collaborative behavior are numerous:

- A step for finding and selecting is required upstream: this is a laborious bidding process, that IT technologies can nowadays simplify in a more efficient way (*i.e.* wider scope of organizations and more and more efficient tools to optimize their selection).
- It is important to highlight that the core skills of each organization cannot be imposed *i.e.* each organization has its own way to achieve its activities, which should thus be respected by the collaborative IT system. However the inter-organizational ways to collaborate often create problems, since a high-level perception of the system is needed, which is not

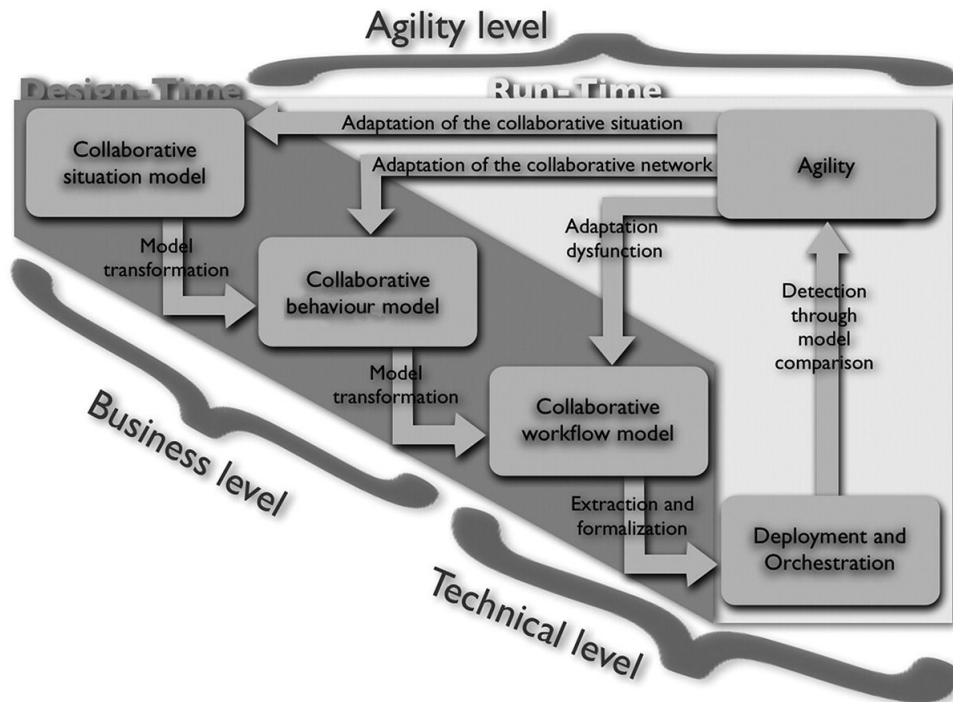


Figure 1.8 – MISE overall structure, [57].

always an obvious thing for specialists of each domains. Fortunately, the problem can be transposed in terms of knowledge gathering and exploitation, so that an IT system could understand the collaborative context and provide an overall perception of the system.

- Obtaining a *technical* workflow, from a *business* process consists in composing technical services in a certain order to effectively fulfill the business process. The service composition discipline has become one of the burning challenges of computer science these last years.
- Providing agility to the system, so that it can be reactive. It is indeed incredibly time and resource-consuming to re-implement an information system for each collaboration. Hence, the IT system should be able to support on-the-fly the design-time and the run-time.

The system relies deeply on the MDA and can be decomposed as a succession of models and model transformations, as depicted in Figure 1.8. In fact MISE design-time can be seen as cascading boxes to obtain the different types of models: the collaborative situation model, the collaborative behavior model and the collaborative workflow model. Then, the run-time consists in deploying the resulting workflow and provides an agility service to allow feedbacks in real-time so that the workflow could be adapted if something goes wrong. MISE has experienced three iterations and each of them has brought its bundle of improvements on one or more of the boxes.

### MISE design-time description

Since this PhD thesis focuses exclusively on the design-time, it is interesting to have a look on the advances made on the design-time through MISE 1.0 and MISE 2.0 before getting to the expected novelties of MISE 3.0. In Figure 1.9 the steps 1 to 6 provide an illustration of the tools that have been implemented at the beginning of the PhD thesis. The chronological improvements can be summarized as follows.

**MISE1.0** was initialized from 2004 and ended in 2010. First, Jihed Touzi's researches [69] focused on the transformation rules from the CIM to the PIM (*i.e.* from a BPMN business process to a UML based logic model workflow), so that the processes could be executed. However, the main hypothesis of his works relied on the fact that the users could themselves provide the CIM. Besides, to be exploited into further PIM, the CIM had to contain a lot of information, and asking the users to provide was an ambitious thing. That is why Vatcharaphun Rajsiri's PhD [70] rather focused on how to automatically deduce a CIM from knowledge about the collaboration. Her works dealt with (i) gathering knowledge on the collaborative context, (ii) establishing two collaborative ontologies (one describing collaborative systems with their actors their roles, ... and the other one containing a high amount of business processes, based on the MIT Process Handbook of Malone et al. [71]) and (iii) implementing the logic rules to deduce collaborative processes that fits the collaborative context based on (i) and (ii). Finally, Sébastien Truptil's PhD [72] took place within the specific crisis context: he established a new metamodel to describe the collaborations between the different stakeholders of such situations. Based on this metamodel, he also implemented a corresponding collaborative ontology and the process deductions rules, which allowed him to go from CIM to PIM. Then he worked on the transformation from the PIM to the PSM, to finally obtain a BPEL file that could be executed.

**MISE2.0** design-time has entirely been realized through Wenxin Mu [73], Nicolas Boissel-Dallier [74] and Sarah Zribi's PhD [75] theses. The two first theses were conducted at the same time and provided complementary approaches. Wenxin Mu's works [73] focused on enhancing the acquisition of knowledge and the deduction of a BPMN process. The novelty relies on three points:

- During the knowledge gathering, function models allow to know the capabilities of the organizations and collaborative network models acquire information about the collaborative network, the partners, the partners' relations, sub-collaborative networks and also collaborative objective (through semantic links between the models drawn by the users and the collaborative ontologies of the IT system).
- New semantic and logic rules to deduce MIS-ready business BPMN processes that are compliant with the ISO 9001:2000 standard (*i.e.* three-level business process: decision, operation and support) ISO [76].

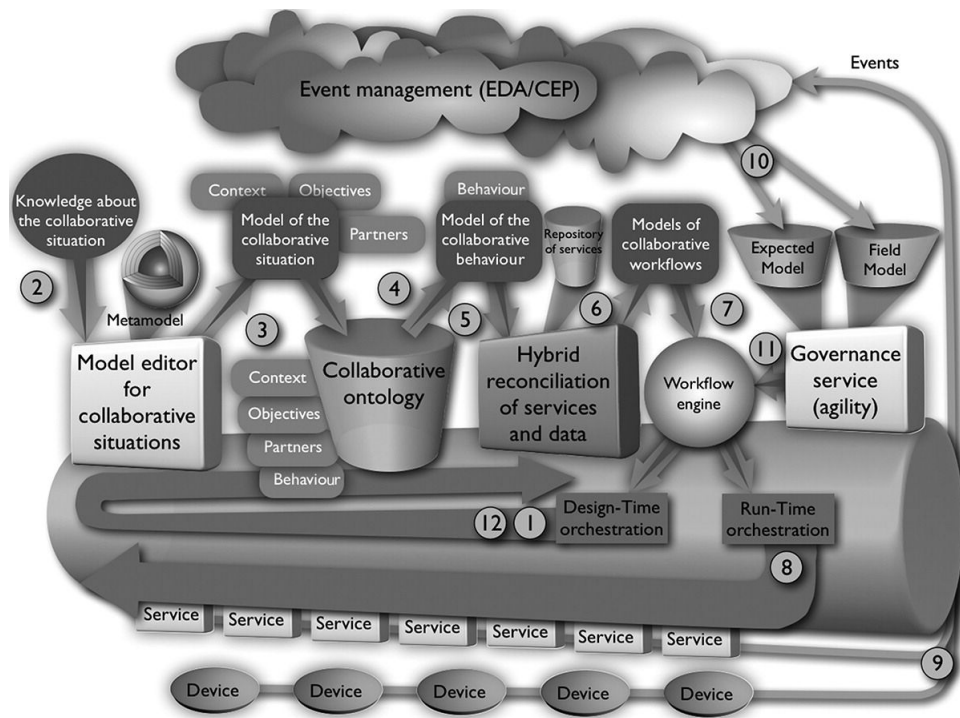


Figure 1.9 – Implementation of MISE 2.0, [57].

- an enhancement of the deduction rules to better deal with gateways.

Right after the PIM deduction, Nicolas Boissel-Dallier [74] focused on automatically getting a PSM. In this context, he implemented a n-to-m reconciliation between business activities of the BPMN PIM process and technical web services to obtain the collaborative workflow to be executed. Finally Sarah Zribi's PhD [75] allowed to integrate the non-functional dimension to N. Boissel-Dallier's reconciliation service: she aims at implementing QoS (Quality of Service) into the reconciliation algorithms.

**MISE3.0** aims at providing an even more “automated” tool for inter-organizational collaboration. Guillaume Macé-Ramète [77] has worked on the whole MISE system in crisis management context. As part of his thesis, he modeled a core collaborative metamodel, which will be more detailed in Chapter 3: the goal is to provide an overall structure for any type of collaborations, that can be specialized with specific domain layers depending on the needs of the user. This metamodel both involves organizational and IT levels of the collaborations. Based on all these researches, experiences, feedbacks, the current PhD thesis comes as a sequel of W. Mu's thesis. Imagine now a projection of her work in a VE paradigm where (i) the partners of the collaboration are not already known and (ii) a new non-functional dimension is added to the deduction from CIM to PIM...

### 1.4.2 OpenPaaS Project

#### Overview

OpenPaaS<sup>2</sup> is a French FUI (Fond Unique Inter-ministériel) project realized from 2012 to the beginning of 2015, within a coalition of academic and industrial partners (Linagora, Brake France, Telecom Sud Paris, Loria in Nancy and Mines Albi). The goal of this project was to provide a new Enterprise Social Network (ESN) that would be open-source and freely downloadable. At this time, most of the ESNs either offer intra-organizational tools for facilitating the communication between the employees, or showcase organizations' activities. However, most of them do not propose any tools to actually support inter-organizational collaborations, contrary to the system interoperability requirements.

OpenPaaS is an advantageous environment to enhance inter-organizational collaborations because of several things:

- On a business level: each organization and its *communities* (i.e. the employees that share the same function within the organization) create an account on the platform and describe themselves. Then, interactions can happen thanks to collaborative services, in a very loosely way: both within the organization so that the employees/communities can communicate with each other and with the other organizations (cf. Figure 1.10).

Furthermore, social networks have now enter the daily life of a lot of people who consequently already know such environment. Thus, the human-machine interactions are facilitated, which is, for example, highly useful for the knowledge gathering step of MISE.

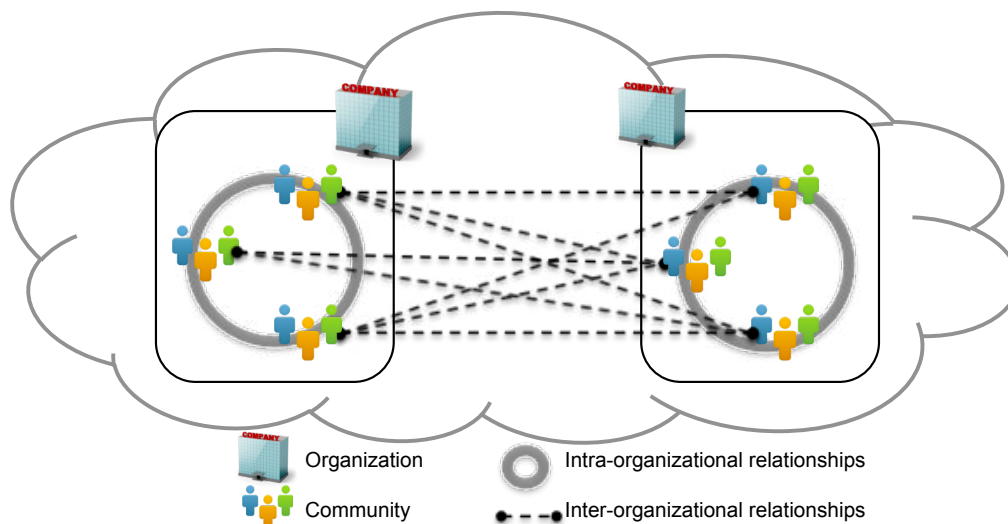


Figure 1.10 – OpenPaaS business level overview.

<sup>2</sup>OpenPaaS Overview: <https://research.linagora.com/display/openpaas/Open+PaaS+Overview>

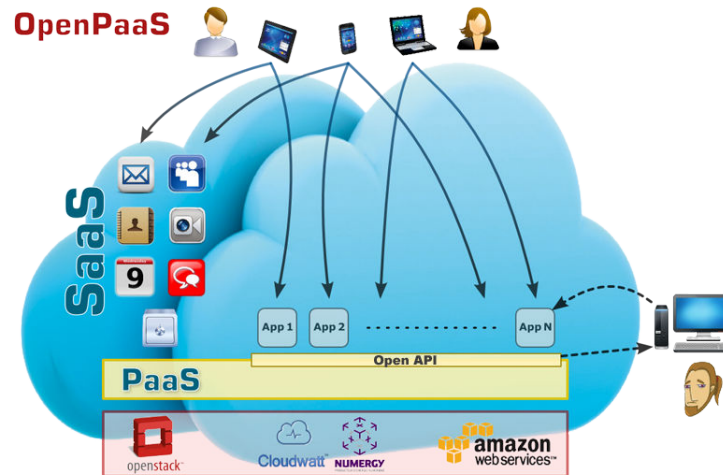


Figure 1.11 – OpenPaaS technical overview.

- On a technical level: it relies on a Platform as a Service (PaaS), which is one of the three layers of Cloud Computing. According to Dillon et al. [78], several concepts of the Service Oriented Architecture (SOA) can be easily applied to Cloud, such as the service description, discovery, composition and management. Besides, basically, the PaaS hosts SaaS (Softwares as a Service). The Figure 1.11 illustrates the use of OpenPaaS: (i) a set of collaborative SaaS are natively provided (such as shared calendar, videoconference, instant messaging, etc.), (ii) the organizations can provide their own SaaS, by deploying them directly on the PaaS via a module manager and (iii) the organizations can use these SaaS (under privacy conditions) (cf. Figure 1.11).

### OpenPaaS design-time

The research works of this thesis that have been led within the OpenPaaS project, leverage the social aspect of OpenPaaS to address new challenges in supporting inter-organizational collaborations, during the design-time.

The Figure 1.12 illustrates in three steps the aims of the design-time supported by OpenPaaS:

1. The communities of the subscribing organizations create their profile via a Profile Modeler, where they describe their business activities.
2. Assuming that a community of any organization has a business opportunity to fulfill, but does not know how to achieve it and who to work with, it can propose a new collaborative opportunity on the platform, via an Objective Modeler.
3. Based on the repository of all communities' profiles and the objective described in the collaborative opportunity model, a business process deduction service selects the



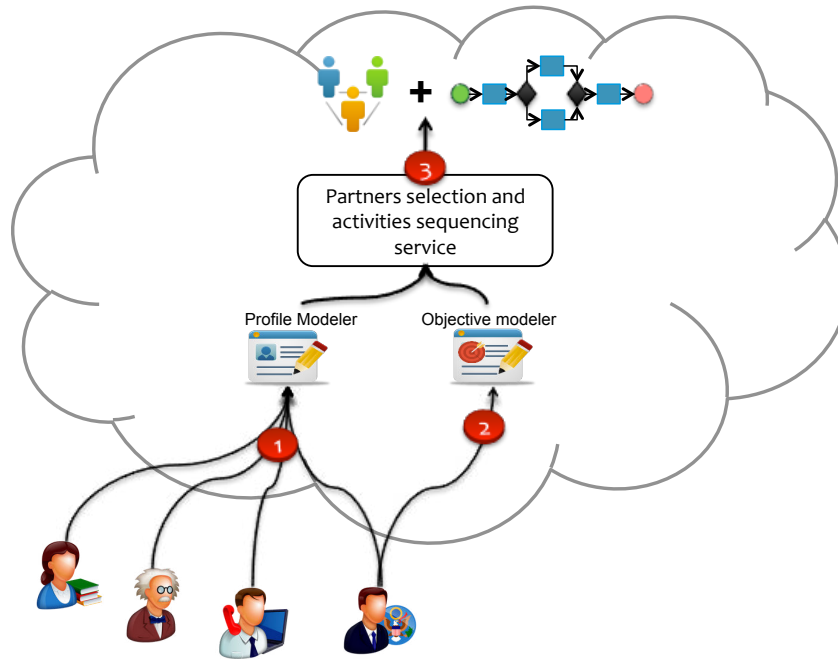


Figure 1.12 – OpenPaaS design-time.

appropriate partners and describes their collaboration with a BPMN inter-organizational process.

### 1.4.3 Problem statement

#### Questions

As mentioned in Part 1.4.1, Vatcharaphun Rajsiri and Wenxin Mu already worked on a system for gathering collaborative knowledge and deducing inter-organizational business processes. However, the specific context of OpenPaaS leads to raise some strong hypothesis of the previous works. Eventually, it is no more about specifying *functional* requirements to collaborate (*i.e.* deduce process that are “working”), but also to optimize them on *non-functional* criteria (*e.g.* time, cost, quality...). Hence, the thesis should answer various questions:

- The process deduction service is integrated within an ESN, which constrains the way to gather information about the collaborative context. Besides, to be fully effective and user-friendly enough, the knowledge gathered from users should be sufficient and minimal.

>Question 1: Which is the sufficient but minimal knowledge to gather so that the business process could then be deduced?

- The coalition of partners is not initially known: while Wenxin Mu's works made the assumption of a set of partners coming together to fulfill their common or individual objective of collaboration, only (i) the objective of collaboration of the broker and (ii) a repository of organizations' profiles are gathered here.

*>Question 2: Which are the functional mechanisms that allow selecting the partners, their business activities and transform that knowledge into a business process?*

- Because it is an open platform dedicated to any company and any type of collaborations (*i.e.* many companies should be able to provide the same business activities), the organizations evolve in competition: when selecting the partners, only the "best" should be kept to achieve the collaboration, along the lines of VE and VSC paradigms.

*>Question 3: Which are the non-functional criteria typically used to select partners (whatever the domain field of the collaboration)? And how to use them in OpenPaaS context?*

- Partners can not be selected one-by-one: for example to optimize the deduced process on time aspects, the set of all fastest organizations does not necessary lead to the fastest process (because of obvious tasks sequencing and parallelism issues when creating the process).

*>Question 4: How to conciliate both functional mechanisms and non-functional optimization when deducing the final process, so that the whole process can be non-functionally evaluated?*

### Outline

Designing automatically inter-organizational collaborations is both a matter of computer and management sciences. Thus, the choices made to answer these questions are in line with both disciplines and also with the projects OpenPaaS and MISE since the results should be integrated as a part of them. Figure 1.13 relates the outline of this PhD report and also highlights the main contributions that have been developed and implemented to answer the four latter questions.

*>Question 3: Which are the non-functional criteria typically used to select partners (whatever the domain field of the collaboration)? And how to use them in OpenPaaS context?*

The non-functional dimension is often met either in management science (*e.g.* to select best partners in bidding processes) or in computer science (*e.g.* to select best web services in service composition problems). Many terms can be used depending on the field of application non-functional *requirements, criteria, factors...* but all of them address the same overall question: which are the criteria that should be taken into account when deciding who to work with? This question is not trivial. The platform offers indeed an automated way to select partners

## Chapter 1. Context and Problem Statement

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when deducing the collaborative processes, which means that (i) the criteria should be adapted to their specific use (*i.e.* be evaluable by an IT system, and consequently objective), (ii) they should comply with the needs of customers (*i.e.* they should adapt to a wide range of types of collaborations since OpenPaaS' collaborations could meet any business domains) and (iii) they should be assessed or informed in a relevant way to ESN context.

Chapter 2 aims at providing a new non-functional framework based on a literature review on non-functional criteria emerging from various business fields, and that is specially applied to ESNs. Non-functional criteria are also important for the two following Chapters since they are also involved when acquiring knowledge: when a company describes its profile it also provides non-functional perception of its business (*e.g.* the cost of its products), and obviously in the process deduction step.

*>Question 1: Which is the sufficient but minimal knowledge to gather so that the business process could then be deduced?*

In line with MISE previous iterations, a work has been realized on knowledge acquisition and exploitation, in order to (i) get organizations' profiles and (ii) get collaborative objectives when organizations propose new opportunities. First, knowledge reasoning means that information should be stored in a knowledge base and in a structured manner (*i.e.* following a specific metamodel) such that it can be exploited to effectively deduce collaborative processes at the end. The system integrates and updates knowledge but also creates semantic links between what the users want to describe and what the IT system already knows: in such a way, it is able to understand the users' needs. However, this means that a work should be led on "what the system already knows". In other words, generic collaborative knowledge bases should be natively implemented (*generic* meaning here that it is totally independent of the organizations). Second, priority has been given to the development of user-friendly interfaces so that the users can easily provide knowledge to the system: a Profile Modeler enables the users to describe their business capabilities and store it into ontologies of collaboration, and an Objective Modeler enables the users to express their new business opportunities.

All of these steps are explained in Chapter 3: Collaborative knowledge management and acquisition.

*>Question 2: Which are the functional mechanisms that allow selecting the partners, their business activities and transform that knowledge into a business process?*

*>Question 4: How to conciliate both functional mechanisms and non-functional optimization when deducing the final process, so that the whole process can be non-functionally evaluated?*

Actually, *Question 4* extends *Question 2*: it is not only a question of selecting partners and order their activities into a process, but also to optimize this selection. As seen in the previous part, it is about global optimization: the process should be deduced and optimize in the same

time to be the most effective. Global optimization is not a new problematic: many algorithms have already been developed in many fields (*e.g.* the traveling salesman and its famous solving methods). Hence, an overview of the available methods is important so that our problem can be positioned before choosing the most adapted method. Eventually, the researches have been oriented towards metaheuristics and more precisely Ant Colony Optimization (ACO) algorithm. However, it is quite uncommon to apply ACO to semantic systems and even more to the ontology exploitation. That is why a big part of the research works focuses on adapting the ACO to the collaborative ontologies exploitation.

Thus, Chapter 4 provides all explanations about the choice of the ACO and how it has been adapted to the OpenPaaS's aims.

Finally, the Chapter 5 illustrates the whole research approach through a use case and offers a concrete visibility to the readers.

The framework for characterizing the collaboration within CNOs was presented in the Workshops of the I-ESA 2014 Conference [79] and the article [80], presented in the Workshops of the IWEI 2013 Conference states the context and raises the problematic of this PhD thesis.

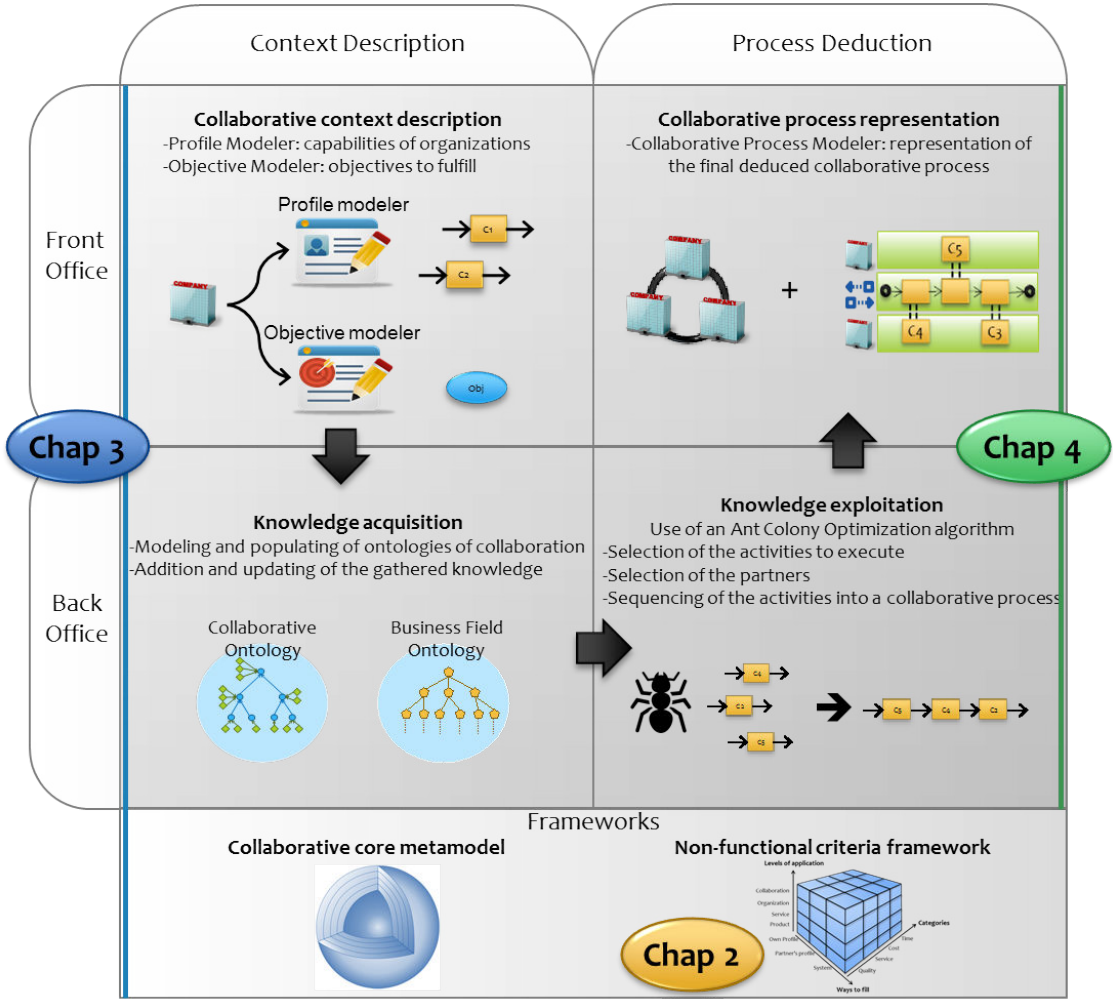


Figure 1.13 – Key problematics of the thesis.

## 1.5 Résumé en français

Depuis quelques années, suite à l'engouement pour le génie industriel et les technologies de l'information, établir et faire vivre les réseaux collaboratifs d'organisations est devenu de plus en plus simple. Il existe de nombreux types de réseaux collaboratifs, qui peuvent généralement être étudiés selon trois axes: (i) le niveau de partage entre les organisations d'un même réseau, (ii) la topologie du réseau *i.e.* la structure de ce réseau et (iii) les perspectives du réseau *i.e.* sa durée mais aussi ses objectifs à plus ou moins long terme. Les concepts d'entreprise étendue, d'entreprise virtuelle, d'organisation virtuelle et de clusters sont souvent décrits dans la littérature, et peuvent être tous décrits via cadre tridimensionnel. Mais il est aussi particulièrement intéressant d'étudier la notion de chaîne logistique, pouvant être définie comme un réseau d'organisations inter-connectées œuvrant ensemble pour contrôler, gérer et améliorer les flux matériels et informationnels, des fournisseurs jusqu'aux utilisateurs [42]. Les chaînes logistiques virtuelles, quant à elles, tendent à intégrer la notion d'information dans la chaîne de valeur de la chaîne logistique. Afin de pouvoir permettre aux organisations d'un réseau de pleinement travailler ensemble, la notion d'interopérabilité a été amenée aux systèmes d'informations: il s'agit de la capacité de plusieurs systèmes à pouvoir interagir ensemble sans modifier profondément leurs comportements ou leurs structures [46].

Afin de supporter les collaborations inter-organisationnelles dans les différents paradigmes cités précédemment, la capacité à établir, jouer, analyser et réaliser un suivi des processus métier collaboratifs est devenu un élément de réussite crucial. Ces quatre étapes du cycle de vie des processus métier peuvent être regroupées en deux grandes parties, le *design-time* concerne la première étape de modélisation du processus métier, tandis que le *run-time* s'intéresse à l'exécution de ce processus. Il est intéressant de noter que tout au long du cycle de vie des processus métiers, de la connaissance est créée, extraite, partagée et exploitée entre les différents partenaires de la collaboration.

C'est dans un tel contexte que le projet interne MISE (Mediation Information System Engineering) a été créé au sein de l'axe Intéropérabilité des Organisations, au Centre de Génie Industriel de l'Ecole des Mines d'Albi-Carmaux. Basé sur une architecture dirigée par les modèles, MISE peut être défini selon cinq étapes clés: (i) l'établissement d'un modèle de la situation collaborative (collecte de connaissances sur le contexte de la collaboration: les objectifs et l'environnement collaboratifs), (ii) déduction d'un modèle comportemental (processus métier), (iii) transformation du modèle comportemental en un workflow orchestrable, (iv) déploiement et orchestration de ce workflow et (v) mise en œuvre d'un service d'agilité permettant d'adapter dynamiquement la collaboration à tout changement de contexte collaboratif détecté. Dans ce cadre, plusieurs thèses ont déjà été réalisées autour de l'automatisation du *design-time* (étapes (i) à (iii)) au cours des itérations de MISE, et chacune a été l'occasion de lever des hypothèses faites par les travaux précédents. Cette thèse s'applique en particulier à lever l'hypothèse que les partenaires de la collaboration sont déjà connus, au moment de la déduction d'un processus métier.

## Chapter 1. Context and Problem Statement

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Cette thèse a été réalisée dans le cadre du projet FUI OpenPaaS visant à implémenter un nouveau réseau social d'entreprises hébergé sous forme d'une plateforme en tant que service, et dont le but est d'offrir aux organisations des services pour faciliter et supporter leurs collaborations intra et inter-organisationnelles. Dans le cadre du *design-time* d'OpenPaaS, des profils d'organisations sont collectés et chaque organisation peut proposer des opportunités de collaboration (étape (i) de MISE). Ces travaux de recherche visent à exploiter ces connaissances pour déduire un processus collaboratif c'est-à-dire: (i) trouver les services métier à mettre en oeuvre pour répondre à l'opportunité, (ii) trouver les partenaires capables de réaliser ces services métier et (iii) ordonner ces services en un processus métier. Etant attendu que plusieurs organisations sont capables de fournir les mêmes services métiers, sur le RSE, il s'agit aussi, selon le contexte de collaboration, de trouver le "meilleur" ensemble de partenaires capables d'intervenir (selon des critères non-fonctionnels tels que le coût, la qualité...).

Pour répondre à cette problématique, le Chapitre 2 s'intéresse tout d'abord aux différents critères non-fonctionnels habituellement utilisés dans le cadre de la sélection de partenaires. Le Chapitre 3 s'intéresse, quant à lui, à la représentation et l'acquisition des connaissances sur la collaboration, devant être collectées pour pouvoir déduire un processus collaboratif viable. Puis, le Chapitre 4 s'attache à exploiter cette connaissance dans le but de déduire un processus collaboratif inter-organisationnel quasi-optimal. Finalement, le Chapitre 5 illustre l'approche adoptée dans ces recherches à travers un cas d'illustration permettant d'amener une vision concrète aux lecteurs.

## 2 On Non-Functional Requirements for Partner Selection

“I never confuse the cost of something with its value.”

– Robin Hobb, *The Mad Ship*

### 2.1 Introduction

From the simplest buyer/seller relationships to the most complex bidding processes, making decision always remains a difficult and laborious step whatever the business field and the nature of the decision. The first reason is that decisions are never unidimensional: the decision maker has to think to many criteria - basically the famous advantages vs disadvantages list for “weighing the pros and the cons”. The second reason concerns the way to exploit these criteria in order to take the “best” decision. About the first previous concern, the first thought often goes to the typical triptych *cost*, *time* and *quality*. However, this triptych is actually too vague and not sufficient to be effectively applied. In this regard, Cagno et al. [81] consider bids through multiple economic and technical criteria. Wu and Su [82] mention that cost and time of completion are the most important factors to configure a competitive VE, but also recognize that other dimensions such as quality, trust, credit, reliability should be considered. Indeed, numerous industrial and academic works have been conducted to address this issue. However in most of the cases the proposed criteria are quite specific to some business domains and/or aren't provided with the corresponding metrics that would make them objectively assessable. Hence, this chapter aims at proposing a *non-functional* framework that relates the criteria usually taken into account for selecting partners and their business services - or products.

In a myriad of already existing surveys, Section 2.2 aims at expressing the specific requirements of this non-functional framework by positioning it both within the literature and the OpenPaaS project context. Then, in Section 2.3, adapted criteria from various fields of application are selected in the literature with their corresponding metrics. Section 2.4 proposes a categorization



of these criteria via a three-dimensional framework by applying them to the specific needs of an ESN such as OpenPaaS. Finally, a short use-case illustrates how this framework can be used.

## 2.2 The need of a new non-functional framework

### 2.2.1 Definition of the “non-functional” dimension

Basically, the ISO 9001:2008 standard [83] defines quality as “the degree to which a set of inherent characteristics fulfills requirements”. These requirements have been defined by several authors, and most of them agree on a difference between functional and non-functional requirements (NFR). According to Van Lamsweerde [84] as well as Doerr et al. [85] the functional dimension concerns the services provided themselves while the non-functional dimension is about quality of service. The ISO/IEC/IEEE 24765:2010 standard [86] is oriented towards software requirements but also offers quite similar definitions that can be expanded to any systems and kept as references:

“ A functional requirement is **1.** a statement that identifies what a product or process must accomplish to produce required behavior and/or results (in [87]) or **2.** a requirement that specifies a function that a system or system component must be able to perform. ”

“ A non-functional requirement is a software requirement that describes not what the software will do but how the software will do it. ”

This Chapter exclusively focuses on the non-functional dimension, by establishing a wide literature review on the usual non-functional criteria used for selecting partners.

### 2.2.2 Overview of the related literature

Actually, in the literature, Non-Functional Requirements (NFR) can be named differently: non-functional factors, non-functional criteria, non-functional properties and even non-price factors also refer to the same concept. These terms depend on the business fields. Hence, Figure 2.1 summarizes the different areas of research concerned by them that have been studied in this Chapter, between both management and computer science. In management science, several NFRs were studied on three main topics: Supply Chain, performance analysis and make or buy relations. In computer science, two topics are particularly prolific on non-functional requirements: software quality and web service selection works.

Here again, the two areas of management science and computer science prevail: from supply chain management, to web service selection, through performance analysis (cf. *Analyze* step of the BPM lifecycle in 1.3.2). Each area uses specific terms, since they actually study different

## 2.2. The need of a new non-functional framework

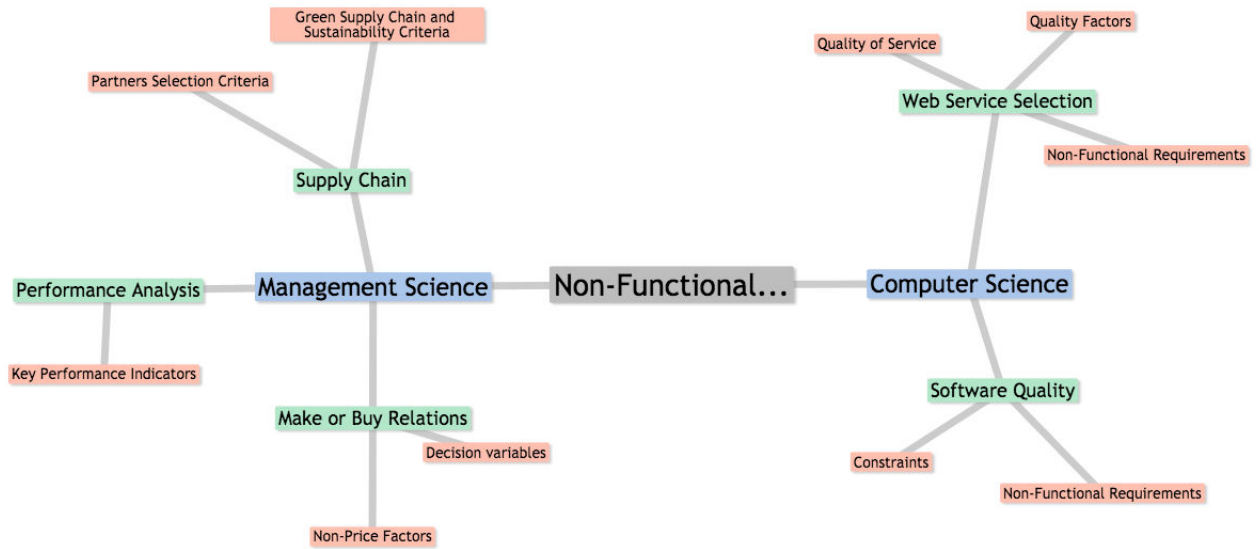


Figure 2.1 – Mindmap of the different topics of interest around NFRs.

points of view on NFRs (e.g. the web service selection NFRs are quite different from the key performance indicators in performance analysis, since the context is not the same). In the whole literature, non-functional criteria, properties, factors and requirements are the most used terms and have been burning topics these last ten years, as requests made on the major scientific databases show in Figure 2.2.

Glinz [88] conducted a literature review on the categorization of non-functional requirements. It appears that, at this time, there was not a domain independent or a standard definition of non-functional requirement in the engineering community. Glinz's observation is that a non-functional criteria is a constraint or an attribute that comes in opposition with the intrinsic functionality and behavior of the system, which complies with the definition adopted in Part 2.2.1. On the one hand, the attributes can be performance level or specific quality requirements expected by the broker. On the other hand, it can also be further constraints that the system should respect e.g. legal, environmental expectations. This Glinz's taxonomy is summarized in the Figure 2.3.

According to Glinz, the difference between performance and quality requirements relies especially on the objectivity of the corresponding criteria: performance concerns rather objective and numerical assessment (e.g. timing, throughput...), whereas quality deals with the perception of the system (e.g. reliability, usability...), which is rather subjective.

Besides, the concept of sustainable development has grown in the late half of the 20th century to become one of the major concerns of the current society. Its precursor, the Man and Biosphere program (MAB) was launched by UNESCO in 1971. About it, Batisse [89] mentions a certain lack of data at this time, which led to controversies, and a determination to establish data

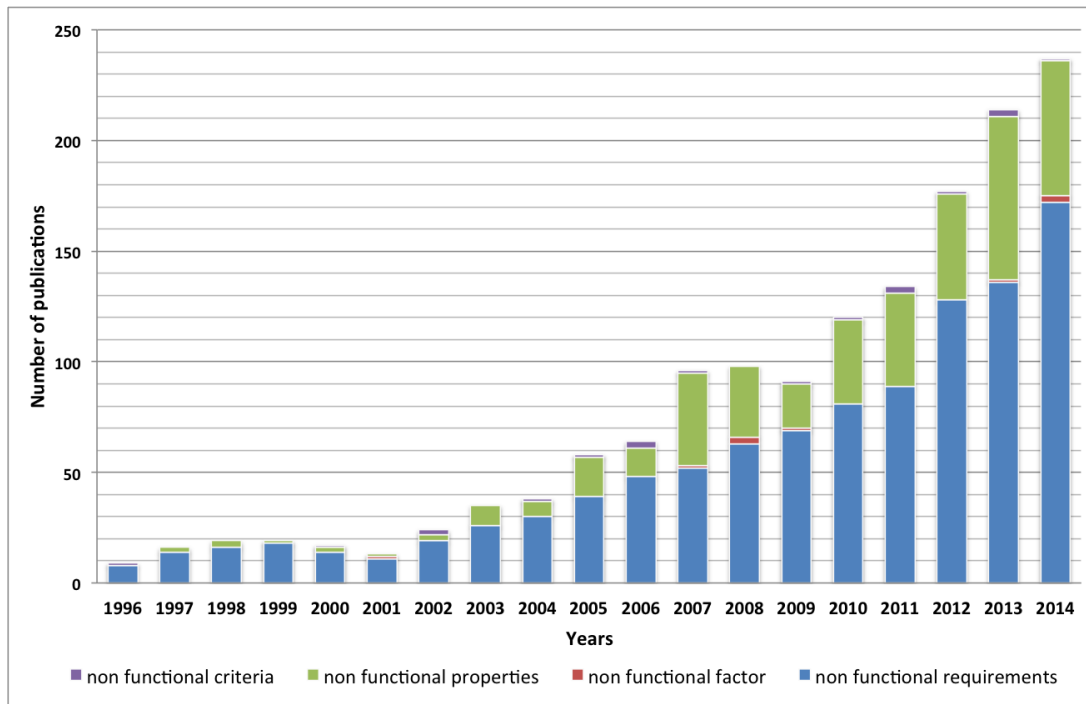


Figure 2.2 – Publications about non-functional criteria, properties, requirements and factors on ScienceDirect (focusing on industry related topics).

acquisition and exploitation to be able to assess environmental problems. The term “sustainable development” was then used for the first time in 1980 [90]. One can note that from the beginning, sustainable development and ecological concerns have implied scientific evidence. And, indeed, in most of the literature, such type of non-functional criteria comes along with the corresponding metrics. That is why, here, the Part 2.3.3 is dedicated to green and sustainable development criteria.

Non-functional criteria concern many areas, through several different keywords; they can be numerical or not, more or less impartial. In brief, apart from the sustainable development topic which has always been a very framed topic, studying non-functional criteria leads to the uncertain dimension of the human perception of what is “good” or not, all the more broad that the criteria can be seen differently from a business domain to another. That is why there is now a need to reconcile all these points of view, in order to obtain a generic non-functional framework able to benefit to most of the existing business fields.

### 2.2.3 OpenPaaS context requirements

Obviously, the new non-functional framework resulting from this study of the literature must cover the needs of the OpenPaaS project. The use of the selected non-functional requirements is indeed constrained by the ESN in several ways:

## 2.3. Survey on non-functional criteria for partner selection and their assessment

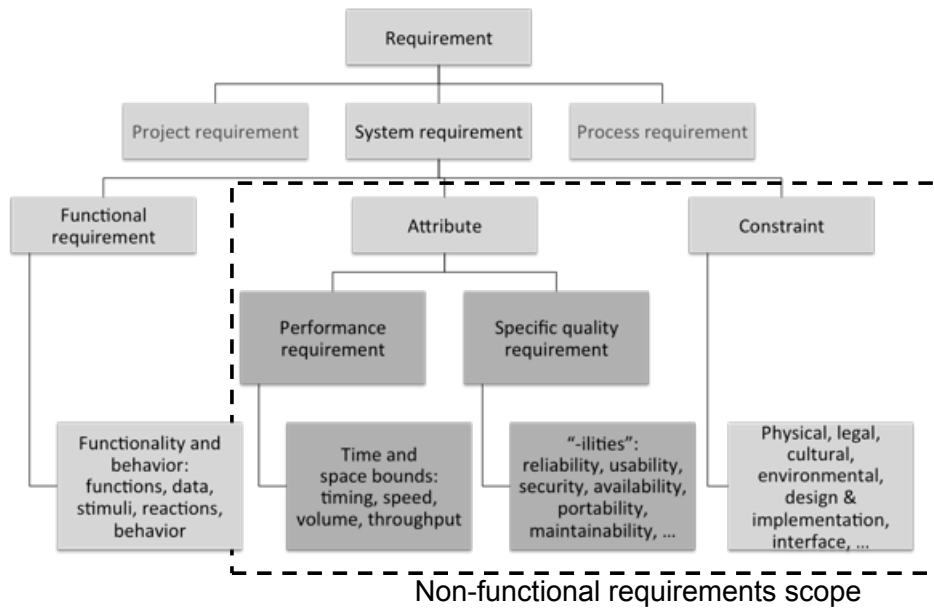


Figure 2.3 – Glinz’s taxonomy for non-functional requirements [88]. ©2007IEEE

- Self sufficiency: the ESN should natively be able to deal both with the assessment of non-functional requirements and their exploitation in the selection of partners during the design-time.
- Objectivity: quality, for example, is a wide topic, which is often rather subjectively understood. In order to enable an automated exploitation, these criteria should be the most objective possible. That means that for each of them, the associated sensitivity range should be adapted and distinguishable by an IT system. As a result, each criteria should go together with metrics.
- Wide scope: OpenPaaS aims at supporting any kind of collaboration, whatever their field of application. Actually, the users should be able to find their usual decision criteria, although all the criteria will not necessarily be used together for one collaboration.

## 2.3 Survey on non-functional criteria for partner selection and their assessment

### 2.3.1 Non-functional criteria

One of the most cited and famous non-functional framework is SERVQUAL, established by Parasuraman et al. [91]. This framework rather focuses on the customer point of view: what

## Chapter 2. On Non-Functional Requirements for Partner Selection

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makes him satisfied of a service and which dimensions does he take into account when assessing the quality of the service. Parasuraman et al. [91] studied several different services, and worked on the gap between the customer expectations and the perception of the provided service. Nyeck et al. [92] claim that this framework has been intensively used since many years, considering SERVQUAL as the “most complete attempt to conceptualize and measure service quality”. According to Nyeck et al. [92], its success is due to the possibility to apply it to many service sectors. In its second version in 1988, SERVQUAL [91] defines the service quality through five dimensions established on subjective trust from the customer as well as on technical skills: *tangibles, reliability, responsiveness, assurance, empathy*. However, to respond our issues, SERVQUAL rather brings the main orientation of research on service selection criteria, since the SERVQUAL remains high-level.

Roman [93] and Boehm et al. [94] propose major (and highly cited) works on the NFR topic. They actually focus on software engineering. Roman [93] proposes a taxonomy of NFR through five constraints:

- Interface constraints which define interactions between a component (software package, hardware device or the whole system) and its environment (users, operating system, hardware, software packages).
- Performance constraints are related to time and space bounds (workload, storage space, response time), security, reliability (integrity of the information maintained or supplied by components) and survivability (*e.g.* off-site copies of databases).
- Operating constraints are linked to the physical constraints, human resources (skills, availability), maintenance, environment and location.
- Life-cycle constraints are dealing with the design, the maintenance and the enhancement process of the component.
- Economic constraints consider the costs on both immediate and long term.
- Political constraints represent the policies and legal issues (local law).

Roman [93] states that, as the component has interactions with its environment, the environment impacts the complexity of the component design. So he describes the NFR as constraints on the environment in order to reduce the component complexity. If the categories of this taxonomy are mainly domain independent, a part of the NFR are domain dependent, *i.e.* oriented towards software engineering problematic (“operating system” cannot be used in a business domain like food processing). NFR classified under *political constraints* and *economic constraints* are common to any business domain. *Performance constraints* and *operating constraints* NFR can also be applied to a product or a service, whatever the business domain is. Other NFR (Interface constraints and Life-cycle constraints) should be adapted to be more generic or at least to cover a wider domain than software engineering only.

### 2.3. Survey on non-functional criteria for partner selection and their assessment

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In the field of virtual manufacturing systems, Davidrajuh and Deng [95] present three factors to select suppliers: *agility*, *leaness* and *quality*. According to Charles [96], *agility* is the ability of an organization to respond quickly and efficiently to the unexpected (*e.g.* changes on customer needs). *Leaness* is the set of effective costs of the supplier: these costs represent the supplier quotes but also various additional costs like transportation, taxes, etc. *Quality*, here, is the ability of the supplier to be, at least, ISO certified and to be evaluated by audits.

Xia and Wu [97] focus on the problem of supplier selection in the field of supply chain management. They propose a four-level hierarchy to evaluate and select suppliers: (i) objective (evaluation and selection of suppliers), (ii) criteria, (iii) sub-criteria and finally (iv) suppliers alternatives. Criteria are both qualitative and quantitative: price, quality and service. Quality and service contain sub-criteria:

- Quality: technical quality of the products, their defects and their reliability.
- Service: services the supplier is able to provide about its products (on-time delivery, supply capacity, repair turnaround time and warranty period).

It is interesting to note that this analytical hierarchy process for supplier selection is not dedicated to a specific business domain.

Garvin [98] tries to answer to the question: *what is quality for a product?* As product quality can be seen through a high cost, it can also be seen just through its characteristics and attributes or it can be a correlation between the performance of the product and an acceptable cost. The objective of Garvin [98] is to aggregate all the different definitions of quality in order to establish a global framework for better understanding the main element of quality. The author has based the framework on eight dimensions: *performance*, *features*, *reliability*, *conformance*, *durability*, *serviceability*, *aesthetics*, *perceived quality*.

Hansen and Bush [99] aim at defining what is the quality of a product and of a service. For this purpose, they have exploited the results of a questionnaire answered by more than 800 people. Finally, eighty criteria were classified according to the SERVQUAL and Garvin's dimensions. This framework is quite product-oriented, as a consequence of Hansen and Bush's field of study (wood purchasing). One can note that Hansen and Bush [99] add *cooperativeness* as one more dimension to the thirteen axes of study about quality coming from SERVQUAL (five dimensions) and Garvin (eight dimensions). In addition, their framework aims at being only oriented towards service or product quality, with the choice of leaving aside price and cost dimensions. Although this framework is quite product-oriented, and rather specific to the wood/lumber purchasing, several criteria are relevant, whatever the field of application:

- Service reliability: "Consistent, on-schedule delivery by supplier", "Product availability" and "Accuracy of supplier's billing system".

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- Responsiveness: “Supplier’s ability to deliver quickly on short notice”, “Eagerness of supplier’s salespeople to meet your needs” and “Supplier rapidly responding to and solving problems”.
- Assurance: “Knowledge and skill of supplier’s sales personnel”, “Manufacturing expertise of the supplier”, “Dealings with supplier being held confidential” and “Supplier’s ability to understand conditions of special orders”.
- Empathy: “Being recognized by supplier’s salespeople as a regular customer”.
- Tangibles: “Supplier’s physical facilities”, “Tools/equipment used” and “convenience of supplier’s location”.
- Perceived quality: “Reputation of supplier” and “Previous experiences with supplier”.
- Cooperativeness: “Supplier’s willingness to fill large orders”, “Supplier’s willingness to fill small orders”, “Supplier-arranged shipping”, “Credit terms offered by supplier”, “Long-term price arrangements offered by supplier” and “Just-in-time (JIT) delivery offered by supplier”.

Ha and Krishnan [100] propose a list of thirty criteria based on a literature review from 1966 to 2000 that are commonly used for selecting partner in supply chain collaboration. Even if many of these criteria also correspond to the criteria kept from Hansen and Bush [99], it is interesting to cross several non-functional frameworks. Also, Ha and Krishnan [100] offer a somewhat generic perception. Actually, their work is based on the propositions of several papers on the topic, written by Dickson [101], Wind et al. [102], Lehmann and O’shaughnessy [103], Perreault and Russ [104], Abratt [105], Billesbach et al. [106], Weber et al. [107], Segev et al. [108], Min and Galle [109] and Stavropolous [110], and twenty of their criteria seem interesting and if not always kept, at least have oriented the researches. “Price” comes as the favorite criteria for nine on ten authors. Seven of them attach importance to the “Delivery” which however does not bring more detailed position (e.g. shipping arrangement or only ability to deliver products?). Then six mention “Quality” as a key factor for selecting partners which notion could also be more detailed. The “Reputation and the position in industry” is actually important for half of the authors, which supports the results of Hansen and Bush [99]. Finally, four of them bring criteria that are not all so far from the one from Hansen and Bush [99]: “Warranties and claims”, “Technical support”, “Attitude”, “Performance history”, “Geographical location”, “Labor relations”, “Response to customer request”, “JIT capability”, “Technical capability”, “Production facilities and capacity”, “Operational controls”, “Maintainability”, “Amount of past business”, “Reciprocal arrangements”, “Environmentally-friendly products” and “Product appearance”.

Min and Zhou [111] propose a set of key components for the supply chain thematic that are directly organized towards the use of this non-functional framework through three types of parameters:

- *Goals*: the “Supply Chain Drivers” that are the driving forces of the supply chain.

### 2.3. Survey on non-functional criteria for partner selection and their assessment

- *Constraints*: the “Supply Chain Constraints” that deal with the feasibility of the supply chain.
- *Decision variables*: the “Supply Chain Decision Variables” related to the performances of the supply chain.

The Table 2.1 depicts this set of components.

<b>Dimension</b>	<b>Key Components</b>
<b>Supply Chain Drivers</b>	Product Availability
	Response time
	Asset Utilization
	Return-on-investment
	Cost behavior
	Real-Time Communication
	Technology Transfers
	Risk of Quality Failure
	Risk of Information Failure
<b>Supply Chain Constraints</b>	Capacity
	Service Compliance
	Extent of Demand
<b>Supply Chain Decision Variables</b>	Location
	Allocation
	Network Structuring
	Number of facilities and equipment
	Number of stages
	Service sequence
	Volume
	Inventory Level
	Size for Workforce
Extent of Outsourcing	

Table 2.1 – Partners selection criteria, [111]

Non-price factors are discussed in the field of the competitive bidding as important criteria that can increase the probability of winning in a competitive bid process in the industry. Competitive bidding is a method used to obtain goods and services at the best price and contract terms by stimulating competition among contractors and suppliers. Barnes et al. [112] state that quality, innovation, adherence to standards and rapid response are the first non-price factors that can provide an advantage into a competitive market. Cagno et al. [81] describe a set of thirteen factors to evaluate a competitive bid, in the context of the design and the construction of a process plant. These factors are classified under four categories: service level, plant performance,



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financial conditions and contractual conditions. If some of them are strongly related to the process plant use-case, others can be extracted to be adapted to a more generic business case such as delivery time, price, terms of payment, financial package, dependability, conformity to tender documents.

### 2.3.2 Metrics

In service quality field, important research domains for non-functional criteria are web services and software engineering. OASIS (Organization for the Advancement of Structured Information Standards) [113], an international consortium creating interoperable industry specifications, has designed a specification to describe quality attributes of web services. These quality attributes are represented by functional and non-functional properties. They are classified under six categories: *business value quality*, *service level measurement quality*, *interoperability*, *business processing*, *manageability* and *security*. Even if this WSQF (Web Service Quality Factors) specification focuses on web services and do not necessary fit with a more generic context, it is interesting to note that it is commonly used to select web services for orchestrating processes, as shown by Zribi et al. [114]. In a way, this selection of web services is similar to the selection of partners based on non-functional criteria. Minus the domain dependent criteria, we can extract non-functional criteria from this specification: price, penalty and incentives, business performance, service provider reputation (for organization reputation in a generic framework), and privacy. Compared to most of the frameworks found in the literature, this specification has the advantage to propose the users ways to evaluate the criteria, which could be called "metrics" even if they do not always correspond to numerical formulas. The Table 2.2 gives a summary of the major criteria, with their corresponding categories and metrics.

Badr et al. [115] studied the web services selection through non-functional properties. They designed a categorization ontology for the non-functional properties: they are divided into Quality of Service (QoS) properties (response time, accessibility, compliance with WSDL, successability, availability, encryption, authentication, access control, etc.) and Context properties (cost, reputation, organization arrangement, payment method, monitoring, location, temporal properties). Comparing this ontology to the WSQF specification, it appears that they share most of their criteria, exception made of three criteria (that exist only in Badr's ontology [115]): the location, the payment method and the organization arrangement. These three criteria are relevant to the framework as they are domain independent and they add additional criteria for partner selection (location of a partner may influence its delivery time, as well as the payment method may facilitate financial transactions). The last criterion, "organization arrangement", is based on the knowledge gathered on the current and previous collaborations. As it allows detecting organization's preferences of partnerships, this feature is interesting to meet the suppliers' relationships category of the framework.

Answering this issue, one of the most complete work on supply chain KPIs is the SCOR (Supply Chain Operations Reference) model developed by the Supply-Chain Council [116]. It is a very

### 2.3. Survey on non-functional criteria for partner selection and their assessment

Category	Criteria	Metrics
<b>Business Value Quality</b>	Price	"Monetary value that a consumer pays for service to provider"
	Penalty/Incentive	Specified in contract. Based on service downtime, maximum or average response times, security requirements...
	Business Performance	Can be specified by the time to complete the service or the throughput. $Throughput = \frac{Amount\ of\ Outcomes}{Time\ Unit}$
	Service Reputation	Based on replies, comments or reviews from customers.
	Service Provider Reputation	Based on brand value, financial soundness, quality of customer service, technical support and sustainability of the service provider.
<b>Service Level Measurement Quality</b>	Response Time	$Response\ Time = ClientLatency + NetworkLatency + ServerLatency$
	Maximum Throughput	$Maximum\ Throughput = \max\left(\frac{Number\ of\ Requests\ Processed}{Measured\ Time}\right)$
	Availability	$Availability = 1 - \frac{Down\ Time}{Measured\ Time}$
<b>Security</b>	Privacy	Protection of privacy information implemented or not. Plus, privacy policy appropriate.

Table 2.2 – Web service selection criteria and metrics, based on [113]

famous management tool for the supply chain function, divided into three main parts: process modeling, performance measurements and best practices. The performance measurements proposed in this framework are particularly interesting here. They are organized in five main dimensions: *reliability*, *responsiveness*, *agility*, *costs* and *asset management efficiency*. Each of these dimensions is decomposed into three levels: first the strategic metrics, then the metrics to identify the causes of a gap in first level, and finally the third as a diagnosis of the second level.

For example, *reliability* can be assessed by "perfect order fulfillment", which can be decomposed into "% of orders delivered in full", "delivery performance", "documentation accuracy" and "perfect condition". Then "% of orders delivered in full" goes with "delivery accuracy" and "delivery quantity accuracy". The SCOR also proposes a calculation method:  $\% \text{ of orders delivered in full} = \frac{\text{Total number of orders delivered in full}}{\text{Total number of orders delivered}}$ . The SCOR model results in more than 500 three-level metrics, which obviously can not be summed up here; even though it is a huge and accurate source for the metrics of the non-functional criteria of the final framework.

#### 2.3.3 Towards green and sustainable development criteria

Srivastava [117] introduces the green supply chain management as a way to deal with the

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influence of supply chain on natural environment, which has become a crucial issue these last years. For the author, this concept should be extended from the product design phase up to the delivery phase, *i.e.* all along the whole supply chain process. Schwarz et al. [118] indeed claim that sustainable development is now a “core business value” for companies and the establishment of metrics helps the integration of this new dimension in decision-making processes. Ashby et al. [119] make a very close link between the two terms green and sustainable supply chain management. Moreover many literature reviews show the growing concerns about way to evaluate and measure the performance of green and sustainable supply chains [120–122]. Derrouiche et al. [123] highlight especially that collaborative networks should now meet the sustainable development requirements through the three usual dimensions: *environmental*, *social* and *economic*.

Bai and Sarkis [124] propose three tables of attributes based on a literature review, according to the three dimensions of the sustainable development. For example, the business and economic table proposes attributes refined in 8 categories *cost*, *quality*, *time*, *flexibility*, *innovativeness*, *culture*, *technology*, *relationship*. Then each category is precised through low-level criteria like *delivery speed* for time, or *suppliers speed* in development for technology. It is interesting to underline that most of the economic and business criteria of this framework are not quite distinguishable of previously cited criteria. That is why this part will only focus on the environmental and social topics. Note that the linkage between the two first paragraphs of this literature review, *i.e.* quality criteria and performance criteria, showed that the first one is very usefull to provide a common vocabulary for the designation of each criteria and the second one is quite oriented towards the formulas or technics to concretely assess them. In the same way, Bai and Sarkis [124] provide a deep study about the different commonly used criteria but do not extend it to the metrics.

In this perspective, the SCOR Reference [116] dedicates an entire part to green topics: the GreenSCOR. Five particular metrics are provided, and should allow users to focus especially on the environmental component of the sustainable development, in supply chain sector:

- *Carbon emissions* (Tons CO<sub>2</sub> Equivalent): helps measuring the green house gas emissions.
- *Air pollutant emissions* (Tons or kg): measures the quantity of CO<sub>x</sub>, NO<sub>x</sub>, SO<sub>x</sub>, volatile organic compounds and particulate emitted.
- *Liquid waste generated* (Tons or kg): “includes liquid waste disposed of or released to open water or sewer systems”.
- *Solid waste generated* (Tons or kg).
- *% recycled waste* (Percent).

Hutchins and Sutherland [125] focus on the social measures of sustainable development. In particular, they deal with the selection of suppliers in the context of supply chain and consequently

### 2.3. Survey on non-functional criteria for partner selection and their assessment

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study the social impact of the companies. Their work on the measures of social sustainability for supply chain decision-making mentions, among others, the work of the United Nations Division of Sustainability Development [126] that categorizes social indicators. However, as rightly highlighted by Hutchins and Sutherland [125], the U.N. Guidelines are very complete and all the criteria could not be applied by a company (*e.g.* access to drinking water or education...), even if some corporations sometimes lead philanthropic activities. Finally they propose four indicators with corresponding examples of metrics, that are not claimed to be exhaustive. Their strength lies in the fact that the criteria are quantifiable and exploit generally public and available information. The indicators and the proposition of corresponding metrics are as follows:

- $LaborEquity = \frac{Average\ hourly\ labor\ cost}{Compensation\ of\ the\ highest\ paid\ employee}$
- $Healthcare = \frac{Healthcare\ paid\ per\ employee}{Market\ capitalization\ per\ employee}$
- $Safety = \frac{Days\ not\ injured\ per\ employee}{Days\ worked\ per\ employee}$
- $Philanthropy = \frac{Charitable\ contributions}{Market\ capitalization}$

#### 2.3.4 Synthesis of the literature review

The evaluation of existing frameworks and standards about non-functional criteria for partner selection lead us to the following conclusion. A major part of existing works focus on a specific sector since they do not need to deal with a very large scope of business fields. The literature shows that non-functional criteria are often seen as cost, delay or quality factors which is quite reductive to represent the variety of non-functional criteria. Moreover, some do not share the same granularity: some criteria can be very high or very low level depending on the studied framework. In order to be used in the context of OpenPaaS, they need to be adapted to a larger scope, but also to be measurable.

Thus, all these criteria need to be merged together in order to obtain a new adapted non-functional framework (*i.e.* that fit industrial current needs), both service or product oriented, and that proposes coherent, relevant and quantitative measures. Besides, one can note that, even if they do not fit perfectly with the pursued goal (*i.e.* covering any for at least, most of existing business domains), an adaptation can be made to keep the most relevant part of these frameworks in our proposal. Still, it remains that some frameworks intend to propose generic partners evaluation criteria but they suffer from a too generic and implicit description: they propose mostly concepts or family of criteria rather than explicit sets of criteria (possibly categorized by business domain).

Most important, none of the already existing non-functional frameworks explains how to assess these criteria, and even mentions if they are adapted to *human* or *computer* evaluation. Although some of them at least linger on associated metrics, they are not adapted at all to the actual

information technologies. They still need to be categorized according to *how their data can be gathered* in an automated context and also adapted to Virtual Breeding Environments (VBE).

### 2.4 OpenPaaS' Application

#### 2.4.1 How to assess non-functional criteria

As an ESN, each subscribing organization must describe itself in a profile. These profiles come as a portfolio of all of their business capabilities that they want to provide for collaborations. Thus this is where the users should access the non-functional assessment. Non-functional assessment could be indeed categorized through three types of attribution:

- Directly in an organization's profile (cf. Figure 2.4 a): when the criteria are rather objective and can directly be informed by the provider on its profile.
- By current or former partner's (cf. Figure 2.4 b): when the criteria are rather subjective. Eventually, these criteria are a way for partners to give a feedback on the work provided by the organization during a collaboration.
- By the system (cf. Figure 2.4 c): when criteria are strictly quantitative and can be assessed during or after the collaboration, the system can compute them itself.

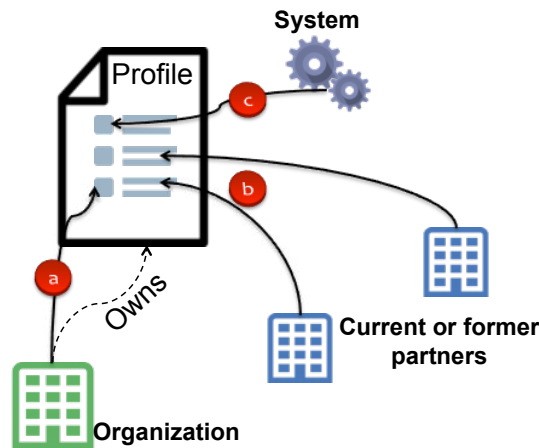


Figure 2.4 – How to assess the criteria on an ESN.

#### 2.4.2 Levels of application for the OpenPaaS' non-functional criteria

In the previous literature review a lot of non-functional criteria are discussed and some of them prove to be much more an assessment of the organization itself than just only for one of its capability. For example, if the organization has an effective and accurate billing system, for

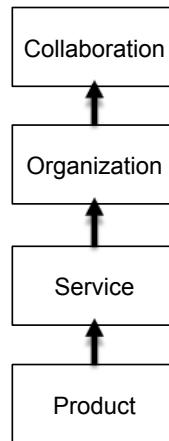


Figure 2.5 – Inheritance of the four levels of application.

example, consequently any of its capabilities will also have such quality of billing system. Here, it is considered that there exists a kind of inheritance of the non-functional criteria can be set up. Here, the *services* inherit from the *organization*.

Moreover, the non-functional criteria not only assess partners and their capabilities in OpenPaaS but also provide the broker a way to express its non-functional expectations for the collaboration. For example, a minimal-cost collaboration but strictly confidential will lead to choose the “best” partners, which necessarily must accept confidentiality agreements. As a consequence the *organization* level inherits from the *collaboration* level. In the same logic, every *service* provided by an organization inherits from its characteristics. Finally, the *product* level leads to questions like the size of the orders or its technical characteristics, which are quite different of what can be assessed on a “pure” service. Furthermore, products usually do not exist without support services all around (billing, transportation...), especially with the emergence of new product-service systems and more generally the whole thematic around servitization. That is why this framework proposes an inheritance from product to service levels.

Four levels have emerged: product, service, organization and collaboration. The Figure 2.5 illustrates these four levels of application of the non-functional criteria.

### 2.4.3 OpenPaaS' non-functional categories

As a formal illustration of what makes a product or a service valuable, Johansson et al. in [127] express four top-level dimensions: quality, service, cost and time. In order to evaluate in a qualitative way these four concepts, the authors propose that the value can be represented as follows:

$$Total\ value = (Quality * Service) / (Cost * Time) \quad (2.1)$$

The usual goals are indeed to improve quality and service, with lower costs and less time of

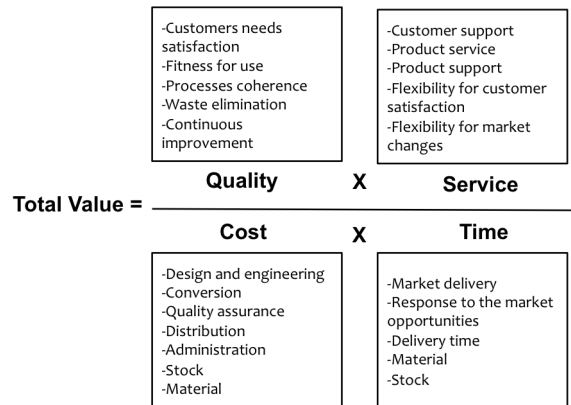


Figure 2.6 – Precise illustration of the value concept, [127].

process. As illustrated in Figure 2.6, the four dimensions can also be defined through various criteria. It is important for the user to organize the numerous criteria so that he can choose the one he wants to apply to his partners selection. For this purpose, it was decided to choose the Equation 2.1 from Johansson et al. as a way to categorize these criteria. It is indeed an intuitive categorization, and it is very relevant to the context since the four dimensions (Quality, Service, Cost and Time) fit quite well the usual industrial approaches for partners selection.

#### 2.4.4 OpenPaaS’ final framework

Figure 2.7 provides an overview of the three dimensions that have been chosen to organize our framework.

Four tables (Table 2.3, Table 2.4, Table 2.5 and Table 2.6) relate the selected criteria for this framework, according to the four Johansson’s categories, and for each of these criteria, the corresponding definitions, metrics and references are given. Their application level and the way to assess the non-functional criteria are also specified, and allow to apply them to OpenPaaS’ context. In an effort to make these tables more readable, the following abbreviations have been used:

- Application level: App. Can be applied on the four levels: Collaboration (Col), Organization (Org), Service (Serv) and Product (Prod).
- Ways to assess the criteria: Who? Can be assessed on the three levels: Own Profile (OP), Partners’ Profiles (PP) and IT System (S).

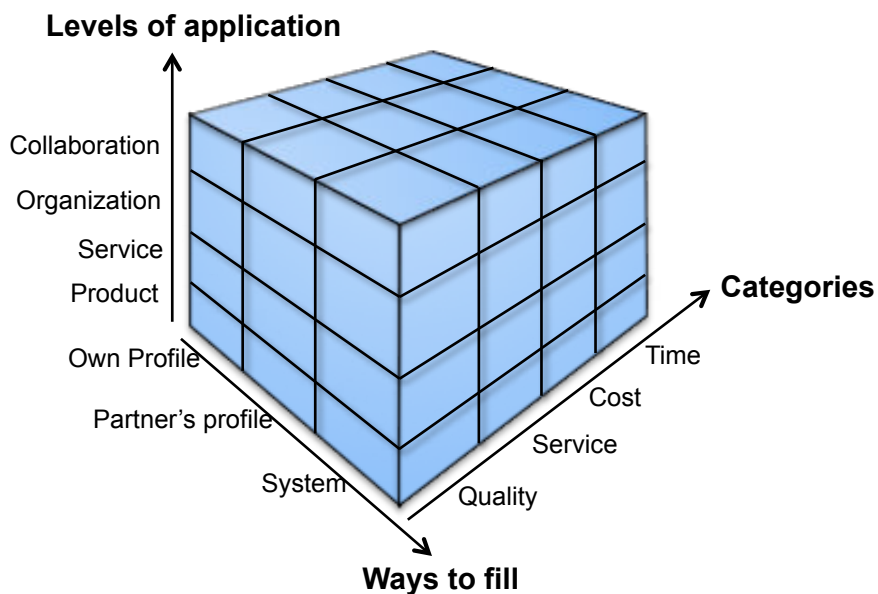


Figure 2.7 – Details of the three dimensions of the non-functional framework, applied to OpenPaaS needs.

## 2.5 The Gruppo Poligrafico Tiberino case

In order to give a concrete point of view on this non-functional framework, this Section aims at confronting it to a real case study. The Gruppo Poligrafico Tiberino (GPT)<sup>1</sup> provides a successful example of CNO and has been widely mentioned and studied in the academic literature thanks to the integration of the University of Perugia during its expansion phase as of 2005. Although these research works are actually independent of the GPT, it offers an ideal real case to illustrate these research works.

### 2.5.1 Gruppo Poligrafico Tiberino, the origins

The GPT is a network of 21 companies working on the field of communication, printing, packaging and related services and products, all situated in the Umbria region, Italy. Saetta et al. [128] provide a complete history of the emergence of GPT. Apart from being recognized for its wines, its truffles and its excellent extra-virgin olive oil [129], Umbria also owns a historical handicraft tradition in printing, for example in Foligno [130]. Saetta et al. [128] explain that the competitive potential of the industries in this area is limited due to the lack of a way to aggregate them together (*i.e.* no leader company to orient them as a whole, in opposition with Airbus and the aerospace valley in the South-West of France for example). That is why in the beginning of the 2000's, three enterprises -namely Pasqui, Litop and Litograf- decided to initiate a collaborative network via the creation of the GPT company. Since then, 16 other

<sup>1</sup>Web site page: <http://www.gptgroup.it/>



## Chapter 2. On Non-Functional Requirements for Partner Selection

Criteria	Definition	App	Who?	Metrics
Technical characteristics	-	Prod	OP	Syntactico-semantic description
Guaranteed lifetime	Lifetime of the product, guaranteed by the constructor	Prod	OP	Number of time unit
Expected quality	Does the real quality matches the technical characteristics	Prod	PP	Average of evaluations
Real lifetime	Does the product conforms to the guaranteed expected life?	Prod	PP	Average lifetime
Eagerness to meet the needs	Eagerness of the organization to understand and answer correctly to the partner's needs	Org	PP	Average of evaluations
Equipment	Equipment used to execute the activity	Serv	OP	Syntactico-semantic description
Knowledge and expertise assessment	Professionalism of the organization on the specific service	Serv	PP	Average of evaluations
Reliability	Does the service conform to the expected and guaranteed accuracy and capacity?	Serv	PP	Average of evaluations
Carbon emissions	Helps measuring the green house gas emissions	Serv	OP	Tons CO2 equivalent per year
Air pollutant emissions	Measures the quantity of CO <sub>x</sub> , NO <sub>x</sub> , SO <sub>x</sub> , volatile organic compounds and particulate emitted.	Serv	OP	Tons or kg per year
Liquid waste generated	"Includes liquid waste disposed of or released to open water or sewer systems"	Serv	OP	Tons or kg per year
Solid waste generated	Solid waste generated by the process to provide the service	Serv	OP	Tons or kg per year
Recycled waste	Percentage of waste recycled by the organization	Serv	OP	$\frac{\sum \text{recycled waste}}{\text{Total waste}}$

Table 2.3 – Quality criteria of the framework

## 2.5. The Gruppo Poligrafico Tiberino case

Criteria	Definition	App	Who?	Metrics
Confidentiality	Each partners allow to sign a confidentiality agreement	Col	OP	Accept or not
Reputation	Reputation of the service provider	Org	PP	Average of evaluations
Organizations agreements	Preferences and history of collaboration	Org	S	Feedback on former and ongoing partnerships
Contact	General assessment of the relationship between the partner and the organization	Org	PP	Average of evaluations
Ability to understand special orders	Efficiency of the company to respond to special or exceptional orders	Org	PP	Average of evaluations
Shipping arrangements	Ability to offer shipping arrangement to the partner	Serv	OP	List of possibilities
Authorization	Accessibility to the available capacities. (i) Monitoring: ask for the advancement, anytime; (ii) Observability : subscribe to advancement notifications	Serv	OP	Accept or not
Location	Execution location	Serv	OP	Geographic coordinates
Large or small orders	Willingness and capacity to respond to large or small orders	Serv	OP	Minimal and maximal sizes of order
Labor equity		Org	OP	$\frac{\text{Average hourly labor cost}}{\text{Compensation of the highest paid employee}}$
Philantropy		Org	OP	$\frac{\text{Charitable contribution}}{\text{Market capitalization}}$
Healthcare		Serv	OP	$\frac{\text{Healthcare paid per employee}}{\text{Market capitalization per employee}}$
Safety	Percentage of waste recycled by the organization	Serv	OP	$\frac{\sum \text{Days not injured per employee}}{\sum \text{Days worked per employee}}$

Table 2.4 – Service criteria of the framework

companies joined them as new members. Saetta et al. [128] study the strategic behavior, and bring the definition of a Virtual Development Office (VDO): “A strategic association/alliance of organizations and the related supporting institutions, adhering to a base long term cooperation agreement and adoption of common operating principles and infrastructures, with the main goal to create innovative Business Opportunities (BOs). This goal is accomplished by introducing a new for-profit company, the VDO, operating as a permanent network management/coordination

## Chapter 2. On Non-Functional Requirements for Partner Selection

Criteria	Definition	App	Who?	Metrics
Price	Estimated price of the service	Serv	OP	Number and currency
Total cost	Total effective cost	Serv	OP	Number and currency
Cost of ownership	Claimed cost of use	Prod	OP	Number and currency per year
Real cost of ownership	What does the product effectively cost on use?	Prod	PP	Average of the costs given by partners and currency per year
Penalty and incentive	Financial penalty or incentive to be contractualized and measured on run time. Fixed by an agreement in the collaboration.	Col	S	Number and currency per time unit delayed
Payment methods	Accepted methods of payment	Org	OP	List of possibilities
Accuracy of billing system	Accuracy if the organizations billing system, from the point of view of the partners: were there mistakes?	Org	OP	$\frac{\sum \text{Successful payments}}{\sum \text{Payments}}$
Credit terms offered	Does the organization accept credit?	Org	OP	Accept or not
Long-term price agreements	Being recognized as regular customer. Long term business relationship arrangement. Concretely, trading range offered	Org	OP	Accept or not. If yes, to be negotiated

Table 2.5 – Cost criteria of the framework

entity. In pursuing these business opportunities the VDO realizes VOs and Virtual Extended Enterprises (VEEs) of network members and/or external partners”. This definition is illustrated by the Figure 2.8. To study this system, the authors provide a decomposition into two steps:

- The creation of the CNO concerns inter alia the selection of partners to evolve in this system. These should be complementary companies likely to bring their various skills and competencies together to develop new BOs (*i.e.* new products or services). The geographically closeness can be first seen as a way to reunite the organizations in spite of the lack of common information systems for example, however the structure must also be adapted to involve further external and more distant partners.
- The management phase deals with the relevant utilization of such CNO both at a management level of the whole structure and at the BO identification and response level.

## 2.5. The Gruppo Poligrafico Tiberino case

Criteria	Definition	App	Who?	Metrics
On time delivery	-	Org	PP	$\frac{\Sigma On\ time\ delivery}{\Sigma Delivery}$
Rapidly responding and solving the problems	-	Org	PP	Average of evaluations
JIT ability	Ability to offer JIT delivery	Serv	OP	Accept or not
Delivery lead time	Deadline for making available from the order receipt	Serv	OP	Number and time unit
Product availability	Availability of the product in stocks	Prod	OP	Number of products
Quick on short notice delivery	Is the organization efficient enough to deliver on short notice?	Serv	OP	Minimal notice period and corresponding delivery time: number and time unit
Agility	Ability to react quickly and effectively to a sudden situation	Serv	OP	Average of evaluations + average of reaction times (number and time unit)

Table 2.6 – Time criteria of the framework

Hence, the selection of partners to answer specific BOs is included in the second phase. According to [130], the creation of these atomic VEs, VOs and VEEs should be supported by decision supporting tools. Thus, this is where the non-functional framework should come as a decision tool.

### 2.5.2 Applying the non-functional framework to the VE/VO/VEE creation

Suppose that the editor of a photography magazine would like to find partners to print its monthly issues, and that the non-functional framework is used to select partners via the VDO offered by the GPT. It is interesting to think about the criteria adapted to this situation that would enable to select the best partners in this context.

First, such type of magazine aims at being competitive on a cost level, however it is not as essential as it is for a daily newspaper. However, the quality of the printing is a key success factor. Leadtimes are also not negotiable since the issues should be available in kiosk the same day every month. That could be summarized by using the following criteria:

- Quality:
  - Expected quality: minimum 4.5/5. The quality of the final product (*i.e.* the magazine) should be very high, since it can be seen as one of the key success factors of a

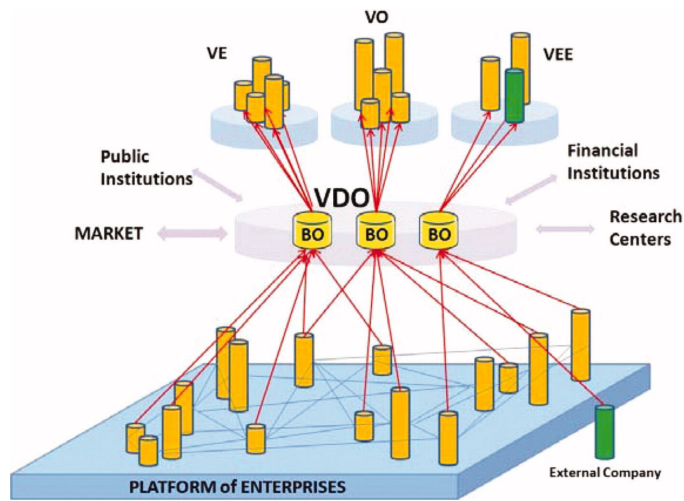


Figure 2.8 – VDO model in GPT, [128].

magazine about photography.

- Eagerness to meet the needs: minimum 4.5/5. It comes along with the expected quality: the partners should have the same enthusiasm for quality as the editor.
  - Knowledge and expertise assessment: minimum 4.5/5. Printing photography, even for a magazine, relies on very technical methods that should be entirely controlled.
  - Reliability: minimum 4.5/5. Such type of magazine implies a constant quality of product.
- Service:
    - Ability to understand special orders: minimum 4/5. For each issue, the number of printed magazines are not the same: in the world of journalism, it depends on the subjects mentioned in the magazine, if they are burning topics they will probably be easier to sell.
    - Large or small orders: large orders accepted. As distributed products at least all over a country, magazines are typically printed in large orders, so that they can be sent to all newsstands.
  - Cost:
    - Price: maximum 1€/product. Depending on the price fixed for the buyers of the magazine, 1€/product is an example of the maximal price the editor (*i.e.* the broker in this case) is willing to pay.
    - Payment methods: bank transfer accepted. Here, the editor would like to pay via bank transfer method and expect the partners to match this constraint.

- Long-term price agreements: yes. As the editor expect to publish a monthly magazine for several years, good relationships on long term are expected, in opposite to one-shot tasks like printing invitation cards for particular celebrations.
- Time:
  - On time delivery: minimum 99%. On time delivery is obviously essential for a monthly magazine.
  - Delivery lead time: maximum 5 days. Supposing that during the month, the editorial board has to select the subjects of the issue and to write or select waiting articles (*i.e.* some articles about traveling for example can be independent of the actuality and thus sent by a photograph months before being published), 5 days could finally remain to actually print the final version of the issue.
  - Agility: minimum 3.5/5, immediate reaction time. Sometimes, editorial boards need to correct final errors at the last moment. Even if it probably doesn't happen too often, the reaction time should be very short, so that there are not too many unsaleable magazines.

## 2.6 Discussion

### 2.6.1 Improving the flexibility with combinations of criteria

The latter non-functional framework tries to address OpenPaaS non-functional partner selection issues by proposing a wide scope of criteria *i.e.* that fits very various contexts of partner selection and criteria that aims at being measurable and the most objective possible. However, its flexibility could be improved for several reasons. First, even if a large scope of criteria have been studied in the literature review, there remain a certain percentage of collaborative projects that are extremely specific on a technical point of view. In such cases, enterprises may not find the exact criteria they need. Then, a lot of enterprises already have established their own framework when selecting their partners. Thus they do not necessarily use the exact same granularity as it is proposed here, and they need to be able to express their own level of criteria.

In this context, one solution could be easily provided by offering the users to mix criteria and aggregate them into a new specific criterion.

### 2.6.2 Inter-dependencies between Non-Functional Criteria

Non-functional criteria may be subject to ranking and/or inter-dependencies. Among the set of non-functional criteria, ranks may be defined to sort criteria according the collaboration goals. For example, confidentiality may be most important than price of the service.

Moreover, non-functional criteria can be interdependent. As underlined by Asadi et al. [131],

## Chapter 2. On Non-Functional Requirements for Partner Selection

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changing the value of one non-functional criteria may change the value of another non-functional criteria. Increasing the ability to respond to a special order may increase the time delivery.

In addition, interdependence and criteria ranking may lead to a complex process selection. Looking at the previous example, it appears that if both ability to respond to a special order and short time delivery are considered as the most important criteria to deal with, their interdependency will make the process of collaborative partners selection difficult (increasing the value of the first one will decrease the value of the second one).

### 2.6.3 Improving the selection of relevant non-functional criteria

Even if this non-functional framework comes as a potentially powerful help as a decision-making tool, the user still needs to provide a significant effort. As he proposes a new opportunity of collaboration in the platform, a work should be carried about what are the relevant non-functional criteria to express the objectives and the constraints of this future collaboration. On this step, for now, the system can not provide any help to the user. However, a first idea to resolve this issue could be to use the SCOR model: it proposes a correlation between processes and metrics that can be applied. Thus the system could ask the users about the type of process they want to build, and a set of corresponding and potentially relevant non-functional criteria could be advised.

Since the SCOR model only focuses on supply chain collaborations, others sources of such correlations concerning other sectors need to be found and applied as well.

## 2.7 Conclusion

More than an updated literature review on the burning subject of non-functional criteria to use for partner selection, this Chapter brings two contributions. (i) The literature review has initially been based on various topics as quality and performances assessment factors, but also IT or any other services and products. Some of them have been industrially approved and used for years now, both in research and industry fields. (ii) There has been a determination to provide metrics or measures associated to each adopted criterion, so that it could be useful and inspiring in industrial "non-automated" real cases as well as in OpenPaaS' automated partners selection step. It also provides a measuring scale so that the users can: objectively and easily assess current or former partners, and have a better understanding and interpretation.

Now that non-functional criteria have been proposed, Chapter 3 aims at representing and acquiring knowledge on collaborative context, and as such will use the resulting non-functional framework for this Chapter to describe the non-functional collaborative context.

The non-functional framework detailed in this Chapter was presented during the I-ESA 2014

conference in [132].



### 2.8 Résumé en français

Lors de la sélection de partenaires, de nombreux critères peuvent être pris en compte pour garder le meilleur candidat. Le plus souvent, c'est le triptyque délai/coût/qualité qui est évoqué. Or, ces trois dimensions ne sont pas assez précises et ne suffisent généralement pas pour être effectivement appliquées, en particulier lorsqu'il s'agit, comme dans cette thèse, d'automatiser la sélection des meilleurs partenaires.

Un critère non-fonctionnel est un critère qui ne définit pas *ce qu'un système peut réaliser*, mais plutôt *la façon dont cela est réalisé*. Du génie industriel à l'informatique, nombreuses sont les disciplines qui se sont intéressées de près ou de loin aux critères non-fonctionnels, dans des contextes variés. Ainsi, afin d'offrir aux utilisateurs un large panel de facteurs pour décrire leurs propres services métier et leurs opportunités de collaboration, une revue de littérature a été réalisée, en s'efforçant de répondre à trois contraintes: (i) le RSE doit être capable d'acquérir et exploiter automatiquement les critères non-fonctionnels retenus, (ii) pour faciliter l'exploitation, les critères doivent être les plus objectifs possible, associés à des échelles de sensibilités exploitables et (iii) doivent couvrir un large scope car le RSE peut être amené à supporter différents types de collaborations.

Dans une première partie, quarante-deux critères non-fonctionnels ont été retenus et classés selon les quatre catégories proposées par Johansson et al. [127]: qualité, service, coût et temps. Puis, des métriques ont été associées à chacun de ses critères afin de les rendre exploitables et le moins subjectifs possible.

Finalement, un framework non-fonctionnel a été proposé afin d'appliquer cet ensemble de critères non-fonctionnels au contexte particulier des RSEs. Ce framework est composé de trois dimensions: (i) les quatre catégories citées précédemment, (ii) le niveau d'application des critères et (iii) les façons d'évaluer ces critères. Concrètement, les critères peuvent être appliqués selon quatre niveaux hiérarchiques: à la collaboration entière, à une organisation en particulier, à un service d'une organisation ou à un produit généré par une organisation. Ils peuvent aussi être évalués par un utilisateur sur son propre profil, un partenaire d'une collaboration actuelle ou passée ou encore automatiquement par le système.

Bien que le framework non-fonctionnel résultant de ce chapitre ne se veuille pas exhaustif, le large point de vue adopté permet de l'appliquer dans de nombreux domaines métiers, tandis que l'association de métriques aux critères le rend adaptable à de nombreux contextes industriels de sélection de partenaires (dans le cadre de RSEs ou non).

# 3 Collaborative Knowledge Representation and Acquisition

“The beginning of knowledge is the discovery of something we do not understand.”

— Frank Herbert, God Emperor of Dune

## 3.1 Introduction

Knowledge Management (KM) is not a recent problem. Indeed, before having been applied to expert systems around the 60's, and then to information systems around the 80's, it actually has its first origin in philosophy through two main terms *epistemology* and *ontology*. Plato, Socrates and Aristotle could be cited as precursor philosophers that have thought of *what is knowledge*. On the one hand, Descartes (1596-1650) and his *Discourse on Method* [133] in 1636, followed by Kant (1724-1804) in 1781 with, for example, the *Critic on pure reason* [134] are two pioneers of epistemology. According to the Stanford Encyclopedia of Philosophy [135], epistemology, in its narrow definition, is “the study of knowledge and justified belief”. On the other hand, Dhondt [136] looks back on the status of ontology in Aristotle's works [137] who was particularly interested in the ways to structure scientific knowledge and how to situate each science in the universal knowledge. Beets [138] explains that the term ontology was taken over by the Scholastic, in particular with the works of Thomas Aquinas (1225-1274). In modern times, the emergence of basic expert systems has then given way to the Semantic Web - first mentioned by the creator of the World Wide Web Tim Berners-Lee. In the Semantic Web field, Davies et al. [139] summarize knowledge management in four phases: (i) knowledge acquisition, (ii) knowledge representation, (iii) knowledge maintenance and (iv) knowledge use.

This Chapter concerns the two first points of this lifecycle and address the issue: *which is the minimal and sufficient knowledge to acquire in order to deduce inter-organizational business processes?* This question can be answered by structuring and implementing ontologies. That is why Section 3.2 proposes a literature review on knowledge management and Semantic Web.

Section 3.3 relates the semantic structure chosen to answer this specific problematic, whilst Section 3.4 focuses on the knowledge bases used to populate the ontologies. Finally, Section 3.5 illustrates the acquisition of collaborative knowledge within the OpenPaaS' context via a simple use-case.

## 3.2 From knowledge management to Semantic Web

### 3.2.1 Introduction to Knowledge Management

#### Definition of Knowledge Management

Dalkir [140] proposes a definition of KM as follows:

“ Knowledge management is the deliberate and systematic coordination of an organization’s people, technology, processes, and organizational structure in order to add value through reuse and innovation. This is achieved through the promotion of creating, sharing, and applying knowledge as well as through the feeding of valuable lessons learned and best practices into corporate memory in order to foster continued organizational learning. ”

In other words, KM aims basically at capitalizing knowledge within an organization, and reusing it with the purpose of improving the efficiency or the relevance of a system. This definition could be easily applied also to networks of organizations, for example to transmit the *know-how* among the partners of a supply chain. However, one can wonder what is actually *knowledge*? This term has been widely debated for centuries, and used by many different disciplines. The definition of knowledge as a “Justified true belief” is commonly accredited to Plato [141]. The Cambridge English Dictionary defines knowledge as the “understanding of or information about a subject that you get by experience or study, either known by one person or by people generally” [142]. Hislop [143] mentions “the ability to define and understand situations and act accordingly”. The definition of Milton [144] is illustrated by Figure 3.1.

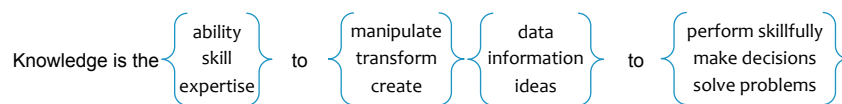


Figure 3.1 – Definition of knowledge, [144].

Effectively, the *acquisition*, the *storage* and the *exploitation* of growing amounts of data are currently important challenges, considering the benefits for organizations (*e.g.* more efficient decision support systems, potential for open innovation, improved supply chain management...). Thus, in computer science, the distinction between data, information and knowledge has been debated, and Rus and Lindvall [145] give a concise summary through the three following definitions (see Figure 3.2):

“ Data consists of discrete, objective facts about events but nothing about its own importance or relevance; it is raw material for creating information. ”

“ Information is data that is organized to make it useful for end users who perform tasks and make decisions. ”

“ Knowledge is broader than data and information and requires understanding of information. It is not only contained in information, but also in the relationships among information items, their classification, and metadata (information about information, such as who has created the information). ”



Figure 3.2 – From data to knowledge through information.

Within this PhD thesis, knowledge does not only “belong” to each organization: on the contrary, the underlying issue here is rather *how to relevantly gather knowledge on all the organizations of the collaborative platform, so that it can be then exploited?* In other words, the organizations are able to provide information (*i.e.* which business services they are able and willing to provide and which opportunities they would like to achieve), and the IT system should be able to contextualize this information in order to transform it into knowledge and exploit it (*i.e.* to deduce the corresponding collaborative platform).

#### Knowledge technologies

With the increasing interest for knowledge and its strong perspectives, many knowledge technologies and tools have emerged in computer science. Milton [144] details five main areas linked to knowledge:

- Knowledge Based Systems also referred as Expert Systems: usually based on Artificial Intelligence techniques to solve problems that are commonly addressed by experts.
- Knowledge Based Engineering Systems: similar to Knowledge Based Systems, they focus on engineering field and also require analyses and computation steps.
- Knowledge Webs: these are websites which goal is to provide a way for users to navigate over knowledge bases.

- Ontologies: can either give a representation of knowledge or a type of file.
- Semantic Technologies: provide sophisticated ways to store and manipulate information. According to Milton [144], “They allow web sites and other web resources to be understood and used by computer, as well as by humans”.

### 3.2.2 Towards semantic web

One of the most famous illustration of Semantic Web is probably the *Semantic Web layer cake*, presented by Tim Berners-Lee [146], and represented in Figure 3.3.

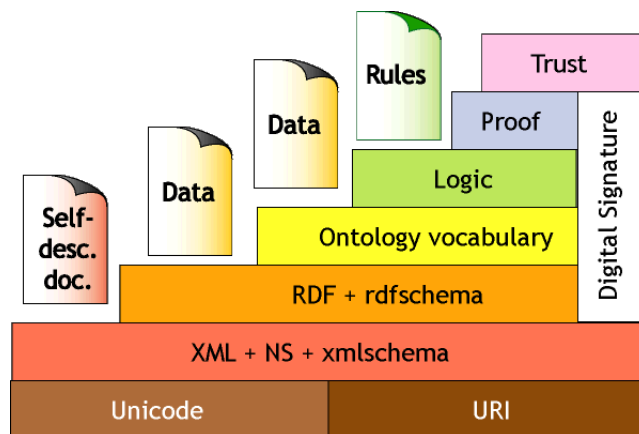


Figure 3.3 – The Semantic Web layer cake, [146].

The *layer cake* presents six main levels of technologies linked to Semantic Web: the foundations rely on XML language and the ability of RDF language to structure information. The ontology vocabulary and the logic layers concern the ways to link these information, and as such creating knowledge and store it in an ontology file. Finally proof is related to the rules that can be set up to test the consistency of an ontology, and trust is rather oriented to the reliability of the knowledge contained in the ontology. This picture has then been updated by the W3C, to finally obtain the *Semantic Web Stack* that can be found in Figure 3.4, in which all the former levels can be found in detail: syntax, data interchange, ontologies, logic, proof and trust. The *stack* details these levels by separating taxonomies from RDF files and from ontologies files. Besides, rules and querying technologies are also split into two boxes, since they express two different way to exploit the knowledge contained in an ontology: the first concerns the creation of new knowledge based on logic rules, whilst the second refers to the ability to retrieve knowledge within an ontology . It also adds a user interface layer on the top of the whole *stack*.

In terms of knowledge representation and acquisition, three layers can actually be put forward here: syntax, data interchange and ontologies/taxonomies.

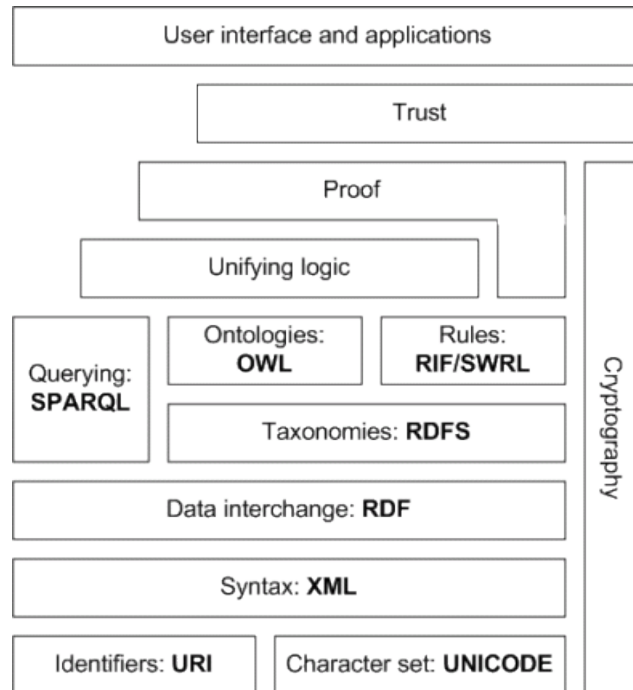


Figure 3.4 – The Semantic Web stack, [147].

### 3.2.3 Ontologies

#### Definition of ontology

Leaving aside the philosophical concerns around the term *ontology*, let's now introduce this term in a computer science perspective. Studer et al. [148] give the following definition, based on the previous definitions of Gruber [149] and Borst [150]:

“ An ontology is a formal, explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. Explicit means that the type of concepts used, and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private of some individual, but accepted by a group. ”

Guizzardi [151] also states that “a domain conceptualization C can be understood as describing the set of all possible states of affairs, which are considered admissible in a given universe of discourse U”. According to Aussenac-Gilles et al. [152] an ontology comes consequently as (i) a *specification* that defines *formal semantic* so that computer systems can exploit information and (ii) a perception on a domain that provides an *interpretative semantic* enabling a link between the human perception and the computer formalization. The W3C [153] rather focuses on

## Chapter 3. Collaborative Knowledge Representation and Acquisition

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*vocabulary*, and precises that the boundaries between those terms are quite fuzzy: “There is no clear division between what is referred to as ‘vocabularies’ and ‘ontologies’. The trend is to use the word ‘ontology’ for more complex, and possibly quite formal collection of terms, whereas ‘vocabulary’ is used when such strict formalism is not necessarily used or only in a very loose sense”.

According to Corcho et al. [154], the ontological engineering requires four main types of components:

- *Classes*: they represent the *concepts* (resulting of the prior human conceptualization of the domain described). They can be organized on gradation levels by using inheritance relations or also metaclasses.
- *Relations*: usually binary relations, they are used to link the classes to each other.
- *Formal axioms*: described by Gruber [155] as assertions that can be used to formalize knowledge that could not be understood with the other components, and also to constrain the potential interpretations of the knowledge (in this sense, axioms enable to check the consistency of an ontology).
- *Instances*: also called *individuals* or *elements*. Each instance “belongs” to one, or several class(es) (that are not disjoint, according to Gómez-Pérez et al. [156]).

In addition, binary relations can also be used to define attributes that precise the concepts. prolific

### Different types of ontologies

Different types of ontology have been defined in the literature, depending on their application and their domains. Guarino [157] recalls the four main types:

- An upper-level ontology describes generic concepts not related to any application or domain.
- A domain ontology specializes the upper ontology concepts to obtain vocabulary specific to a domain.
- A task ontology also specializes upper ontology concepts to describe tasks or activities.
- An application ontology specializes both domain and task levels of ontology. According to Guarino [157], “these concepts often correspond to roles played by domain entities while performing a certain activity”.

The strength of upper-level ontologies seems to be their reusability, since they can be specialized to fit various domains and tasks, and consequently various applications. Obitko [158] also proposes potential merges of domain and task ontologies. Both points of view are illustrated by Figure 3.5.

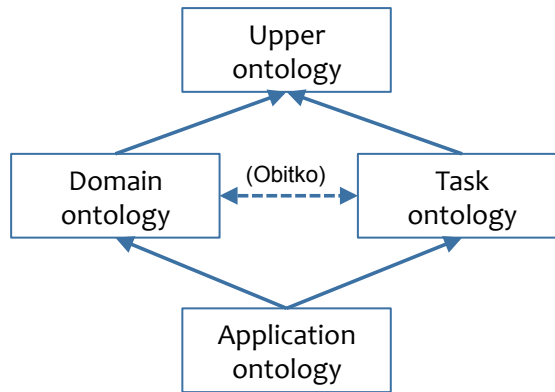


Figure 3.5 – Different types of ontology, from [157] and [158].

### 3.2.4 Tools for supporting ontology-based systems

The willingness to structure ontologies has also led to the creation of tools and standards. First various languages emerged to represent knowledge at a technical level. Associated to these languages, integrated tools were created either as Application Programming Interfaces (APIs) to help the developers, or as human interface softwares rather oriented towards the strict users (or to provide easy visualization of the ontologies). This Part summarizes some of these tools and explains the choices that have been made in this PhD thesis.

#### Representation languages

As can be seen on Figure 3.4, many standard languages are commonly associated to Semantic Web. Gómez-Pérez and Corcho [159] offer a Semantic Web stack exclusively oriented towards the semantic languages (see Figure 3.6). In parallel, in 2007, Cardoso [160] comes back to the study of the works of Gómez-Pérez and Corcho [159] and reveals that the promising languages at this time were not so used five years later. Actually, he conducted a study on the use of ontologies, and, among other, provides an overview of the languages and their use in academic and industrial worlds. Thus, it is interesting to confront the different languages to their amount of users.

**XML (eXtensible Markup Language)** derives from SGML (Standard Generalized Markup Language), and thus is a tag-based language. It has been launched in 1996 by W3C and Signore et al. [161] argue that, thanks to its independence from platform and programming languages,



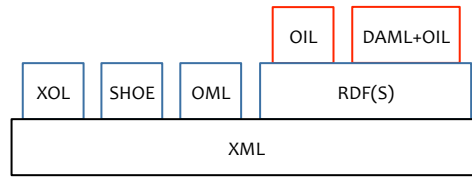


Figure 3.6 – Languages for Semantic Web, [159]. ©2002IEEE

XML “plays a fundamental role towards interoperability” (*i.e.* technological but also semantic interoperability). XML comes along with: DTD (Document Type Definition) and XSD (XML Schema Definition) that enable to define the structure of the file and with XML Namespaces providing *nameset* identified by URI<sup>1</sup> references that can be used as elements and attributes in the XML document. Typically, XML is the reference language when it comes to exchange data and it also the base of many other description languages.

**XOL (XML-based Ontology exchange Language)** has been defined by Karp et al. [162]) as a language for exchange of ontology and as such, Gómez-Pérez et al. [156] adds that it only provides a reduced knowledge representation. Noy et al. [163] explain that XOL allows defining classes, a class hierarchy, slots, facets, and instances. According to Cardoso [160], in 2007 only 0,9% of ontologists worked with XOL.

**SHOE (Simple HTML Ontology Extension)** was developed at the University of Maryland<sup>2</sup> and provides an extension of HTML that can be used to give web pages a semantic meaning. Actually, SHOE aims at improving the search systems based ontologies, but does not offer a way to create or define them. Hence, Heflin and Hendler [164] argue that the key challenge of this language is to exploit knowledge bases for improving queries. SHOE represents 1,9% of the ontology languages users in 2007 [160].

**OML (Ontology Markup Language)** is considered as a XML serialization of SHOE, according to Antoniou et al. [165]. Cardoso [160] highlighted in 2007 that OML was not quite used by ontologists (0% of users according to Cardoso [160]).

**RDF (Resource Description Framework)** “is a framework for expressing information about resources”, according to its W3C definition [166]. It has actually been thought as a way to exchange information between computer systems (*i.e.* not intended to be displayed by human). RDF has been a first step into the Semantic Web by enabling to define resources and link them

---

<sup>1</sup>URI (Uniform Resource Identifier) is a string of characters used to identify a name or a resource over a network.

<sup>2</sup>Web site page: <https://www.cs.umd.edu/projects/plus/SHOE>

## 3.2. From knowledge management to Semantic Web

to each other, and can be written in XML. In this sense, all statements in RDF follows the triple *<subject> <predicate> <object>*, for instance *<Ludwig van Beethoven> <composed> <Für Elise>*.

**RDF-S (RDF Schema)** is a “semantic extension of RDF”, according to its W3C recommendation [167]. As such, it is a primitive language that includes notions of *classes* and *properties*: classes can be decomposed into *sub-classes* and properties into *sub-properties*. Also, the notion of *type* and *range* are introduced to allow reasoning mechanisms.

The Code 3.1 written in XML sets *Human* and *Song* as top-level classes. *Composer* is a sub-class of *Human* and *hasComposed* is a property which domain is *Composer* and range *Song*. Consequently, when instancing *ludwigVanBeethoven* as a *Composer* it also means that he is a *Human*, and using the property *hasComposed* he is associated as the composer of the resource *http://www.music.fake/songid/furElise*. RDF-S is used by more than 64% of the ontologists, in second position, according to Cardoso [160].

```
1 <?xml version="1.0"?>
2
3 <rdf:RDF
4 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
5 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
6 xml:ex="http://www.music.fake/composers#"
7
8 <!-- Defining Classes -->
9 <rdfs:Class id="Human">
10   <rdfs:comment>All humans </rdfs:comment>
11   <rdfs:subClassOf rdf:resource="#rdfs:Resource"/>
12 </rdfs:Class>
13
14 <rdfs:Class rdf:ID="Composer" rdfs:comment="A music composer">
15   <rdfs:subClassOf rdf:resource="Human"/>
16 </rdfs:Class>
17
18 <rdfs:Class rdf:ID="Song" rdfs:comment="A song">
19   <rdfs:subClassOf rdf:resource="#rdfs:Resource"/>
20 </rdfs:Class>
21
22 <!-- Defining Properties -->
23 <rdf:Property rdf:ID="hasComposed">
24   <rdfs:domain rdf:resource="#Composer"/>
25   <rdfs:range rdf:resource="#Song"/>
26 </rdf:Property>
27
28 <!-- Defining Instances -->
29 <ex:Composer rdf:ID="ludwigVanBeethoven">
30   <ex:hasComposed rdf:resource="http://www.music.fake/songid/furElise"/>
31 </ex:Composer>
32
33 </rdf:RDF>
```

Code 3.1 – Example of a RDF-S code.

**OIL (Ontology Inference Layer)** was developed for enabling knowledge representation and ontologies exchange, based on both RDF and XML by Horrocks et al. [168]. It defines an ontology on three levels: the object layer deals with the instances, the first meta-level aims at structuring the ontology and the second meta-level allows to characterize the ontology.

**DAML (DARPA Agent Markup Language)** is named after the US Defense Advanced Research Projects Agency (DARPA). As defined by McGuinness et al. [169], it aimed at “making web content more accessible and understandable”. Based on RDF, the DAML language is divided into two parts: (i) DAML-ONT which focuses on ontology structure by describing classes, subclasses, properties, restrictions and individuals and (ii) DAML-LOGIC oriented towards inferences and logical implications. DAML+OIL came as the fourth most used language by ontologists with 12% of users [160].

**OWL (Ontology Web Language)** is the worthy successor of DAML and OIL - DAML+OIL- and as such based on RDF-S and XML. With this language, in 2004, the W3C [170] proposed a way to standardize the structure of web ontologies. Basically it is implemented as XML files, and includes notions for cardinality, equality, property characteristics and restrictions, class intersection and versioning. It actually includes three sublanguages:

- OWL Lite: allows quick reasoning but is the less expressive sublanguage since it forbids union and cardinalities over 1. Thus, it seems more adapted to thesauri or taxonomies.
- OWL DL: is more expressive than OWL Lite, but also has some constraints: for instance, a class cannot be an instance of another class. Hence, it still guarantees decidability with finite time computations and provides computational completeness (all conclusions are computable).
- OWL Full: is the most expressive of those three sublanguages (a class can be a collection of individuals as well as an proper individual), however complete reasoning is not guaranteed.

Because of its decidability and its level of expressivity, OWL DL is probably the most successful language for ontologies and has been used until now in the works of the research team Interoperability of Organizations in Mines Albi. There are two main reasons: (i) the facility to work with large amount of OWL DL ontologies available over the Internet and (ii) the facility to work with former internal ontologies. Also, thanks to its success (the most used language in 2007, with almost 80% of users among ontologists, according to Cardoso [160]), several tools have been developed around the OWL language (e.g. OWL API [171] that provides an API to easily manipulate OWL ontologies and the famous software Protégé<sup>3</sup> that offers an interface to visualize and manipulate ontologies).

---

<sup>3</sup>Web site page: <http://protege.stanford.edu/>

### 3.2. From knowledge management to Semantic Web

Code 3.2 still presents a music ontology. One can see that beside classes, individuals and relations, a *sameAs* semantic relation has been added to express the fact that the song Für Elise is also known as Bagatelle No. 25 in A minor ( line 35): both individuals mention the same song of Beethoven.

```
1
2 <rdf:RDF xmlns="http://www.music.fake/Music.owl#"
3   xml:base="http://www.music.fake/Music.owl"
4   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
5   xmlns:owl="http://www.w3.org/2002/07/owl#"
6   xmlns:Music="http://www.music.fake/Music.owl#"
7   xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
8   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
9   <owl:Ontology rdf:about="http://www.music.fake/Music.owl"/>
10
11 <!-- Defining properties -->
12
13   <owl:ObjectProperty rdf:about="&Music;hasComposed">
14     <rdfs:domain rdf:resource="&Music;Composer"/>
15     <rdfs:range rdf:resource="&Music;Song"/>
16   </owl:ObjectProperty>
17
18
19   <!-- Defining classes -->
20
21   <owl:Class rdf:about="&Music;Human"/>
22
23   <owl:Class rdf:about="&Music;Composer">
24     <rdfs:subClassOf rdf:resource="&Music;Human"/>
25   </owl:Class>
26
27   <owl:Class rdf:about="&Music;Song"/>
28
29
30   <!-- Defining instances-->
31
32   <owl:NamedIndividual rdf:about="&Music;Bagatelle_No._25_in_A_minor">
33     <rdf:type rdf:resource="&Music;Song"/>
34     <rdfs:comment rdf:datatype="&xsd:string">Bagatelle No. 25 in A minor</rdfs:
35       comment>
36     <owl:sameAs rdf:resource="&Music;furElise"/>
37   </owl:NamedIndividual>
38
39   <owl:NamedIndividual rdf:about="&Music;furElise">
40     <rdf:type rdf:resource="&Music;Song"/>
41     <rdfs:comment rdf:datatype="&xsd:string">Für Elise</rdfs:comment>
42   </owl:NamedIndividual>
43
44   <owl:NamedIndividual rdf:about="&Music;ludwigVanBeethoven">
45     <rdf:type rdf:resource="&Music;Composer"/>
46   </owl:NamedIndividual>
47 </rdf:RDF>
```

Code 3.2 – Example of a OWL ontology.

**OWL 2 (Ontology Web Language Version 2)** was launched in 2009 by the W3C [172] to address various lacks of OWL 1. Grau et al. [173] mention several limitations of the first version of OWL such as the lack of expressivity (lacks of constructs in OWL 1 DL that led to the creations of new surrounding patterns), datatype expressivity restrictions, syntax issues, etc. Actually, various syntaxes can be used when implementing an OWL 2 ontology (e.g. RDF/XML Syntax for a RDF serialization or Functional Syntax...). The OWL/XML syntax provides an XML serialization of OWL 2. Both Protégé and OWL API tools can be used in OWL 2 language. In this PhD thesis, it has been chosen to work with the OWL/XML serialization. OWL 2 is more verbose than OWL 1, but it has no real impact since ontologists actually rarely manipulate directly ontologies file [173]. Code 3.3 corresponds to the same ontology as Code 3.2 in OWL 2 language, using OWL/XML syntax.

```
1 <Ontology xmlns="http://www.w3.org/2002/07/owl#"
2   xml:base="http://www.music.fake/Music.owl"
3   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
4   xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
5   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
6   xmlns:xml="http://www.w3.org/XML/1998/namespace"
7   ontologyIRI="http://www.music.fake/Music.owl">
8   <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#" />
9   <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#" />
10  <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#" />
11  <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#" />
12  <Declaration>
13    <Class IRI="#Composer" />
14  </Declaration>
15  <Declaration>
16    <Class IRI="#Human" />
17  </Declaration>
18  <Declaration>
19    <Class IRI="#Song" />
20  </Declaration>
21  <Declaration>
22    <ObjectProperty IRI="#hasComposed" />
23  </Declaration>
24  <Declaration>
25    <NamedIndividual IRI="#Bagatelle_No._25_in_A_minor" />
26  </Declaration>
27  <Declaration>
28    <NamedIndividual IRI="#furElise" />
29  </Declaration>
30  <Declaration>
31    <NamedIndividual IRI="#ludwigVanBeethoven" />
32  </Declaration>
33  <SubClassOf>
34    <Class IRI="#Composer" />
35    <Class IRI="#Human" />
36  </SubClassOf>
37  <ClassAssertion>
38    <Class IRI="#Song" />
39    <NamedIndividual IRI="#Bagatelle_No._25_in_A_minor" />
40  </ClassAssertion>
41  <ClassAssertion>
42    <Class IRI="#Song" />
43    <NamedIndividual IRI="#furElise" />
44  </ClassAssertion>
```

```
45 <ClassAssertion>
46   <Class IRI="#Composer"/>
47   <NamedIndividual IRI="#ludwigVanBeethoven"/>
48 </ClassAssertion>
49 <SameIndividual>
50   <NamedIndividual IRI="#Bagatelle_No._25_in_A_minor"/>
51   <NamedIndividual IRI="#furElise"/>
52 </SameIndividual>
53 <ObjectPropertyDomain>
54   <ObjectProperty IRI="#hasComposed"/>
55   <Class IRI="#Composer"/>
56 </ObjectPropertyDomain>
57 <ObjectPropertyRange>
58   <ObjectProperty IRI="#hasComposed"/>
59   <Class IRI="#Song"/>
60 </ObjectPropertyRange>
61 <AnnotationAssertion>
62   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
63   <IRI>#Bagatelle_No._25_in_A_minor</IRI>
64   <Literal datatypeIRI="&xsd:string">Bagatelle No. 25 in A minor</Literal>
65 </AnnotationAssertion>
66 <AnnotationAssertion>
67   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
68   <IRI>#furElise</IRI>
69   <Literal datatypeIRI="&xsd:string">Fur Elise</Literal>
70 </AnnotationAssertion>
71 </Ontology>
```

Code 3.3 – Example of a OWL 2 ontology, with OWL/XML syntax.

## 3.3 Definition of the ontology-based system

### 3.3.1 Structure of the problem, towards a collaborative metamodel

An ontology relies both on a way to structure knowledge with, for example, classes and properties, and also to describe the associated vocabulary. Hence, before populating the ontology with individuals (*i.e.* instantiating the classes), it is important to define its structure that will make it properly (i) adapted to the actual needs of the system and (ii) machine-processable.

#### Top-down versus bottom-up approaches

In the field of cross-organizational collaborations, top-down and bottom-up approaches are both commonly used: they provide two different ways of achieving a collaborative workflow. In the first case, business objectives should be decomposed into sub-objectives and/or business services, which are decomposed into technical services that could then be ordered into a sequence. In [174], Schulz and Orlowska recommend to use the two methods as follows: the top-down approach allows the coalition of organizations to establish its common workflows by describing their interactions, while the bottom-up approach is rather adapted for each organization to specialize its tasks with its own private workflows. According to this recommendation and

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as preconized also by Ko et al. [175] the top-down approach seems highly adapted in the case of business objectives and capabilities decomposition as required for the business process deduction.

### Ontology and Model Driven Architecture

In Chapter 1, Model Driven Engineering and Model Driven Architecture were introduced and the whole MISE program was positioned over this type of IT architecture. In the late 90's, the OMG set up the Meta-Object Facility (MOF) standard, based on UML, whilst they foresaw the danger of the emergence of several non-compatible metamodels at a time when the use of models in computer science was exploding [176]. Atkinson and Kühne [177] provide the vision of OMG's infrastructure (see Figure 3.7) a four-layer decomposition, from a meta-metamodel decomposed into a meta-model, to a model (the User Concepts layer) and data or instances (the User Data layer).

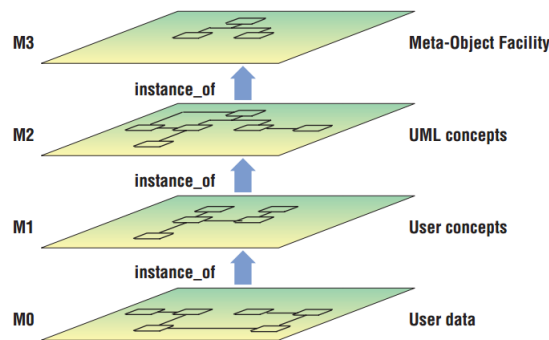


Figure 3.7 – OMG's modeling infrastructure, [177]. ©2003IEEE

In MISE program, Bénaben [12] proposes to gather knowledge about collaborative situations, by using a metamodel as a “receptacle” that would be (i) loose enough to adapt any collaborative situation and (ii) meaningful enough to contain exploitable knowledge. Hence, the metamodel states the generic concepts of any collaborations and their relations to each other. Based on this metamodel, a collaborative ontology can then be developed and implemented by establishing the same structure (classes, relations and axioms), and then populated with instances of the concept to characterize specific collaborations. This approach is schematized in Figure 3.8.

### A metamodel to support inter-organizational collaborations

As previously mentioned, an ontology is coherent if its structure fits exactly the needs: in the case of this PhD thesis, the functional goal is to support collaboration by gathering capabilities and collaborative objectives and deducing corresponding business processes.

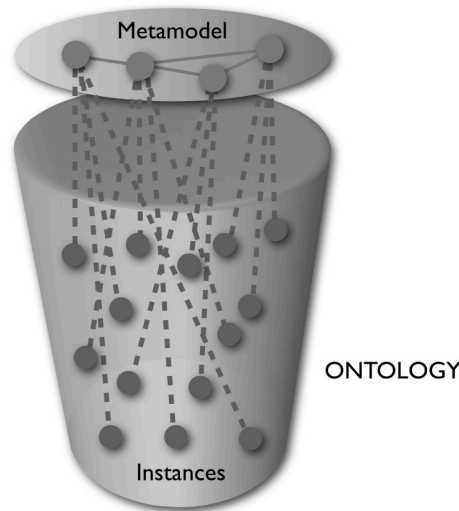


Figure 3.8 – Metamodel as a receptacle to build ontologies , [12]

Basically, a metamodel layer is commonly used to describe a system, and UML is one of the most used language for that. Cranefield and Purvis [178] argue several reasons for that: besides the strong IT community awareness of UML standard, the UML class diagram is very close to the RDF-S language. In fact, the W3C also pinpoints many direct relations between the two languages in [179]: UML is able to represent all RDF-S concepts (on which OWL is based). Finally, UML has been dedicated to human-to-human exchange, and, for this reason, it is easier to introduce the structure of an ontology using this standard, even if the ontology development involves RDF-S.

The collaborative ontology developed to support collaborations during this thesis is based on the metamodel established within the MISE project. This metamodel has evolved through the three iterations of the project and the various applications that has been made of it. Macé-Ramète et al. [77] propose a *core* metamodel that provides the generic concepts of a collaboration and that can be specialized with *layers* according to the specific applications (e.g. crisis management). This approach is illustrated in Figure 3.9.

This core metamodel (see Figure 3.10) is based on five main parts:

- Behavior part deals with the concepts linked to the collaborative process, and as such includes the process, event and activity classes.
- Actors part concerns all the classes in relation with the partners of the collaboration, it obviously corresponds to the partner class but also the collaborative network, mediator,



### Chapter 3. Collaborative Knowledge Representation and Acquisition

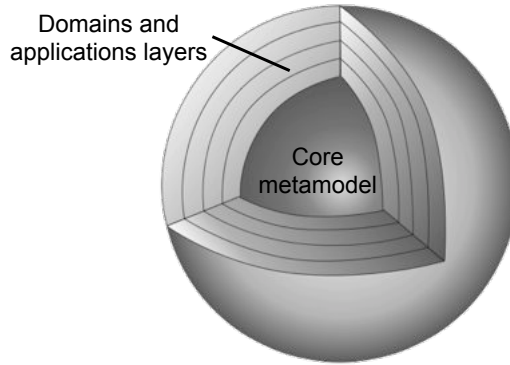


Figure 3.9 – MISE core metamodel and its layered structure, [77]. ©2012IEEE

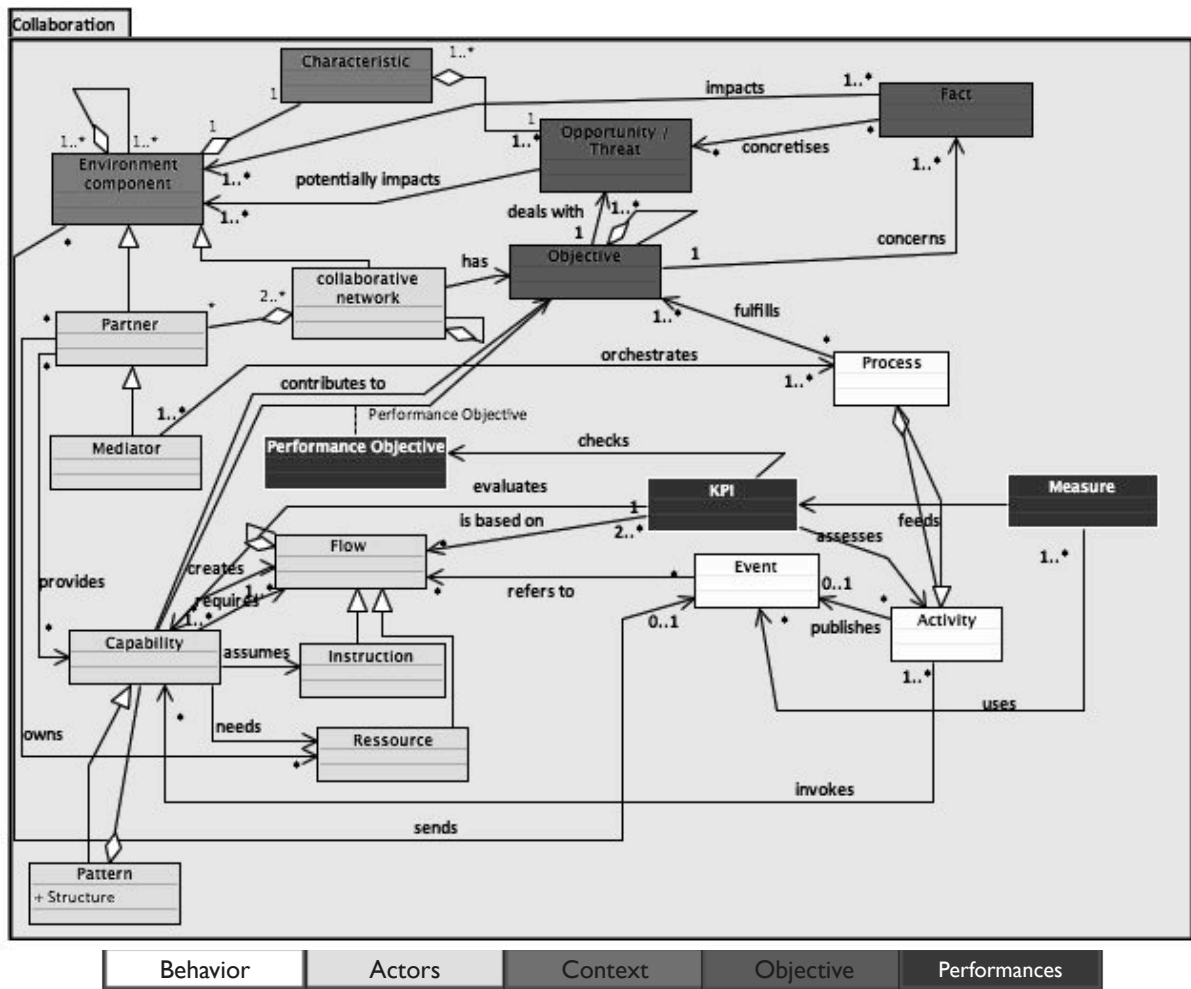


Figure 3.10 – MISE core metamodel definition, [77]. ©2012IEEE

capability, flow, instruction, resource and pattern classes.

### 3.3. Definition of the ontology-based system

- Context rather focuses on the context of the collaboration with the environment components and the characteristics of the collaborative opportunity.
- Objective part brings the notion of opportunity (or threat in crisis management), fact which can explain to the emergence of the collaboration.
- Performance notions allow assessing the system during the run-time of the process, and as such relies on Key Performance Indicators (KPI) that are measured, and which values should fit the best the performance objectives.

Schematically the core metamodel comes along with a clear global mechanisms: (i) the *Behavior* of the collaboration and its *Performances* can be defined according to the *Context* and the *Objective* and the *Actors* of the collaboration. Since these research works only focus on the deduction of the *Process*, only some concepts have been kept and can be found in Figure 3.11.

The metamodel in Figure 3.11, can be explained from the *Process* class definition. A *Process* aggregates several *Activities*. These *Activities* actually invoke the *Capabilities* that are provided by *Partners*, and to be feasible, these *Capabilities* need *Flows* (i.e. require input and create output). Besides, when a collaborative *Opportunity* emerges, it actually deals with a specific *Objective* of collaborative, which relies on a specific set of *Capabilities* (that are invoked as *Activities* and ordered into a *Process*) that is fulfilled by a *Process*, and a set of *Capabilities*. As it comes to the *Actors* of a collaboration, the set of *Partners* of a collaboration forms a *Collaborative Network* which actually exists to answer a specific *Objective*. Eventually, the *Mediator* class can be seen as a type of *Partner*, whose goal is to orchestrate the *Process*.

It is interesting to note that since the *Mediator* comes as a specialization of *Partner* class, the role of the MIS in the *Process* is comparable to that of a *Partner*, and for this reason, the MIS has its own pool in a collaborative business process (see Appendix B).

The concepts around the description of the environment and the measure of the performances have been left aside, not because they were irrelevant in such a system (e.g. the system could be further improved by a performances measure approach), but rather because they are not used to answer our specific problematic.

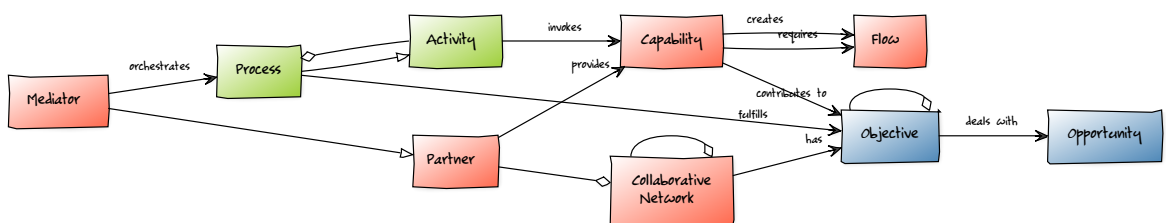


Figure 3.11 – Extraction of the classes of interest within the PhD thesis context.

However, the metamodel presented in Figure 3.11 is not sufficient to deduce collaborative

network in this PhD thesis’ context. Hence, it will be now extended and completed according to several different requirements due to this specific context.

### 3.3.2 From the collaborative metamodel to the adapted ontology-based system

Over all the concepts defined in Figure 3.11 and their relationships, some of them describe things that could not be acquired during the run-time of the system, and, on the contrary, some could not be defined before run-time. It is actually very important to distinguish the different types of knowledge, to really understand how the system works.

#### “Persistent” knowledge

The persistent knowledge corresponds to the knowledge that should initially be implemented into the system so that it can work as expected. Here, the final goal is to deduce inter-organizational collaborative processes to respond to collaborative objectives, which means (i) find the capabilities that should be invoked, (ii) find which partners are able to provide these capabilities and (iii) order these activities into a process. Basically, the first question that emerges is *which capabilities contributes to an objective?* The colored classes of the class diagram illustrated in Figure 3.12 refer to the corresponding concepts: for each *Objective* and its *Sub-objectives*, there exists a set of *Capabilities* that achieve it.

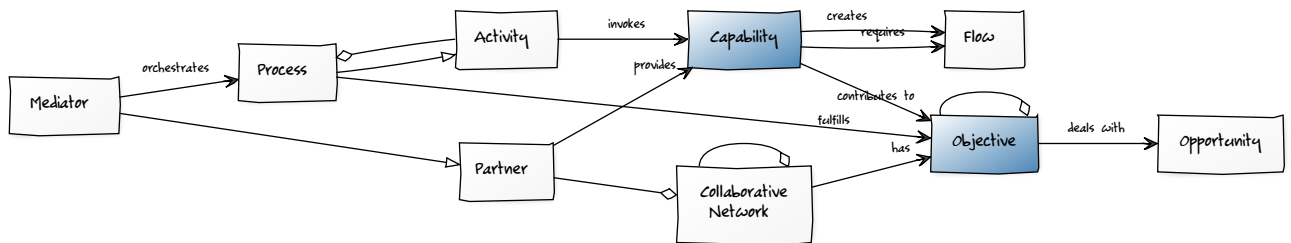


Figure 3.12 – Persistent knowledge to provide.

This approach is similar to the notion of task ontology mentioned in Part 3.2.3. Task ontologies and domain ontologies are quite complementary and allow to obtain application ontologies. A similar approach has been chosen for these works: the Collaborative Ontology has been implemented as task ontology, and the Business Field Ontology as domain ontology. Let’s precise their structures.

**The Collaborative Ontology (CO)** describes the collaborative objectives that can be achieved and how (*i.e.* the capabilities to invoke to achieve the objectives). Concretely, it has been structured as follows: *Objectives* are broken down into complementary *Sub-Objectives* (*e.g.* either the top-level objective should be achieved, or all its sub-objectives) and for each *Objective*, complementary *Capabilities* contributes to achieve it. This decomposition is represented in

Figure 3.13.

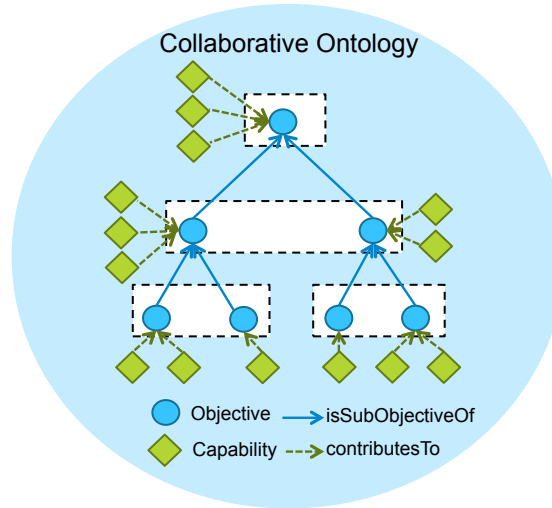


Figure 3.13 – Simplified representation of the CO.

**The Business Field Ontology (BFO)** Let's figure that "Buy" is an objective to achieve, the CO would not make the difference between the two opportunities "Buy candies" and "Buy cars". Consequently, the further BFO provides a way to specialize the opportunities according to their business domain. The only concept of the BFO is *Domain*, and each domain can be decomposed into *SubDomain*. This is depicted in Figure 3.14.

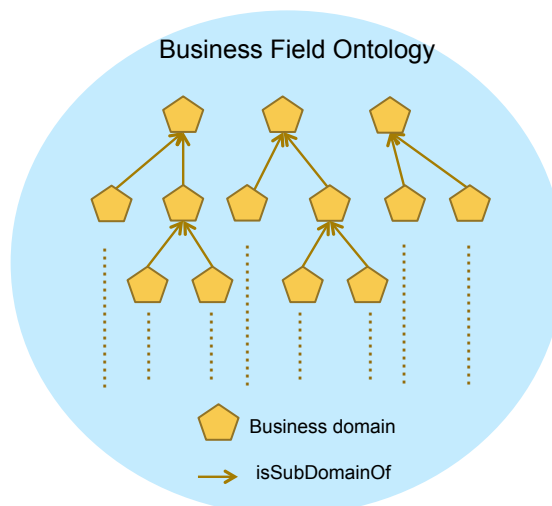


Figure 3.14 – Simplified representation of the BFO.

“Social” knowledge

What could be called “social” knowledge is the knowledge that is gathered when the users are asked to provide their own information. Indeed, two types of information come directly from the users: (i) the capabilities they are able to provide and willing to share within collaborations and (ii) the business opportunities they would like to be achieved. Within the metamodel, four concepts are concerned: the *Partner* that provides its *Capabilities* and its *Flows*, and the proposals of *Opportunities* (see Figure 3.15).

Concerning the *Capabilities* offered by a *Partner*, the metamodel has been founded on the IDEF-Østandard [180]: the capability is on the center, surrounded by its flows - requires input and creates output -, its resources and its instructions, as proposed in Figure 3.16. However, in this case, resources and instructions are useless, but the input and output allow actually to order the capability when deducing the process (*i.e.* a capability can be placed before another if its output are those required by the further, see Chapter 4).

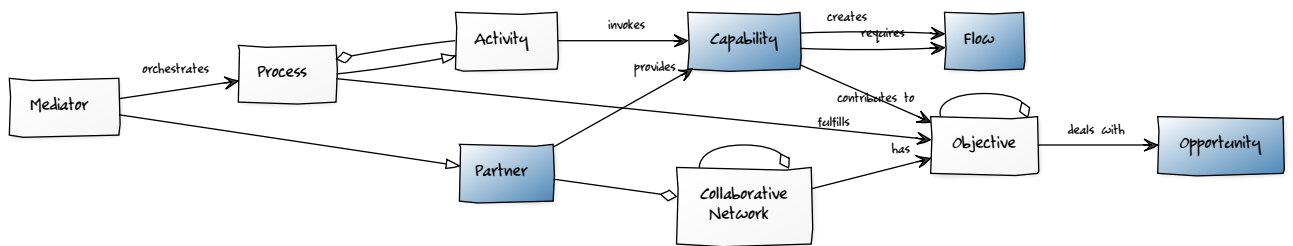


Figure 3.15 – Social knowledge to acquire.

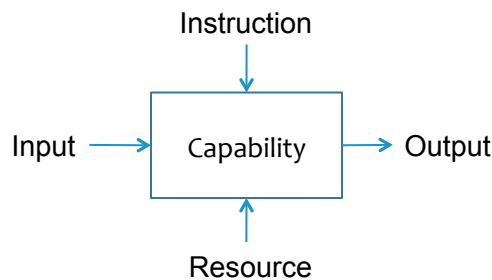


Figure 3.16 – Representation of a capability using the IDEF-0 standard.

Actually, at this point, some limitations can be pinpointed over the metamodel, and an adaptation can be proposed.

**Capability and PartnerCapability** It is confusing to use the concept *Capability* either to express the persistent knowledge or the social knowledge. Hence, it is proposed to split this concept into *Capability* for the CO and *PartnerCapability* for the capabilities provided by the organizations (see Figure 3.17). Hence, *PartnerCapability* specializes *Capability*.

### 3.3. Definition of the ontology-based system

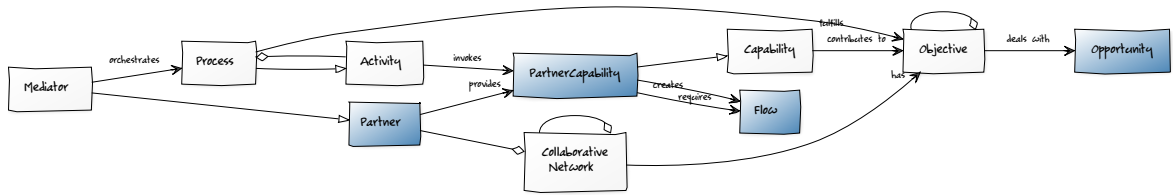


Figure 3.17 – Updated metamodel according to the social knowledge to acquire.

**Integration of Business Fields and Flows Refinement** As expressed in Part 3.2.3, task and domain ontologies are quite complementary and specific application of them can be situated at their intersection. In other words, *PartnerCapabilities* and *Opportunities* are situated at the intersection between the “users world” and respectively the *Capabilities* and the *Objectives* of the CO. This is where the BFO is used: on the one hand, an *Opportunity* deals with an *Objective* of the CO, and also concerns one or more *BusinessField(s)* and on the other hand, a *PartnerCapability* corresponds to a specific *Capability* of the CO, but its *Flows* actually concern specific *Business Fields*.

The linkage of the *BusinessFields* is however different for the *Opportunities* and for the *PartnerCapabilities*. Different notions of *BusinessFields* intersection and union have been added in order to describe the *Opportunities* and the *PartnerCapabilities* more precisely, and consequently obtain more accurate final collaborative processes.

- Description of *Opportunities*: First, in order to obtain a more flexible use of the *BusinessFields* contained in the BFO, there is a possibility to choose the intersection of two *BusinessFields*. Hence, in Figure 3.18, one can see that one of the domains linked to the *Opportunity* consists actually in the intersection of two *BusinessFields* of the BFO. Another domain has been added that is only linked to a single *BusinessField*. This *Opportunity* should be understood as corresponding to a specific *Objective* in the CO. Moreover, it concerns two domains: the first is at the intersection of two *BusinessFields*, while the other concerns only one *BusinessField*: concretely, that means that the final collaborative *Process* to be deduced will have to provide two output *Flows*: one must be at the intersection of *BusinessFields* corresponding to the first domain of the *Opportunity*, the other one should concern the *BusinessField* of the second domain of the *Opportunity*. Eventually, each domain should be described with its *domainType*: either physical or informational. Back to the example in Figure 3.18, the first domain has an informational *domainType*, and the second domain has a physical *domainType*. In terms of collaborative *Process*, that means that, among the two output *Flows*, one need to be a physical one and the other an informational one.
- Description of *PartnerCapabilities*: As it comes to describe the *Flows* of a *PartnerCapability*, those can also be described at the intersection of two *BusinessFields*, like “Output2” in Figure 3.19. Besides, a *PartnerCapability* can have several input *Flows* and output *Flows*.

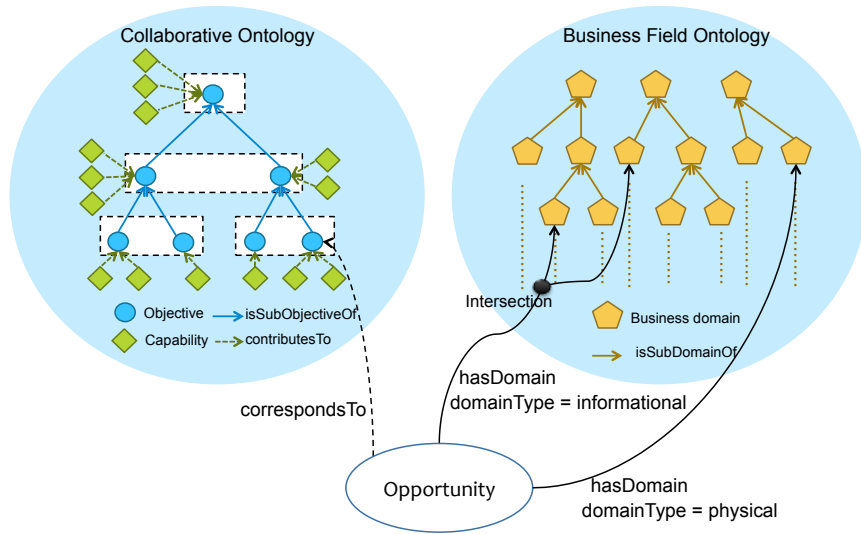


Figure 3.18 – Description of an *Opportunity*.

If more than one *Flow* constitutes the output of a *PartnerCapability*, that means that the *PartnerCapability* is able to provide the “union” of the *Flows*: either one of them, or both could be used by a successor *PartnerCapability* in the final *Process*. Hence in Figure 3.19, the *PartnerCapability* is able to offer “Output1” and “Output2”, which could be used (one of them or both) by a further *PartnerCapability*, as input. Note that, because of consistency reasons, it is not possible for a *PartnerCapability* to have no physical input if it has a physical *Output*.

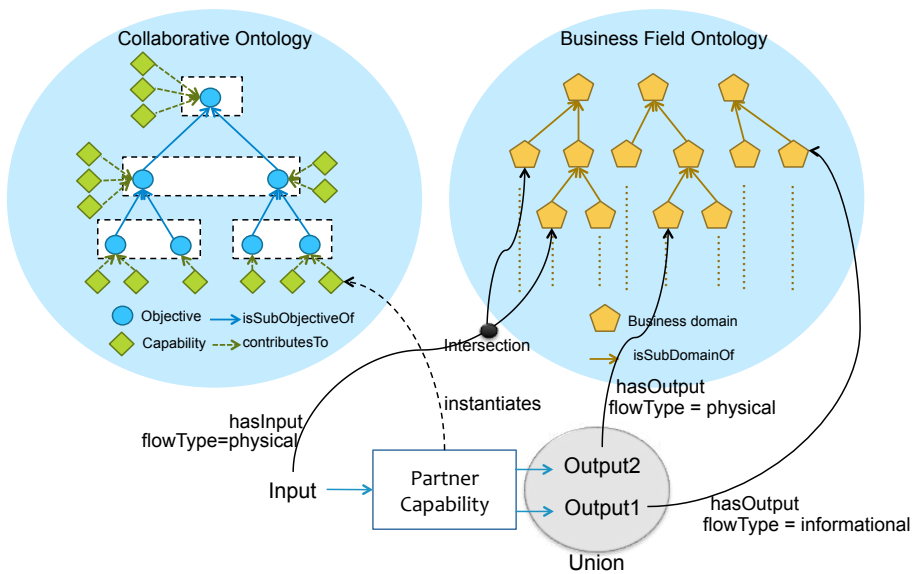


Figure 3.19 – Description of a *PartnerCapability*.

### 3.3. Definition of the ontology-based system

**Non-functional attributes** The particularity of both *PartnerCapabilities* and *Opportunities* are that, since they are provided by users, they not only focus on *what* but also on *how*. Indeed, assuming several organizations can provide the same *Capability*, the choice of a partner can only be made on specific criteria. On the one hand, *PartnerCapabilities* can be assessed on non-functional criteria as proposed by the non-functional framework in Chapter 2. Hence, each criteria comes as an attribute of *PartnerCapability*. On the other hand, *Opportunities* not only focus on the *Objectives* that should be achieved but also their definition should provide a way for the users to express their non-functional needs. Hence, a list of criteria with their corresponding objectives and weights (to provide the relative importance of the non-functional objectives) should be associated with the *Opportunities*. Figure 3.20 details both classes with example of attributes, which are not all precised here for obvious reason of readability.

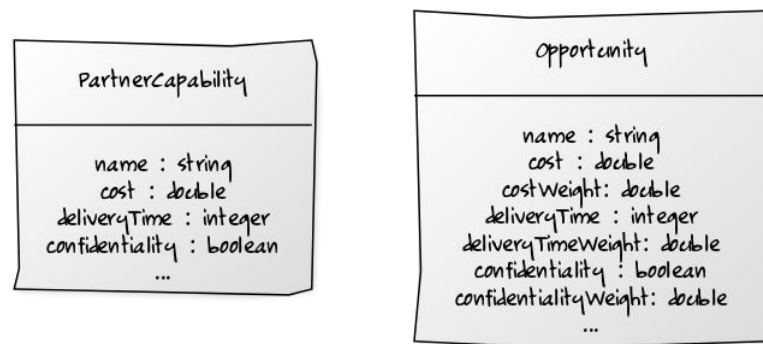


Figure 3.20 – *PartnerCapability* and *Opportunity* concept detailed.

**Extended Collaborative Ontology** *PartnerCapabilities* are eventually stored to be reused to answer any further *Opportunity*. However, here, the *Opportunities* are not stored: they are considered as one shot *Opportunities* and are only used when deducing the collaborative processes. That means, that the *PartnerCapabilities* should be integrated as knowledge in an ontology. An Extended Collaborative Ontology (ECO) is proposed, which goal is to store the social knowledge. It includes, *Objectives*, their set of *Capabilities* and the correspond *PartnerCapabilities* with their *Flows*. Actually, this is the minimal and sufficient knowledge needed for the further deduction of collaborative processes (*i.e.* the ECO can be considered as the application ontology here). To clarify this approach, the Figure 3.21 provides a clear description of the ECO.

One can note, that the ECO also embeds knowledge from the CO and the BFO, and could call it redundancy. However, this is a way to separate persistent knowledge from “social knowledge”: it is useful for enhancing the maintainability of the ontology-based system.



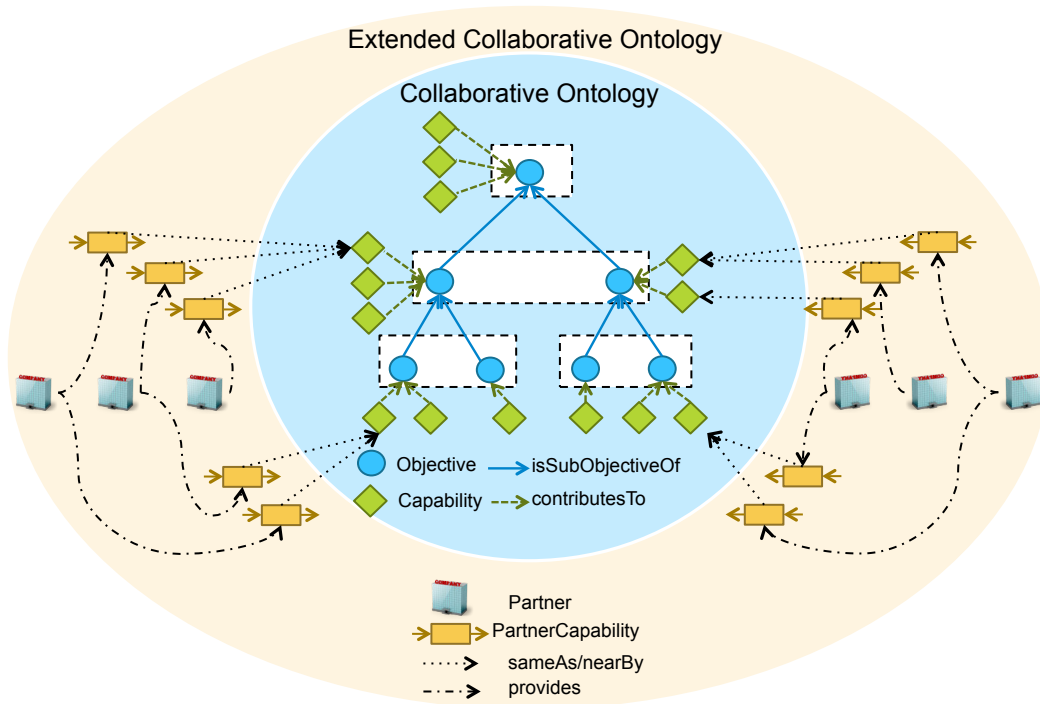


Figure 3.21 – Extended Collaborative Ontology structure.

**“Deduced” knowledge**

Based on the ECO, the system is able to exploit its knowledge to provide collaborative processes that fulfill the objectives of the collaboration. In other words, the exploitation goal is to deduce five classes (see Figure 3.22): the *Process* is made of *Activities* that invoked the *Partner’s PartnerCapabilities*. The set of the *Partners* of this *Process* are gathered as a *CollaborativeNetwork* - which could be broken down into *SubCollaborativeNetworks* depending on the topology of the collaboration (see Chapter 1) -. Besides, this *Process* is intended to be orchestrated by the *Mediator* during the run-time. As such, the *Mediator* is considered as a specific *Partner* (i.e. it is a central *Partner* that invokes *Partners* and their *Activities* all along the *Process*, see Chapter 4 and Appendix B).

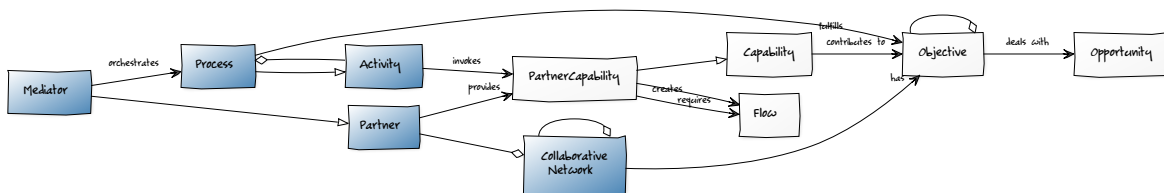


Figure 3.22 – Knowledge to be deduced.

## 3.4 Populating the ontologies

Now that the structures of CO and BFO ontologies have been established, they should be populated with concrete instances. This means that (i) adapted knowledge bases should be found whatever their structure or format and (ii) they should be transformed into individuals.

### 3.4.1 Knowledge bases for the Collaborative Ontology

Numerous knowledge bases exist around the notion of processes and activities (which could be also called as capabilities, skills, business services or business functions, etc.).

#### SCOR (Supply Chain Operations Reference) model

The SCOR model is one of the most famous knowledge base to describe processes and activities within enterprises. It does not only focus on performance metrics (as exploited in Chapter 2), but also conveys a source of knowledge on inter-organizational supply chain processes, around six top-level *management processes*: *plan*, *source*, *make*, *deliver*, *return* and *enable*. These levels are themselves decomposed into two sub-levels, as illustrated by Council [181] in Figure 3.23 level 2 is about the strategy of the supply chain (e.g. *make-to-order* or *make-to-stock* strategy) and level 3 focuses on the main steps that should be performed to achieve the level 2 process. The Supply Chain Council mentions the level 4 which should allow to describe the implementation of the processes. However this level is out of the scope of SCOR.

The inconvenience of the SCOR is the difficulty to find *Objectives* among its processes and activities, hence, it is hardly exploitable to populate the CO.

#### PCF (Process Classification Framework)

PCF [182] has been established by the American Productivity & Quality Center (APQC) surrounded by some 80 organizations, and provides a “taxonomy of cross-functional business processes”. It is actually most used for benchmarking and performance activities and claims to define processes comprehensively. The framework offers twelve top-level categories of processes: five concern operating processes (e.g. *develop vision and strategy* or *deliver products and services*) and the seven others deal with management and support services (e.g. *manage financial resources* or *manage information technology*). Then, these categories are themselves broken down into four levels: *process group*, *process*, *activity* and finally *task*. Besides, PCF has also been developed to fit specific business fields such as aerospace and defense, banking, downstream petroleum, education... Actually it covers fifteen different fields. All these versions of PCF are freely available as PDF and Excel files and Figure 3.24 provides a sample of the classification by focusing on the “Manage employee requisitions” topic.

Similarly to the SCOR, the PCF’s structure is not easily adaptable to the transformation into

## Chapter 3. Collaborative Knowledge Representation and Acquisition

	Level	Application	Examples
In Scope Applicable Across Industries	1	Level 1 processes are used to describe the scope and high level configuration of a supply chain. SCOR has five level 1 processes.	Plan, Source, Make, Deliver, and Return
	2	Level 2 processes differentiate the strategies of the level 1 processes. Both the level 2 processes themselves as well as their positioning in the supply chain determine the supply chain strategy. SCOR contains 26 level 2 processes.	Example Make level 2 processes: <ul style="list-style-type: none"> <li>› Make-to-Stock</li> <li>› Make-to-Order</li> <li>› Engineer-to-Order</li> </ul>
	3	Level 3 processes describe the steps performed to execute the level 2 processes. The sequence in which these processes are executed influences the performance of the level 2 processes and the overall supply chain. SCOR contains 185 level 3 processes.	Example Make-to-Order level 3 processes: <ul style="list-style-type: none"> <li>› Schedule Production Activities</li> <li>› Issue Product</li> <li>› Produce and Test</li> <li>› Package</li> <li>› Stage</li> <li>› Dispose Waste</li> <li>› Release Product</li> </ul>
Not in Scope Industry Specific	4	Level 4 processes describe the industry specific activities required to perform level 3 processes. Level 4 processes describe the detailed implementation of a process. SCOR does not detail level 4 processes. Organizations and industries develop their own level 4 processes.	Example Issue Product level 4 processes for the electronics industry: <ul style="list-style-type: none"> <li>› Print Pick List</li> <li>› Pick Items (Bin)</li> <li>› Deliver Bin to Production Cell</li> <li>› Return Empty Bins to Pick Area</li> <li>› Close Pick Order</li> </ul>

Figure 3.23 – SCOR decomposition overview, [181].

### 6.0 Develop and manage human capital

#### 6.2 Recruit, source, and select employees

##### 6.2.1 Manage employee requisitions

- 6.2.1.1 Align staffing plan to work force plan and business unit strategies/resource needs
- 6.2.1.2 Develop and open job requisitions
- 6.2.1.3 Develop job descriptions
- 6.2.1.4 Post requisitions
- 6.2.1.5 Manage internal/external job posting Web sites
- 6.2.1.6 Modify requisitions
- 6.2.1.7 Notify hiring manager
- 6.2.1.8 Manage requisition dates

Figure 3.24 – Sample of APQC’s PCF, [183].

*Objectives* and *SubObjectives* since it provides a “linear” decomposition on its four levels.

### PSL (Process Specification Language)

The PSL[184] aims at “creating a process representation that is common to all manufacturing applications, generic enough to be decoupled from any given application, and robust enough to represent the necessary process information for any given application”. It has been developed by the National Institute of Standard and Technology (NIST), with the university of Toronto and formerly surrounded by other industrial and academic contributors. The PSL specification [184] details four concepts within the PSL Core, defines as follows:

- *Activity*: a type of action.
- *Activity-Occurrence*: an event or action that takes place at a specific place and time.
- *Timepoint*: a point in time.
- *Object*: anything that is not a timepoint or an activity.

Besides, relations are defined between these concepts. One of the difficulty to adapt PSL to populate CO is its lack of bottom-up approach: it is quite difficult to define which PSL's concept could be transformed into *Objectives*.

#### SUMO (Suggested Upper Merged Ontology)

SUMO was developed at the beginning of the 2000's with the aim to provide a large and free upper ontology, that would finally become a standard. Pease et al. [185] explains that the main challenge to obtain such upper-level ontology is to align various sources of knowledge. For instance, SUMO website [186] explains that the upper ontology is based on: WordNet which is a lexical database for English [187], many domain ontologies from communication to sports through transportations and MILO (Mid-Level Ontology) which goal is to bridge the gap between the upper-level provided by SUMO and the domain ontologies. Thus, SUMO finally offers a formal ontology with 25,000 terms and 80,000 axioms. The structure of SUMO and its mapping to MILO and the domain ontologies is illustrated in Figure 3.25. SUMO was written in the SUO-KIF<sup>4</sup> language, but has also been translated in OWL.

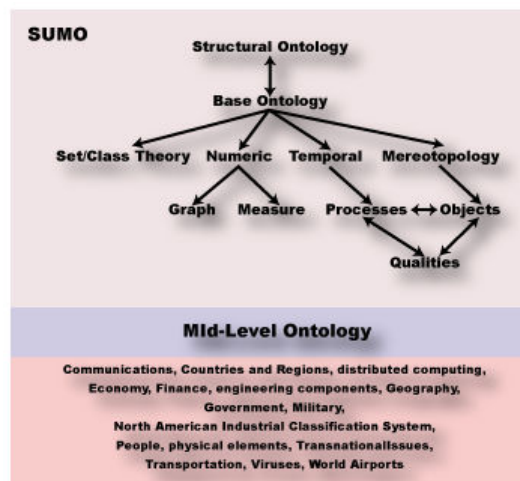


Figure 3.25 – SUMO structure, [186].

<sup>4</sup>Standard Upper Ontology Knowledge Interchange Format, derived from KIF to support the definition of the SUMO

## Chapter 3. Collaborative Knowledge Representation and Acquisition

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Here again, whilst SUMO could bring a very large amount of knowledge, it is quite hard to think about a transformation of its structure into CO's metamodel.

### MIT Process Handbook

The MIT Process Handbook is a key initiative of the MIT Center for Coordination Science to create "rich online libraries for sharing and managing many kinds of knowledge about business" [188]. First proposed under a MIT licence, the MIT spin-off company Phios<sup>5</sup> proposes a commercial version since 1996. An online version is available<sup>6</sup> available and freely usable. As explained by Malone et al. [71], this handbook aims at representing industrial processes to help managers deal with several situations: (i) redesigning business processes, (ii) design new processes, (ii) organize and share knowledge about organization process and more generally (iii) to support business processes. To respond to these needs, two problems had to be addressed: (i) the representation of organizational processes that would take into account different levels of abstraction and (ii) collecting and analyzing real cases to define how similar functions can be performed.

The MIT process handbook embeds more than 5000 processes, besides the repository also offers alternative models such as APQC's PCF and the SCOR model. Each process defines a collection of activities that can be broken down into sub-activities. Also, the processes achieve goals. Thus a bottom-up approach can be easily applied when using the process handbook. Another advantage of the MIT Process Handbook is that, within a project with the Department of Informatics of the University of Zurich, it was OWLized, as detailed by Kiefer et al. [189], and is available online<sup>7</sup>.

The handbook is organized around six key concepts, as related by Rajsiri [190], and illustrated in Figure 3.26

- *Processes* are composed of activities that can in turn be split into sub-activities.
- *Resources* are related to the input and output of the processes.
- *Dependencies* allow the coordination between activities in the process.
- *Goals* are achieved by processes.
- *Exceptions* concern fails in the processes.
- *Bundle* is a group of related specializations.

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<sup>5</sup>Web site page: <http://phios.com/>

<sup>6</sup>Web site page: <http://process.mit.edu/>

<sup>7</sup><https://files.ifi.uzh.ch/ddis/oldweb/ddis/research/completed-projects/semweb/ph-owl/index.html>

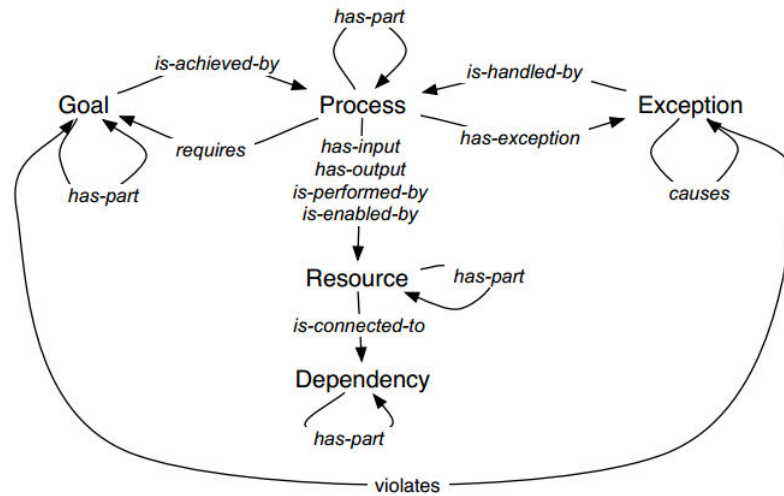


Figure 3.26 – MIT Process Handbook schema, [191].

### RosettaNet and ebXML

RosettaNet<sup>8</sup> is a consortium of over 400 leading information technology, electronic components, semiconductor manufacturing and solution provider companies, that has been founded in 1998 and is also a subsidiary of GS1 US -formerly known as Uniform Code Council, Inc. RosettaNet proposes a collection of standards which goal is to facilitate the exchange of information within B2B collaborations. There are 7 PIPs® (Partner Interface Process) specifications that are defined by Damodaran [192] as “standardizing business documents, the sequence of sending these documents, and the physical attributes of the messages that define the quality of service”.

ebXML<sup>9</sup> (electronic Business using XML) is a suite of standards brought by OASIS and UNCEFACT, approved as ISO-15000 [193]. Initiated in 1999, this initiative also aims at standardizing e-commerce on five levels: business process, collaboration protocol agreements, core data components, messaging and registries and repositories.

Actually both rather focus on *technical* exchange standards, and not really on a *business* level, which make them quite difficult to exploit them as knowledge bases and transform them into OWL ontologies.

### BOWL (Business-OWL)

The research works of Ko [175] as part of the Genesis project, faced the closest issues. Actually, Genesis aimed at providing enterprises a way to obtain on-the-fly cross-enterprises collaborative processes with non-functional concerns (*e.g.* cost, quantity, lead time...), based on the expression

<sup>8</sup><https://resources.gs1us.org/rosettanel>

<sup>9</sup><http://ebxml.xml.org/>

## Chapter 3. Collaborative Knowledge Representation and Acquisition

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of a collaborative objective. Ko et al. have based their approach on a Hierarchical Task Network (HTN) ontology called Business-OWL (BOWL). The strength of their works relies on the implementation of an ontology not only as a knowledge base but that also embeds the resulting business task decomposition of the HTN. Although this approach is quite interesting, the whole BOWL file does not seem available online, hence it is quite hard to evaluate if it would be adaptable. Nevertheless, the BOWL application is very close to this PhD thesis objectives, which is quite interesting to note.

Finally, the MIT Process Handbook [71] is the most adapted to the CO, since its structure contains all the concepts of CO and OWL files are available online, free of use, which is really convenient to extract individuals.

### 3.4.2 From OWL MIT Process Handbook to the Collaborative Ontology

In order to populate the CO based on the MIT Process Handbook, an 1-to-1 model transformation has been made:

- From MIT Process Handbook's *Goals* to CO's *Objectives*
- From MIT Process Handbook's *Processes* to CO's *Capabilities*

Table 3.1 summarizes the transformations that have been done.

MIT Process Handbook	CO
<i>Goal</i>	<i>Objective</i>
<i>Process</i>	<i>Capability</i>
(Process) <i>requires</i> (Goal)	(Capability) <i>contributesTo</i> (Objective)
(Goal) <i>is-achieved-by</i> (Process)	(Objective) <i>isAchievedBy</i> (Capability)
(Goal) <i>has-part</i> (Goal)	(Objective) <i>hasSubObjective</i> (Objective)

Table 3.1 – Model transformation from MIT Process Handbook to CO.

As a result an OWL ontology file was obtained, that contained all the *Goals* and *Processes* available in the online version of the MIT Process Handbook. The Appendix C provides a sample of the populated CO - implemented with OWL API [171] as ontology reader and writer.

That being said, the MIT Process Handbook has not been implemented for the specific needs of the automated deduction of business processes, but rather to help process designers to analyze processes and find other alternatives [194]. Consequently, the resulting deduced processes are not always as good as expected.

### 3.4.3 Knowledge bases for the Business Field Ontology

Knowledge bases about business domains are quite common, since most governments classify their organizations by business activities for statistical purposes. This Part aims at giving a quick overview on some of these classification and choosing an adapted one to populate the BFO.

#### **North American Industry Classification System (NAICS)**

NAICS<sup>10</sup> allows classifying business establishments since 1997. The initiative was launched by Canada, the United States and Mexico. According to [195], the last version has been established in 2012 and can be bought online, but the categories and their structure can be browsed for free. It includes twenty top-level classes, from agriculture to public administration, which are decomposed into four sub-levels. Definitions are given for each individual whatever its level.

As focused on North American business domains, some domains that could be encountered in other areas are not included.

#### **Statistical Classification of Economic Activities in the European Community (NACE)**

NACE [196] was initiated by the European Union in the 70's, with the same purposes as NAICS in North America. NACE derives from the International Standard industrial classification of all economic activities (ISIC) and is in its second revision since 2006. It is composed of four levels, from sections to divisions, groups and finally classes. It proposes 21 top-levels sections, decomposed into 615 classes.

As focused on European business domains, some domains that could be encountered in other areas are not included.

#### **International Standard industrial classification of all economic activities (ISIC)**

ISIC [197] was established by the United Nations Statistics Division. Its fourth revision has been released in 2008 and most of the national or communities classifications are based on it and derives it to fit geographical areas specificity. It can be found for free online<sup>11</sup>. ISIC relates 21 top-level activities and has four hierarchical levels (Sections, Divisions, Groups and Classes) and at each level, definitions are given with including and excluding rules to help organizations find their right business domain. Besides, it can be considered as the most "international" business activities classification since it has not been specified for specific geographical areas (*i.e.* some activities can have been evicted from derived classifications since they are not represented over the corresponding area). For this reason, and because of the ease of access to this classification,

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<sup>10</sup><http://www.naics.com/>

<sup>11</sup><http://unstats.un.org/unsd/cr/registry/isic-4.asp>



it has been chosen to populate the BFO.

### 3.4.4 From the ISIC to the Business Field Ontology

The ISIC classification is really convenient, since the codes and their title (on the four levels) are downloadable as text files. A simple parser has allowed to obtain a OWL file for the BFO, by following the further transformation: each *Section*, *Division*, *Group* and *Class* becomes a BFO's *Domain*. Then each decomposition from *Section* to *Division*, from *Division* to *Group* and from *Group* to *Class* becomes a *hasSubDomain* relation. A sample of BFO can be found in Appendix D.

## 3.5 Illustrative use case

Brake France<sup>12</sup> is a French food wholesaler company for enterprises. As part of OpenPaaS and end user partner, a use-case has been based on its business activities: here, it focuses on a particular bid for chocolate products. Intentionally simple, this case aims at giving the readers a clear illustration of the concepts detailed all over this Chapter and also at situating the users interaction with the RSE when (i) defining their profiles and (ii) proposing collaborative opportunities.

### 3.5.1 Organizations' profiles modeling

As a first step, each of the organizations of the platform uses the Profile Modeler in order to create its own profile by detailing the capabilities it is able to provide and want to share in collaborative contexts. Let's take the example of Brake France enterprises (see Figure 5.3):

- The organization creates a new *PartnerCapability* and link it to "Place Order" which is a *Capability* proposed in CO, since it is one of its main capabilities as a wholesaler.
- Concerning the *Flows* of this *PartnerCapability*, the input and output are detailed: (i) the input is informational and concerns the "Combined office administrative service activities" class of the ISIC classification, whilst (ii) the output is also informational and concerns an intersection of two domains have been chosen for the output: "Manufacture of cocoa, chocolate and sugar confectionery" and "Wholesale of food, beverages and tobacco". Thus, the output specifies the fact that the "Place Order" capability concerns the ability of buying wholesale of food from chocolate manufactures.
- Finally, non-functional criteria are given. Actually, only the criteria which way to inform is categorized as "own profile" can be initially provided by Brake France, since the other criteria will then be assessed either by the system, or by future partners. Here, Brake

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<sup>12</sup><http://www.brake.fr/pub/fr/accueil/accueil.php>

France informs that the PartnerCapability can be executed in one day, with the possibility of confidentiality.

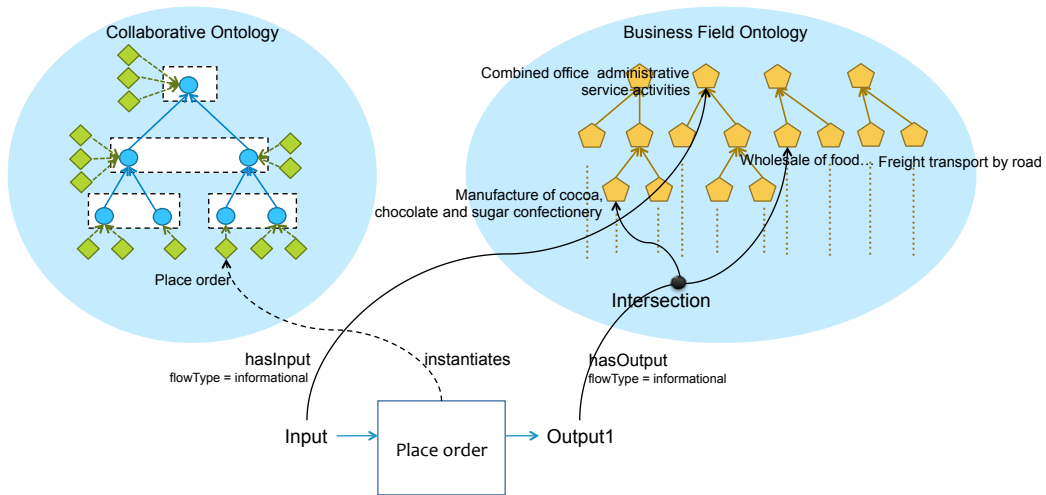


Figure 3.27 – Example of PartnerCapability: Brake France’s “Place order” capability.

Actually, Brake France’s profile is finally composed of the whole set of capabilities it is able to provide two capabilities: “order” and “Deliver” as a wholesaler, and the non-functional criteria applied either on the PartnerCapabilities they have defined, or on the whole Partner profile, depending of the level of application if the corresponding criteria. Hence, Brake France’s profile is illustrated in Figure 3.28.

### 3.5.2 Collaborative Objective description

Concerning the collaborative *Opportunity* that Brake France would like to achieve, it concerns a buying objective. Hence, the organization proposes a new *Opportunity* that is linked with the “Buy” *Objective* of the CO. The users can link as many domains as needed to specify the business

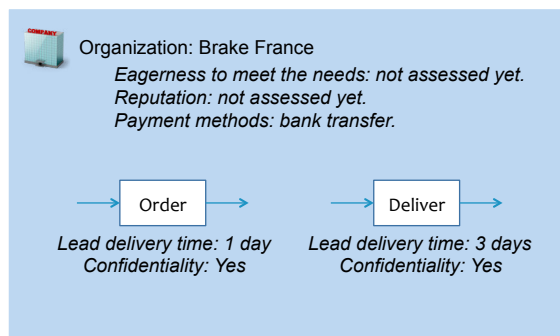


Figure 3.28 – Example of profile: Brake France’s profile.

fields of the collaboration. For instance, here, the “Buy” objective is linked with two domains (see Figure 3.29): one at the intersection of “Freight transport by road” and “Manufacture of cocoa, chocolate and sugar confectionery” and one concerning “Combined office administrative service activities”. The first domain specifies that, as a result of the process, Brake France would like to receive, by freight transport, chocolate products coming from manufactures of chocolate. By adding the second domain, Brake France also specifies that an informational administrative flow should also be generated by the process. In terms of non-functional requirements, Brake France would like here the lead delivery time to be less than 15 days, for a quantity of 300 products and a maximum total cost of 1500 euros. The weights of these criteria are 0,7 for the total cost and 0,3 for the lead delivery time.

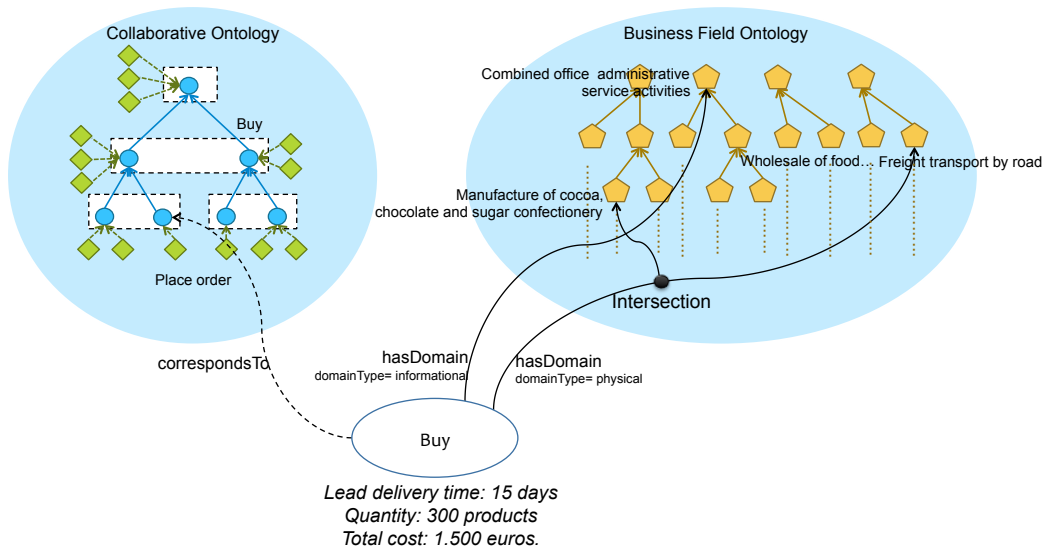


Figure 3.29 – Example of opportunity: bid for chocolate products and road delivery.

## 3.6 Contributions, Discussions and perspectives

### 3.6.1 Contributions

The representation of knowledge in IT context has been widely explored these last decades, however with the increasing interest for Big Data discipline these last years, one key challenge of knowledge-based systems concerns the acquisition of knowledge. Hence, the ontology-based system described in this Chapter still suffers from some limitations that are discussed here.

### 3.6.2 Discussions and perspectives

#### The everlasting knowledge bases issue

**Difficulties to access real knowledge bases** The lack of industrial knowledge bases with easy access remains one of the key limitations here. Actually here, the persistent knowledge allows to provide viable and relevant processes with the relation between objectives and capabilities of the CO. Hence, the viability of the final process raises the problem of the relevancy of the initial knowledge base (here, the MIT Process Handbook): the relevancy here is not “absolute” but rather totally relative to the expectations of the users with this type of ESN. Moreover, the ambition of creating from scratch a very broad knowledge base, whatever the collaborative contexts, would probably be disproportionate given the huge variety of collaborations that have nothing to do with each other (e.g. supply chain collaborations, administrative collaborations...).

That being said, that question does not remain unexplored, quite the contrary. Two behaviors seem to emerge that can be highly complementary:

- The inter-organizational collaborative networks create their own collaborative processes and store these processes as past cases. Then, the door is open to the broad and captivating world of machine learning, or, for example, case-based reasoning, as proposed in the works of Bergmann and Schaaf [198].
- Using already existing knowledge bases apparently unsuitable (*i.e.* following a different structure or metamodel), and finally adapt it, as in [199]

The underlying semantic issues concerning the second proposition makes it an interesting object to study more deeply.

**Towards the adaptation of external collaborative ontologies** Back on Chapter 1, the notion of interoperability was defined according to three levels: *integrated* when all the partners use the same exchange standards, *unified* when a common metamodel is shared and *federated* to allow matching between models built on different metamodels. The approach described in this Chapter clearly implements a unified interoperability. What about implementing a federated approach?

The research works of Tiexin Wang and Sébastien Truptil in the Industrial Engineering Center at Mines Albi propose such approach [199]. Within his PhD thesis, Tiexin Wang aims at providing a model transformation to enhance data sharing among heterogeneous IT systems. In [200], he provides a syntactico-semantic reconciliation that allows to find the similarity of the classes and relations of a metamodel with those of another metamodel. Hence, it could be directly used within this PhD thesis’ works: the users could provide their own collaborative ontologies, and the system could transform it to fit the CO’s structure.

## Chapter 3. Collaborative Knowledge Representation and Acquisition

At a lower level, this tool can be very useful to initially enhance CO by easily merging other knowledge bases with it, which would be very laborious as a human task.

**Enhancing user experience** It is customary to say “If you can do something complicated, you can do something simple”. The user experience described here is not really optimized. However, if the syntactico-semantic reconciliation allows to exchange data from different metamodels it is because it is able to reason on the meaning and writing of the words. In Part 3.3.2, users directly find their corresponding capabilities and objectives in CO and link them with their *partnerCapabilities* and *opportunities* via *sameAs* and *nearBy* relations. Given the number of individuals in CO, the task can be laborious. Also, the users are not guided in this step and misunderstandings could evict them of further deduced collaborations.

To address this issue, the syntactico-semantic reconciliation can reason on the words given by the users to directly find the potential corresponding individuals in CO as illustrated in Figure 3.30. The whole system is detailed in [201].

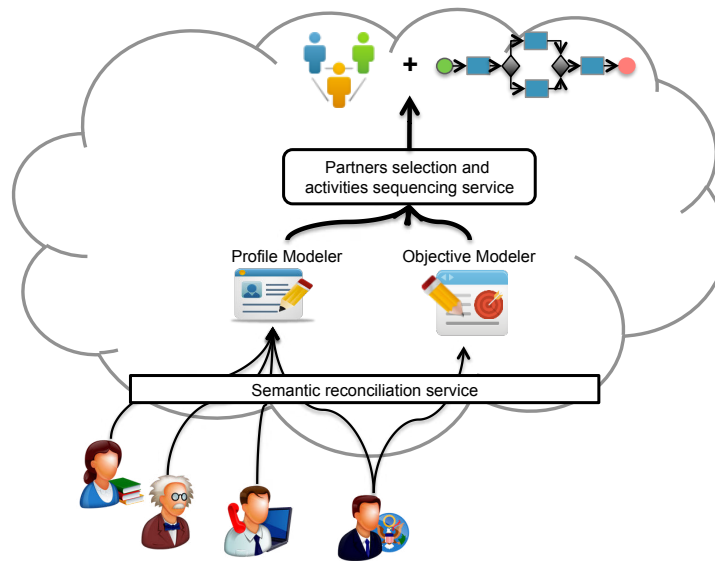


Figure 3.30 – New interactions of the users with the system, [201].

## 3.7 Conclusion

This Chapter detailed an ontology-based system in two parts: (i) the representation of knowledge *i.e.* the metamodel used to structure the ontologies CO and BFO so that they can be properly adapted and machine-processable and (ii) the acquisition of collaborative knowledge coming from users' information. The persistent knowledge (*i.e.* CO and BFO) is considered as always true and allows to link capabilities with the objectives they achieve. Social knowledge mentions the knowledge gathered with users' interactions: the collaborative *opportunities* and their own

*partnerCapabilities.*

Basically, the minimal and sufficient knowledge is now acquired. Last but not least, this knowledge should now be exploited to provide the brokers quasi optimal collaborative processes, which means: finding the capabilities that achieve the opportunities, then, finding the best set of partners able to provide these capabilities and finally order these capabilities into a process.

The next Chapter will therefore focus on the exploitation of this gathered knowledge in order to deduce quasi-optimal collaborative process in response to business opportunities.

This approach was part of the works presented in the conferences Pro-VE 2014 [202] and SCC 2014 [203].

### 3.8 Résumé en français

Des philosophes de la Grèce Antique jusqu'aux systèmes d'information modernes, la gestion de la connaissance a toujours été une problématique omniprésente. Ce chapitre s'intéresse à définir et structurer la connaissance minimale que le RSE doit acquérir afin de pouvoir ensuite déduire un processus collaboratif, en réponse à une opportunité.

Plusieurs technologies ont été développées en informatique afin de pouvoir élaborer des systèmes à base de connaissances, des systèmes experts aux systèmes sémantiques. Dans les années 2000, Tim Berners-Lee introduit le concept de *Web Sémantique* reposant sur différentes technologies selon cinq couches: (i) le langage RDF permet de structurer de l'information au sein d'un fichier XML, (ii) les ontologies sont utilisées pour stocker des connaissances et les lier entre elles, (iii) des règles logiques permettent d'exploiter les connaissances d'une ontologie pour en créer de nouvelles, (iv) une couche "preuve" a pour but d'assurer la cohérence d'une ontologie et (v) une couche "confiance" est dédiée à la fiabilité des connaissances. C'est la couche ontologie qui nous intéresse ici particulièrement.

Une ontologie repose d'une part sur une structure précise pour stocker de la connaissance de façon pertinente et, d'autre part, sur des individus (les connaissances) liés entre eux. Un métamodèle collaboratif est proposé pour structurer la connaissance stockée: il est basé sur les travaux réalisés dans le cadre du projet interne MISE. Ce métamodèle est adapté au contexte et aux contraintes liés au RSE. Finalement, il en résulte l'implémentation de deux ontologies: la Collaborative Ontology (CO) vise à décrire la façon dont les *Objectifs* de collaboration (amenés par les opportunités des utilisateurs) peuvent être remplis en exécutant des *Capacités* (amenées par les organisations et leurs services métier), et la Business Field Ontology (BFO) permet d'appliquer les individus de la CO, qui sont génériques, à des domaines métiers particulier.

Concrètement, la CO présente une décomposition d'*Objectifs* de collaboration (ex. "vendre") en sous-objectifs complémentaires. Chaque *Objectif* est aussi décomposé en l'ensemble des *Capacités* complémentaires permettant de le réaliser. La BFO consiste en une décomposition hiérarchique simple de domaines métiers. La CO est peuplée en utilisant la description de processus industriels proposée dans le MIT Process Handbook [71], et la BFO selon les activités proposées dans la classification ISIC [197]. Finalement, ces deux ontologies ont été implémentées sous forme de fichiers OWL2.

La description des profils et des opportunités par les utilisateurs résulte directement de la structure de ces deux ontologies. Un profil contient toutes les *Capacités* offertes par une organisation. Chaque *Capacité d'organisation* est définie par un lien sémantique à une *Capacité* de la CO et détaillée selon les facteurs non-fonctionnels retenus dans le Chapitre 2. De plus, ses flux (entrées et sorties) sont décrits grâce aux domaines métier disponibles dans la BFO. De même, chaque *Opportunité* est définie par un lien à un *Objectif* de la CO, par des objectifs non-fonctionnels associés, et un ou plusieurs domaines métier de la BFO.

Finalement, une Extended Collaborative Ontology (ECO) est obtenue et inclut la CO et l'ensemble des *Capacités* (et leurs flux) proposées par les organisations du RSE. Afin de répondre aux opportunités de collaboration, cette ECO peut maintenant être exploitée.





# 4 Knowledge Exploitation: Collaborative Business Processes Deduction

“Suppose presently the ants began to store knowledge, just as men had done by means of books and records, use weapons, form great empires, sustain a planned and organised war?”

– H.G. Wells, *The Empire of the Ants*

## 4.1 Introduction

Already in ancient Greece, Athenian generals did not take any vital decisions - like for battles, for instance - before having consulted the Pythia in Delphi. Decision making, either as a single individual or as a whole society, has always been a laborious step. Buchanan and O Connell [204] remind that after that Hamlet debated his timeless question “to be, or not to be?”, men like René Descartes, Blaise Pascal and Pierre de Fermat tended to rationalize such process during the 17th century. In modern time, the arrival of the first computers, around the 50’s, has resulted in a huge revolution both in academic and industrial worlds. Initially very expensive, the computational power soon became affordable and Power [205] mentions the first computerized models to assist decision making and planning in the 60’s. Eventually, Decision Support Systems (DSS) became a proper research area around the 70’s. Power [205] distinguishes five DSS axes: *communications-driven*, *data-driven*, *document-driven*, *knowledge-driven* and *model-driven*. Power [205] defines knowledge-driven DSS as “computer systems with specialized problem-solving expertise. The expertise consists of knowledge about a particular domain, understanding of problems within that domain, and skill at solving some of these problems”. When it comes to reason on ontologies to assist in decision making processes, the term “ontology-driven decision support systems” is generally used in the literature.

Chapter 3 aimed at representing and structuring knowledge on inter-organizational collaborations. The goal of this Chapter is now to exploit it as an ontology-driven DSS, in response to a

collaborative opportunity, by providing the broker a “good” (*i.e.* depending on non-functional criteria as proposed in Chapter 2, and chosen by the broker) way to fulfill it *i.e.* a quasi-optimal collaborative business process. Section 4.2 shows that the classical methods for exploiting ontologies and also exact methods (*i.e.* to find the optimal collaborative process among all the possibilities) are actually limited in this case because of the combinatorial nature of the problem. Hence, it has been decided to focus on metaheuristics which have proven efficient for resolving NP-hard problem. That is why Section 4.4 provides an overview on different metaheuristics used for this kind of problem and Section 4.5 describes the choice and the adaptation of an Ant Colony Optimization algorithm to the specific exploitation of CO and BFO. Finally, Section 4.6 brings an overview on the performances of the proposed algorithm.

### 4.2 Towards a limitation of the classical methods to exploit ontologies

The Semantic Web Stack (cf. Figure 3.4) extends the ontologies box with two other axes: (i) semantic reasoning through rules and (ii) data retrieving with querying. Those are ways to exploit and benefit from the knowledge stored in ontologies. Several approaches have emerged in both axes and this part aims at bringing a short overview on the possibilities they offer and the limitations that have been encountered.

#### 4.2.1 Semantic reasoning

##### Description Logics and ontologies

According to Horrocks et al. [206], the OWL ontology language has been highly influenced by Description Logic (DL). Baader et al. [207] define DL as follows:

“ Description logics (DLs) are a family of knowledge representation languages that can be used to represent the knowledge of an application domain in a structured and formally well-understood way. The name description logics is motivated by the fact that, on the one hand, the important notions of the domain are described by concept descriptions, *i.e.*, expressions that are built from atomic concepts (unary predicates) and atomic roles (binary predicates) using the concept and role constructors provided by the particular DL; on the other hand, DLs differ from their predecessors, such as semantic networks and frames, in that they are equipped with a formal, logic-based semantics. ”

Hence, it provides them a logical formalism and brings to OWL languages huge possibilities for reasoning. Basically, DL is composed of two components, the Tbox and the Abox:

## 4.2. Towards a limitation of the classical methods to exploit ontologies

DL	Operators
$\mathcal{AL}$	Atomic negation, concept intersection, universal restrictions, Limited existential quantification
$\mathcal{C}$	Complement
$\mathcal{H}$	Role hierarchy
$\mathcal{I}$	Inverse property
$\mathcal{O}$	Nominals
$\mathcal{N}$	Cardinality restriction
$\mathcal{Q}$	Qualified cardinality restrictions
$\mathcal{R}$	Limited complex role inclusion axioms; reflexivity and irreflexivity; role disjointness.

Table 4.1 – DL extensions and their operators.

**The Tbox** brings *terminology*, described by Baader and Nutt [208] as “the *vocabulary* of an application domain”. Basically, it includes *concepts* - set of individuals - and *roles* - relationships between these individuals. For instance, the further declaration allows defining the concept *woman* at the intersection of two other pre-defined concepts *Human* and *Female*:

$$Woman \equiv Human \sqcap Female$$

**The Abox** contains *assertions*. Precisely, both *concept assertions* and *role assertions* [209] are embedded. For instance, the two further declarations state that the Person Lilu is a Female - and consequently a Woman - and that Lilu’s husband is Korben:

$$\begin{aligned} &Female \sqcap Person(Lilu) \\ &hasHusband(Lilu, Korben) \end{aligned}$$

DL provides a set of constructors: from the basic  $\mathcal{ALC}$  (*Attributive concept Language with Complements*) to its numerous extensions [207]. Introduced by Schmidt-Schauß and Smolka [210],  $\mathcal{ALC}$  is the addition of the *Attributive Language* and the complement operator. Many extensions have emerged based on  $\mathcal{ALC}$ , some of which are further detailed with their specific operators in Table 4.1. Note that  $\mathcal{S}$  stands for  $\mathcal{ALC}$  as in the  $\mathcal{SHOIN}$  DL, for instance.

Based on DLs, the OWL languages propose different levels of expressiveness (cf. Chapter 3) that, according to Horrocks et al. [206] and Motik et al. [211], can be transcribed as follows: OWL Light corresponds to  $\mathcal{SHFF}$ , OWL-DL to  $\mathcal{SHOIN}$  and OWL 2 to  $\mathcal{SROIQ}$ . As underlined by Baader et al. [207], most of the DLs are fragments of first-order predicate logic (for example, transitivity closure of roles requires second-order logic).

With such an expressiveness, ontologies are not only about storing and structuring knowledge into knowledge bases but also providing a smarter way to create new knowledge: in other words *infer* new knowledge.

### Semantic Web inferences

While Scharrenbach et al. [212] mention *axioms* as explicit knowledge, they introduce *inferences* as implicit knowledge. In other words, *axioms* describe basic assumptions that could not be proven: the English Cambridge Dictionary defines it as “a formal statement or principle in mathematics, science, etc., from which other statements can be obtained” [213]. Regarding the word *inference*, the English Cambridge Dictionary expresses it as “a guess that you make or an opinion that you form based on the information that you have” [214]. In its definition of Semantic Web, the W3C embeds Artificial Intelligence via the use of *inference* [215]:

“ Broadly speaking, inference on the Semantic Web can be characterized by discovering new relationships. On the Semantic Web, data is modeled as a set of (named) relationships between resources. “Inference” means that automatic procedures can generate new relationships based on the data and based on some additional information in the form of a vocabulary, e.g., a set of rules. ”

In order to infer new knowledge, a set of rules can be associated to an ontology. For instance, a simple inference could be “If Gérard is the father of Serge, and Serge the father of Simon, then Gérard is the grandfather of Simon”.

In fact, here, any of the corresponding DL operators available with OWL 2 could be used with the purpose to establish inference rules and deduce new knowledge within the ontologies. For this purpose, number of reasoners have been developed like Jena [216], Pellet [217], Fact++ [218] or Hermit [219].

### Use of inferences to exploit collaborative ontologies

Within their PhD theses, Rajsiri [7], Truptil et al. [72], Boissel-Dallier et al. [74] and Mu [220] have also studied the deduction of BPMN and BPEL collaborative processes by exploiting collaborative ontologies. Eventually, Mu et al. [221] present a meta-model and the corresponding knowledge exploitation for the deduction of business processes following the BPMN. Mu et al. [221] are centered on the use of a collaborative ontology with first-order logic rules to obtain a BPMN process from (i) a set of partner wishing to work together but without knowing how exactly to do this and (ii) business objectives of collaboration. For instance, one of the rule established by Wenxin Mu allows defining t0-level functions (corresponding to A0-level in SADT models) from the objective of a collaborative network (*i.e.* a set of partners with common collaborative objectives). This rule states that if a collaborative network has a collaborative objective, then there exists a main function model which has a main function, which name is the same as the objective [220]:

$$\begin{aligned} & \forall CollaborativeNetwork(X) \\ & (\forall ObjectiveRelationship(CollaborativeNetwork(X), Objective(X_1))) \\ & \rightarrow \exists MainFunctionModel(X) \wedge \exists MainFunction(X_1) \in MainFunctionModel(X) \end{aligned}$$

## 4.2. Towards a limitation of the classical methods to exploit ontologies

The rules allowed by first-order logic and particularly by OWL 2 expressiveness form the cornerstone of Semantic Web because it allows to easily propagate relationships among the individuals of an ontology. Hence, the ontology-based systems become always more intelligent along their utilization. Moreover, the exploitation of collaborative ontologies via first-order logic rules, in order to deduce collaborative inter-organizational processes has already proven successful. However, it does not provide a way to make a choice when several solutions are viable unless if this choice is imposed, in which case the chosen solution would not be optimized.

### 4.2.2 Ontology queries

#### Definition of Semantic Web queries

Basically, ontology querying makes the parallel with data retrieving within databases (*i.e.* by using the the Structured Query Language - SQL - with relational databases). The W3C [222] defines it as follows:

“ Query in the Semantic Web context means technologies and protocols that can programmatically retrieve information from the Web of Data. ”

#### Scope on ontology query possibilities

The most famous language for ontology querying is SPARQL (SPARQL Protocol and RDF Query Language), which was created and developed by the W3C [223] in order to allow information retrieving within RDF information representation. As defined in the W3C recommendation [223], it has four query forms:

- SELECT: “Returns all, or a subset of, the variables bound in a query pattern match”.
- CONSTRUCT: “Returns an RDF graph constructed by substituting variables in a set of triple templates”.
- ASK: “Returns a boolean indicating whether a query pattern matches or not”.
- DESCRIBE: “Returns an RDF graph that describes the resources found”.

Imagine a RDF graph as described in Code 4.1

```
1 :Aristotle :owns :Ferrari.  
2 :Ferrari rdfs:type :Car.  
3 :owns rdfs:domain :Person.
```

Code 4.1 – Example of a RDF graph.

A very simple example of a SPARQL query can be found in the Code 4.2.

## Chapter 4. Knowledge Exploitation: Collaborative Business Processes Deduction

```
1 SELECT ?Person ?Car
2 WHERE {?Person :owns ?Car}
```

Code 4.2 – Example of a SELECT SPARQL query.

The result of such a query corresponds to Table 4.2. Such result can actually be serialized to JSON, XML, CSV or TSV.

Owner	Car
Aristotle	Ferrari

Table 4.2 – Result of the SPARQL query.

SPARQL provides many filter and operator mappings as SQL does for databases. One of the key feature of the last version of the W3C recommendation lies is the federated queries that allow querying to several remote SPARQL endpoints, and as such merge multiple sources of knowledge.

The four types of queries made available with SPARQL are really convenient to retrieve any data in an ontology as fast and efficient “unitary operations”. Besides, the perspective on ontologies merging are quite interesting. However, its limitations relies in the fact that the partners of the collaboration are not already known, which makes the problem a combinatorial one as shown in the next Part.

### Combinatorial problem for exploiting the collaborative ontologies

This Part aims at bringing an overview on the combinatorial problem of exploiting the collaborative ontologies to find the optimal collaborative process to fulfill a specific collaborative objective. Actually, the high number of combinations comes directly from the structure of the ECO which is depicted in Figure 4.1.

According to Figure 4.1, in order to fulfill the *Objective*  $O_1$ , five possibilities exist at the objective-level because of the complementarity of the *Objectives* at each decomposition level as in Equation 4.1.

$$\left\{ \begin{array}{l} (O_1) \\ (O_{21}, O_{22}) \\ (O_{211}, O_{212}, O_{22}) \\ (O_{21}, O_{221}, O_{222}) \\ (O_{211}, O_{212}, O_{221}, O_{222}) \end{array} \right. \quad (4.1)$$

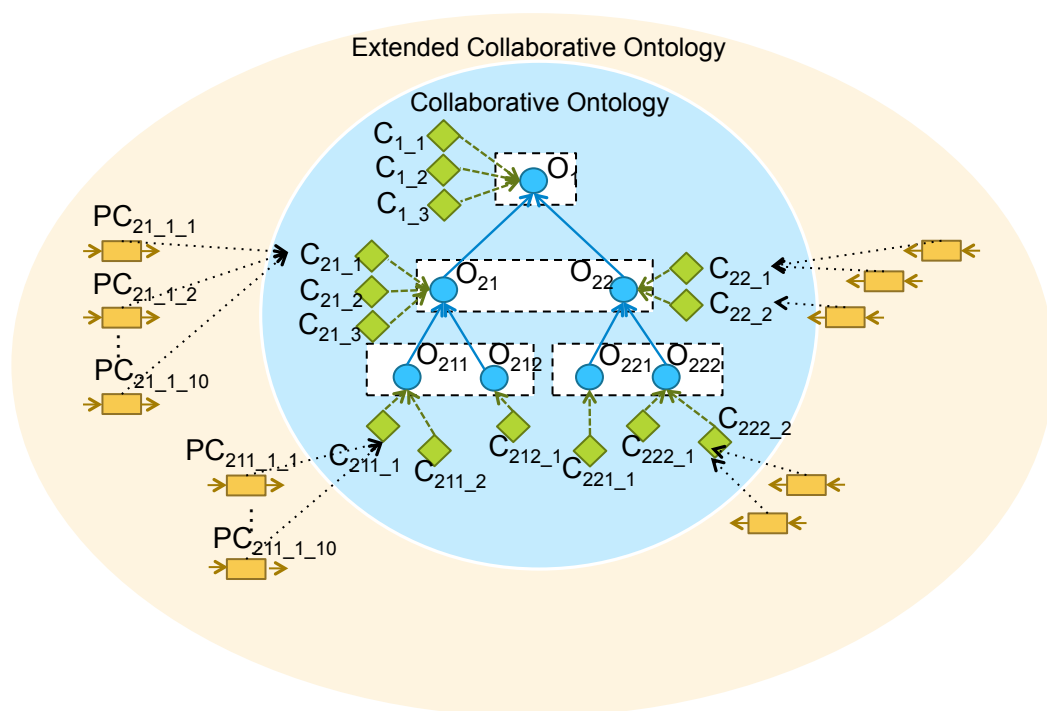


Figure 4.1 – Collaborative Ontology.

Each *Objective* can be fulfilled if all the corresponding *Capabilities* are executed.

For example, for *Objective*  $O_1$ , three *Capabilities* should be executed:  $C_{1_1}$ ,  $C_{1_2}$  and  $C_{1_3}$ . Then, imagine that for each of these *Capabilities*, ten organizations are able to provide it, there are  $10^3$  combinations that allow fulfilling  $O_1$  directly (*i.e.* without using  $O_{21}$  and  $O_{22}$  and their own decomposition).

When applying this logic to the five possibilities in Equation 4.1 and assuming that there are always ten *PartnerCapabilities* that provide each *Capability*:

- $O_1 \rightarrow 10^3$  solutions
- $(O_{21}, O_{22}) \rightarrow 10^{3+2}$  solutions
- $(O_{211}, O_{212}, O_{22}) \rightarrow 10^{2+1+2}$  solutions
- $(O_{21}, O_{221}, O_{222}) \rightarrow 10^{3+1+2}$  solutions
- $(O_{211}, O_{212}, O_{221}, O_{222}) \rightarrow 10^{2+1+1+2}$  solutions

Eventually, there are more than two millions solutions. Hence, deducing all the possible consequent collaborative processes and finally choose the best (*i.e.* according to non-functional requirements) process becomes fast a highly combinatorial approach.



## Chapter 4. Knowledge Exploitation: Collaborative Business Processes Deduction

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Note also that taking each best *PartnerCapability* for each *Capability* would be convenient but is unfortunately not realistic because of time concerns: the process must be built before being assessed.

Even if this kind of approach would not be so hard to set up by using ontology reasoning and queries, the high number of potential combinations makes it really resource and time-consuming, as soon as a certain number of organizations have subscribed to the collaborative PaaS.

### 4.3 Related topics

#### 4.3.1 Collaborative processes deduction from ontology exploitation

Of all the research works studied on the topic, the research works of Ko [224] as part of the Genesis project, faced the closest issues. Genesis aimed at providing enterprises a way to obtain on-the-fly cross-enterprises collaborative processes with non-functional concerns (*e.g.* cost, quantity, lead time...), based on the expression of a collaborative objective. Ko et al. have based their approach on a Hierarchical Task Network (HTN) ontology called the Business-OWL (BOWL). Hence the intelligence of the system is directly embedded into the ontology. On the one hand, this approach provides an efficient way to deduce inter-organizational collaborative processes. On the other hand, it prevents users to import their own CO so that their own knowledge bases could be exploited. As underlined in Chapter 3, the scope of open-access knowledge bases on collaboration is quite limited. That is why letting companies import their own knowledge adds more flexibility to the system.

#### 4.3.2 Partner selection and service composition

Many research works have been led in the field of service composition with the guiding thread of the establishment of business processes in order to model new CNOs. These works usually deal with two main topics: (i) the management science and most of all (ii) the computer science. Those are the two investigated topics for this section.

##### Service composition in management science

In management science, many works focus on the establishment of supply chain networks and more generally on the creation of Virtual Enterprises (VEs). Sha and Che [225] propose a Genetic Algorithm that allows finding an optimal set of partners able to provide the required business services in the context of a supply chain. Based on a “macro-process” also called a collaborative pattern, they discover candidate partners and achieve a global optimization on various non-functional criteria as cost or capacity. This method is interesting because of the multi-objective context and the necessity of finding a whole optimal set of partners, which is

not the same as finding each atomic best partners. Even if in our case this algorithm cannot be applied, because of the hypothesis of an already known “macro-process”, it leads to an interesting use of a metaheuristic.

Crispim and de Sousa [226] propose a way to select partners in the context of a VE. Making the hypothesis of a star-like collaboration (*i.e.* a central decision maker and a network of linked partners all around), and project(s) whose activities are known, Crispim and de Sousa [226] use a Tabu Search algorithm in order to find the best set of partners to achieve the project(s), according to various global objectives and constraints.

Many other works have been led in management science around the composition of services or the discovery of partners, however this sample is quite representative of (i) the methods usually applied in this field (*i.e.* metaheuristics) and (ii) the strong hypothesis made (*i.e.* the activities of the collaborative process and for some of them the structure of a first CNO intended to be further developed to be more adapted to the collaborative objectives).

#### **Service composition in computer science**

Concerning computer science, the literature is prolific on service composition, since it is one of the main breakthroughs made possible particularly with the emergence of the SOA paradigm. Dustdar and Schreiner [227] have proposed a survey on web services composition solutions, which are not so far from the scope of this PhD thesis, since web services composition approaches can generally be adapted and conducted on a business level (and vice versa). They divide the topic into two approaches: (i) the static composition aims at composing services in design-time, and relies on the hypothesis that partners are fixed; (ii) the dynamic one allows the discovery of services during the run-time and leads to evolving processes. Because of obvious reasons linked to inter-enterprise business agreements, and in line with the idea of automated one shot bids, the dynamic approach is clearly discarded for this PhD thesis. According to Dustdar and Schreiner [227], the service composition is closely linked to business workflows, since each business task provides information for finding corresponding technical services: a condition to fit the operational needs, the linkage among the web services with message flows, events, its provider. These last information should also be deduced in the context of business process deduction. However, one can observe that the technical and business approaches are conducted on two completely different abstract levels and consequently with different input hypothesis. For instance, Boissel-Dallier et al. [74] propose a semantic reconciliation from  $n$  business services to  $m$  web services, in order to obtain a BPEL file from a BPMN process. The transformation concerns the use of ontologies as knowledge bases for the matching between business tasks information and web services annotations: what is known about a business task is (i) its business role, (ii) its flows (input, output) and optionally (iii) its provider (*i.e.* one can think of “generic” business partners to be found and whose role is only made clear on a technical level). When compared, the deduction of a business process is however only based on information about “what the broker wants to do”, which could be only compared to a very

high-level 'business role' of the process, that should be decomposed.

Rao and Su [228] present Artificial Intelligence (AI) planning composition defined by a five-tuple  $\{S, S_0, G, A, \Gamma\}$ , with  $S$  the set of all possible state of the world,  $S_0$  the initial state,  $G$  the goal state of the world,  $A$  the set of actions available and  $\Gamma$  the presets and effects of each action if executed. Besides, Wang et al. [229] dedicate their survey on bio-inspired algorithm for web services composition. According to them, with the current required Quality of Service (QoS) evaluation, the issues of services composition have evolved: and based on the explanation of Canfora et al. [230], it has become NP-hard problems, and their solving algorithms have evolved consequently. Section 4.4 is therefore entirely dedicated to the service composition through current promising metaheuristic approaches.

Besides, Wang et al. [231] introduce an Ant Colony Optimization algorithm (ACO) enabling to find a quasi-optimal services composition from a workflow. Even if the functional issue is not exactly the same, the application of the ACO to the specific graph composed by a workflow is quite interesting and will be more detailed in Part 4.4.2.

## 4.4 Resolution of np-hard problems via metaheuristics

### 4.4.1 Metaheuristics

As mentioned by Wang et al. [229], new methods have emerged in the service composition field in order to optimize the deduced final result: one is based on local optimization, when the performances of each task is assessed (*e.g.* cost optimization, the costs of all the tasks can indeed be added to obtain the global cost), and the second on global optimization (*e.g.* global delivery time of the business process, time assessment should take task parallelism or sequencing into account, and consequently the process should be entirely deduced before assessment).

Within this PhD thesis, the second category of optimization is the most interesting, since the non-functional preferences of the broker can be based on very heterogeneous criteria including time. According to Blum and Roli [232], the term *metaheuristic* comes from the greek words *meta* which means "beyond, to a high-level" and *heuriskein*, *i.e.*, "to find". Rosenberg et al. [233] claim that "A metaheuristic is an iterative generation process which guides a subordinate heuristic by combining different concepts for exploring and exploiting the search space". Blum et al. [234] also add the notion of a general algorithm that should be slightly adapted to resolve specific problems. In their definition, Osman and Laporte [235] precise that this type of method allows finding near-optimal solutions through exploration, exploitation and learning strategies:

“ A metaheuristic is formally defined as an iterative generation process which guides a subordinate heuristic by combining intelligently different concepts for exploring and exploiting the search space, learning strategies are used to structure information in order to find efficiently near-optimal solutions. ”

#### 4.4. Resolution of np-hard problems via metaheuristics

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Dréo et al. [236] classify optimization methods: from combinatorial to continuous problems, and within the combinatorial problems, they detail approximate methods that lead either to specialized heuristics or metaheuristics, which can then be “of neighborhood” or distributed. Metaheuristics of the first type progress by taking into account a single solution at a time, whilst those of the second type handle a population of candidate solutions at the same time. Luke [237] uses the terms “single-state” and “population-based”.

##### Overview on metaheuristics

The first key challenge of metaheuristics is the choice of one of them among plenty of existing metaheuristics, which are usually based on the study of specific behaviors *e.g.* nature-based, physics-based or also even chemistry-based [238]. This Part aims at bringing a short overview on “classical” metaheuristics that have been widely studied during the last decades. For instance, Rosenberg et al. [233] describe four famous types of metaheuristics: Tabu Search (TS), Genetic Algorithm (GA), Simulated Annealing (SA) and Ant Colony Optimization (ACO).

A brief overview on metaheuristics frequently applied on service composition allows to situate this PhD thesis and to explain the authors’ choice of metaheuristic.

**The SA and the TS** are described as single-state methods by Luke [237]. The SA is inspired from annealing in metallurgy, which consists in controlling materials heating and cooling to obtain a better quality by increasing the size of the crystals (*i.e.* in terms of thermodynamics, lower the energy of the material to obtain a more stable state) [239]. According to Dréo et al. [236], the SA is known as a demanding method in terms of adjustments (*e.g.* to control the cooling), and can become very time-consuming, usually leading to parallel implementation. There is no notion of *memory*, in SA, which means that solutions cannot be based on previous simulations. In the literature, the SA can be associated with a GA to obtain more efficient algorithms in service composition like in the works of Gao et al. [240] or with a TS in the works of Ko et al. [241]. The TS is based on human memory mechanisms. Schematically, it consists in exploring the neighborhood of an initial candidate solution, to find better candidates. All along an iteration, a solution can be chosen even if it is worst than the previous, in order to avoid local minima. Then, Dréo et al. [236] explain that a memory of the last explored solutions is kept, so that the mechanism is able to forbid them: it avoids studying an already retained solution (and local minima by the same time).

**The GA** is considered as population-based and is a type of evolutionary algorithm [237]. According to Luke [237], comparing to single-state methods, the evolutionary algorithms work with a sample of solution, not just one: each potential solution affects the choice of the next candidate. Jaeger and Mühl [242] consider the GA as characterized through a loop within four phases as applied in QoS aware web service composition: the generation of a base population composed of various solutions from random combinations, the selection of a even

number of solutions, the crossing of these chosen solutions to obtain new children solutions in the population and finally the mutation of individuals. This algorithm is applied both in computer and management sciences, and for instance, Sha and Che [225] applied it to select partners in a supply chain network design work. The limitations of this algorithm come from the fact that the crossing step only works if all the solutions (*i.e.* chromosomes) have the same number of individuals (*i.e.* genes). Consequently, the hypothesis that a macro-process exists enables to encode the chromosome structure from the process pattern. However, in these PhD research works, two business processes could have different number of tasks (depending on their granularity levels), and still fulfill the same collaborative objectives, thus they cannot be crossed together.

**Ant colony algorithms** are particularly adapted for combinatorial optimization in a graph structure. Dorigo and Birattari [243] explain that, in theory, this type of metaheuristics can be applied to any discrete optimization problem for which some solution construction mechanism can be conceived. In the case of the composition of business process services composition, this is ideal.

Schematically, an ant colony algorithm is based on the biologic behavior of ants when searching for food. The ants evolves in a specific graph that can be constrained or not (*i.e.* ability or not for an ant to go from one node to any other node of the graph). Each ant, in the algorithm, builds a candidate solution. Then, the solution is assessed: if it is a good one, the pheromone on each path of the solution is increased (*i.e.* intensification step, [244]). The pheromone is the hormonal substance that attracts ants: thus the following ants of the algorithm will be influenced to visit the previous “good solutions” paths. However, always increasing pheromone could lead to converge too quickly to one solution, preventing the ants to explore other arcs of the graph. For this reason, each time an ant visits a path between two nodes, the pheromone of this path is also decreased (*i.e.* diversification step, [244]).

Actually, as described by Dorigo and Stützle [245], ACO algorithms have evolved towards several types: from the basic ants system that has given way to extensions like elitism (the global best solution has its pheromone trails reinforced at each iteration), Max-Min Ant System (all the paths are initialized with a maximal pheromone amount, and this amount cannot lower under a minimal amount), or also rank-based (the amount of pheromone deposited is weighted for each solution according to its rank).

### 4.4.2 The need to adapt the Ant Colony Optimization to the exploitation of an ontology

Because of the ability of the ants to travel over a graph structure, the ACO seems quite adapted to exploit ECO. The agents (*i.e.* ants) can thus be constrained in their “paths” so that they can explore the solutions space in a proper way. This brings a real strength when deducing

#### 4.5. Exploitation of the collaborative ontologies by an Ant Colony Optimization

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collaborative processes, since it can be adapted to fit the matching from collaborative *Objective* to either the corresponding *Capabilities*, or its *SubObjectives*. It also allows obtaining candidate solutions by any completion criteria, and not only a fixed number of individual as in the GAs.

Beside problems as the “traveling salesman”, ACO possibilities have been explored in various field, such as decision trees exploitation [246] or also data-mining advances with, for example, the Ant-Miner algorithm, which goal is to discover classification rules from gathered data [247]. However, ECO brings here an unusual graph structure, in which the initial search space is a directed acyclic graph, which means that the edges of the graph have a direction (e.g. from *Objectives* to *SubObjectives*) without cycles.

Wang et al. [231] detail such ACO, adapted to a directed acyclic graph. In that article, the graph is actually a workflow and the goal of the ACO is to find a quasi-optimal services composition for that workflow (i.e. finding the best set of service candidates that fulfill each of the abstract services of the workflow). For this purpose, Wang et al. [231] define the workflow as a AND/OR according to the AND/OR relationships between services and their successors. Ants begin their travel on the start event of the workflow, and then follow the workflow: when they meet AND nodes, they are replicated and when they meet OR nodes, they chose one of the path. Functionally speaking, such services composition makes the assumption that the workflow is already known. Hence, the selection is made “one-by-one” for each service of the workflow, which means that all the nodes (considering each node is a service) are always studied by the ants to find a candidate solution. In these PhD research works, candidates’ solutions either strictly belong to this high-level graph (i.e. if the solution corresponds directly to the *Capabilities* of the top-level *Objective* of the graph), or should be composed from several lower-level sub-graphs (i.e. if the *Objective* is decomposed into its *SubObjectives*: each of the *SubObjectives* can be seen as the top-level *Objective* of a sub-graph which can be potentially decomposed itself).

Eventually, as mentioned by Gendreau and Potvin [248], “now, the challenge is to adapt a meta-heuristic to a particular problem (...), which usually requires much less work than developing a specialized heuristic from scratch”. In line with this sentence, the next Section aims at adapting the ACO to the specific combinatorial problem of the exploitation of ECO.

#### 4.5 Exploitation of the collaborative ontologies by an Ant Colony Optimization

The deduction of an inter-organizational collaborative process remains the critical part of the whole system. The challenge of the deduction algorithm described in this sub-section is to provide a near-optimal cross-organizational business process. Here, “near-optimal” is used to mention a business process that offers good trade-off according to non-functional criteria as cost, delivery time, quality, etc. Concretely, the selection of all the cheapest complementary capabilities for an objective will definitely provide the cheapest process. However, it is obviously not the case for the time criterion for example because of the parallelism or the sequencing

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possibilities during the service composition (*i.e.* when the capabilities are ordered into a collaborative process).

That is why the ambition of this deduction algorithm is to exploit the minimal knowledge it holds from ECO, in order to simultaneously provide (i) a relevant set of partners, (ii) their quasi-optimal set of capabilities and (iii) the appropriate sequence of capabilities.

According to the famous maxim “divide and conquer”, the following parts allow to first describe the optimization problem and provide a main ACO algorithm, and then detail its three sub-algorithms (*i.e.* three steps of the ACO): the *Exploration* phase, the *Construction* phase and the *Evaluation* phase. Finally, an improved version of the *Exploration* is proposed. This ACO algorithm takes advantage of the graph structure of ECO: the ants “find their way” all along the semantic relationships that link the *Objectives*, the *Capabilities* and the *PartnerCapabilities*.

### Problem description

A process can be described as a sequenced set of capabilities of organizations. Thus, this optimization has two main goals: (i) find a “good” set of capabilities and (ii) deduce the sequences of capabilities to be able to assess the corresponding process.

In the following Section, the variable *capa* is associated with the *Capabilities* contained in CO, whereas *pCapa* designates the *PartnerCapabilities*.

A set of capabilities is modeled as a vector of complementary *PartnerCapabilities*  $pCapaSet = (pCapa_1, \dots, pCapa_n)$ . The variable *objective* also corresponds to the collaborative *Objective* proposed by the broker. The variable *process* is used to refer to the deduced process corresponding to the sequencing of *pCapaSet*.

Initially, the number of cycles  $N$  and the number of ants per cycle  $A$  are given. Each ant generated begins the algorithm with an empty  $pCapaSet = null$ . All the paths of the ECO are also initialized with the same amount of pheromone  $\tau_0$ . One ant goes through three parts:

**Exploration** The ant explores the ECO, from the collaborative *Objective*, stored in variable *objective* to the *PartnerCapabilities*, according to specific constraints due to the structure of the ECO. At the end of the Exploration, the local pheromone is updated (*i.e.* decreased for the diversification of further candidate solutions) for each parent branch of each *pCapa* of the chosen *pCapaSet*, according to the formula 4.2.

**Construction** Construction and feasibility : the previous set of *PartnerCapabilities* is ordered. According to the input and output of each *Capability* (*i.e.* the business domains), they are linked to each other in order to obtain a process. If this process is effectively deduced, then it shows that this process is feasible: it is a candidate solution.

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**Evaluation** This potential solution is evaluated according to  $k$  non-functional objectives given by the user. For each potential *process* previously deduced, a vector  $S_{process}^k$  is generated. Then the  $k$  evaluations are aggregated and finally  $S_{process}$  represents the global evaluation for this potential solution. The pheromone on the visited arcs of the two best solutions of each cycle evolves according to the formula 4.3 (*i.e.* increases for the intensification of the visited paths).

The Algorithm 1 presents the corresponding main algorithm. The variables *nFOjectives* and *nFOjectivesWeights* correspond respectively to the non-functional objectives (*e.g.* less than 500 euros) asked by the broker when giving the *Objective* of the collaboration, and the weights associated to each of these non-functional objectives.

---

**Algorithm 1** OpenPaaS's ACO main algorithm.

---

```

1: procedure MAIN-ACO(objective)
2:   Initialize N the number of cycles, A the number of ants per cycle
3:   Initialize pheromone on all the nodes of the ECO with  $\tau_0$ 
4:   repeat
5:     Initialize  $S_p^k$ 
6:     for Ant=1 to A do
7:        $pCapaSet \leftarrow$  Exploration(objective)
8:       Update local pheromone on each  $pCapa$  in  $pCapaSet$ , with Equation 4.2
9:        $process \leftarrow$  Construction(capaSet, objectiveDomains)
10:      if  $process$  is feasible then
11:         $S_{process} \leftarrow$  Evaluation(process, nFOjectives, nFOjectivesWeights)
12:      end if
13:    end for
14:    Determine the best and second-best solutions
15:    Update global pheromone on the corresponding capaSet according to Equation 4.3
16:  until non-functional objectives are fulfilled or N is reached
17: end procedure

```

---

The pheromone evolves according to two steps:

- Local pheromone: each time a path of the graph is visited, its pheromone decreases according to :

$$\tau_{arc} = (1 - \rho) \cdot \tau_{arc} + \rho \cdot \tau_0 \quad (4.2)$$

- Global pheromone: at the end of each cycle. Based on the works of Dorigo and Gambardella [249] and Bullnheimer et al. [250], and as underlined by Doerner et al. [251], an update of the global pheromone applied on the two best solutions' trails is sufficient. Hence, an increasing of the pheromone of all its parent arcs according to:

$$\tau_{arc} = (1 - \rho) \cdot \tau_{arc} + \rho \cdot \Delta\tau_{arc} \quad (4.3)$$

with  $\tau_{arc}$  the amount of pheromone on the *arc*,  $\rho$  the pheromone evaporation rate ( $\rho \in [0; 1]$ )



and  $\Delta\tau_{arc}$  as follows:

$$\Delta\tau_{arc} = \begin{cases} 10 \cdot \tau_0 & \text{if } arc \in \text{bestsolution} \\ 5 \cdot \tau_0 & \text{if } arc \in \text{secondbestsolution} \\ 0 & \text{if } otherwise \end{cases} \quad (4.4)$$

The three modules *Exploration*, *Construction* and *Evaluation* are the fundamental cornerstone of this ACO and each of the following sub sections are dedicated to them.

### Exploration

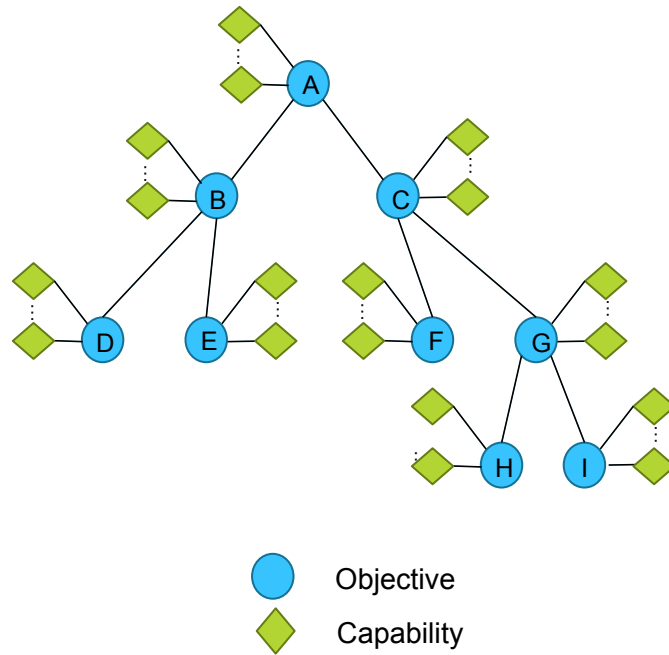
Concretely, the Exploration phase is composed of a set of constraints that the ants have to respect when searching for a set of *PartnerCapabilities*. Actually, these constraints are due to the decomposition of the *Objectives* and *Capabilities* in the ECO. The constraints can be expressed by simple logic rules. In order to simplify this explanation, the Figure 4.2 aims at illustrating the transformation from CO to a logical graph, which is in fact the graph used by the ants in the ACO.

These are the rules of transformation that have been applied here:

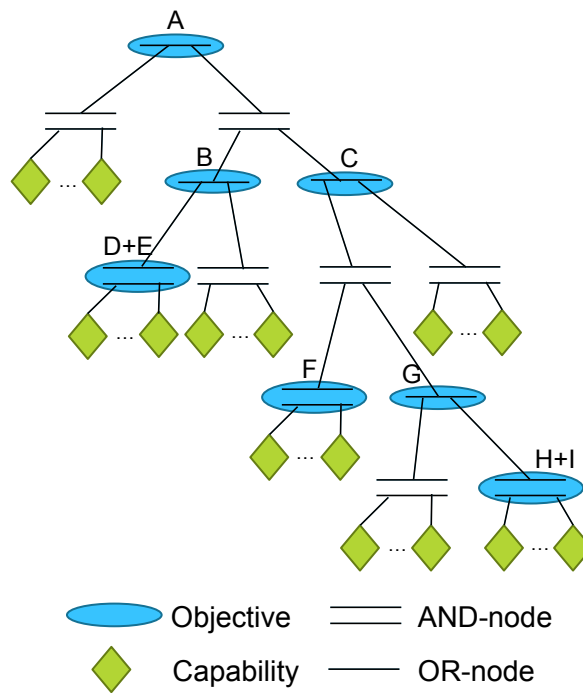
- The decomposition from an *Objective* to its complementary *Capabilities* is modeled with a AND-node, since all the *Capabilities* should be executed to fulfill the *Objective* of collaboration.
- The decomposition from an *Objective* to its complementary *SubObjectives* is modeled with a AND-node, since all the *SubObjectives* supersede together the high-level *Objective*.
- The decomposition from a *Capability* of CO to its linked *PartnerCapabilities* is modeled with a OR-node, since only one organization should be chosen to execute the *Capability* in the process.
- Each *Objective* that has a *SubObjective* is modeled as a OR-node, since the choice should be made between the set of *PartnerCapabilities* to directly fulfill it, or the set of *SubObjectives* that decompose it.
- Each *Objective* that has no *SubObjective* is modeled as a AND-node, since the only children consist in the set of the corresponding *Capabilities*.

For instance, the *Objective* A is transformed into a OR-node that leads either to a final AND-node for all the *Capabilities*, either to a AND-node of two *SubObjectives* B and C. Since D and E are two final *SubObjectives* of the arc they are merged together into a AND-node of all their corresponding *Capabilities*.

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● Objective  
◆ Capability



● Objective    = AND-node  
◆ Capability    — OR-node

Figure 4.2 – Transformation from CO to a logical graph.

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Based on this graph, the Exploration algorithm (cf. Algorithm 2) could be implemented. *objectiveList* is initiated with *objective*, the *Objective* of the collaboration. All along the algorithm this list evolves with the decomposition into *SubObjectives*. The list *listpCapa* is null at the beginning and grows every time an ant chooses a *PartnerCapability*. First, the ant is dropped on *objective*, then it chooses a child node in CO, according to the Equation 4.5 : it can be an *Objective* or a *Capability*.

- If it is an *Objective*, this *SubObjective* and its complementary *Objectives* are kept and added to *objectiveList*, and as the parent *Objective* has been processed it is removed from *objectiveList*. The ant re-do this loop.
- In the case of a *Capability*, the child and its complementary *Capabilities* are kept in *listCapa* for further decomposition, and as the parent *Objective* has been processed it is removed from the *objectiveList*. Once *listCapa* contains *Capabilities* to execute, the ant needs to find partners able to provide each *Capability*. For one *Capability* of CO, many children *PartnerCapabilities* are able to provide it, but with different non-functional criteria. The ant chooses one of them, according to the usual Equation 4.5.

---

**Algorithm 2** OpenPaaS's ACO exploration sub-algorithm.

---

```
1: procedure EXPLORATION(objective)
2:   Initialize objectiveList with objective
3:   Initialize listpCapa null
4:   while objectiveList not empty do
5:     for all currentObj in objectiveList do
6:       Initialize listCapa null
7:       children ← children nodes of currentObj
8:       child ← chosen node in children, according to Equation4.5
9:       if Type of child = 'Capability' then
10:        Add listCapa ← child and its complementary capabilities
11:       else if Type of child = 'Objective' then
12:        Add objectiveList ← child and its complementary objectives
13:       end if
14:       Remove currentObj from objectiveList
15:       for all capa in listCapa do
16:         pCapa ← chosen node in children, according to Equation4.5
17:         Add pCapa to listpCapa
18:       end for
19:     end for
20:   end while
21: end procedure
```

---

The choice of the children node depends usually on two parameters  $\eta_{arc}$  the attractiveness of each arc going to each children, and  $\tau_{arc}$  its amount of pheromone. The variable *arcs*

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represents the whole set of children arcs available, and  $arc$  one of them.

$$arc = \begin{cases} \underset{J}{\operatorname{argmax}}_{u \in arcs} [(\tau_u)^\alpha \cdot (\eta_u)^\beta] & \text{if } q \leq q_0 \\ J & \text{if } q > q_0 \end{cases} \quad (4.5)$$

$q$  is a random variable chosen between 0 and 1, and  $J$  is chosen according to the following probability distribution:

$$p_{arc} = \frac{(\tau_{arc})^\alpha \cdot (\eta_{arc})^\beta}{\sum_{h \in arcs} [(\tau_h)^\alpha \cdot (\eta_h)^\beta]} \quad (4.6)$$

The attractiveness of an arc  $\eta_{arc}$  is found by applying the further Evaluation assessment explained in Section 4.5, applied to only one *Capability*. Given the non-functional *Objectives*  $P = p_1, \dots, p_n$  expressed and weighted by  $W = w_1, \dots, w_n$  the broker, the attractiveness of one arc is  $\eta_{arc} = \sum_{i=1}^n (w_i \cdot p_i)$ .

Obviously, this Formula can only work when the arc is positioned between a *Capability* and a *PartnerCapability* (case 1 in Equation 4.7). For these reasons,  $\alpha$  and  $\beta$  have been fixed as follows:

$$arc = \begin{cases} \alpha = 1 \text{ and } \beta = 2 & \text{if } case1 \\ \alpha = 1 \text{ and } \beta = 0 & \text{if } otherwise \end{cases} \quad (4.7)$$

Finally, the whole set of *PartnerCapabilities* is set up. The next step is to build the corresponding process.

#### Construction

The process to be deduced here must respect the BPMN 2.0 specification [252]. As stated in Chapter 1, one of the benefits of the second version of the BPMN Standard relies on its ability to be orchestrated. In such a perspective, the deduced process must contain a pool for each partner of the collaboration but also a MIS pool which goal is to interact via message flows with all the partners during the orchestration, as stated in Appendix B. In fact, the whole skeleton of the collaborative process is therefore included in the MIS pool. This Construction phase only focuses on the deduction of the MIS pool process skeleton, since the generation of the partner tasks only consists in the replication of the MIS tasks in the right partner pool, and the creation of e message flow between the corresponding MIS task and the partner task.

The *Construction* algorithm takes as inputs *objectiveDomainList*, the domains linked to the *Objective* of the collaboration, and *pCapaSet*, the *PartnerCapabilities* selected by the previous *Exploration* algorithm. Note that each domain in *objectiveDomainList* actually includes a list of *BusinessFields* (one or two *BusinessField(s)*) if it concerns an intersection between two *BusinessFields*) and a type (*i.e.* physical of informational), as explained in Part 3.3.2. In the same way, each *PartnerCapability* of *pCapaSet* has a list of input and output *Flows*, which also have

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a list of *BusinessFields* (with one or two *BusinessField(s)*, if the *Flow* concerns an intersection of *BusinessFields*) and a type (i.e. *informational* or *physical*).

In order to build the collaborative process' skeleton, the whole algorithm is divided here in five steps:

- The first step begins with a right-to-left construction, by trying to use most of the *PartnerCapabilities* of *pCapaSet*.
- The second step is a left-to-right completion, which is a mirror algorithm of the first step: instead of trying to find *PartnerCapabilities*'s predecessors by linking input *Flows* to preceding output *Flows*, it focuses on finding successor *PartnerCapabilities*.
- The third step aims at creating the remaining start event and optional end events.
- The fourth step finally "clean" the collaborative process by adding the parallel gateways.

In the further *Construction* algorithms, it is assumed that the methods of the *Process* object *createElement(type, inputList, outputList)* and *createSequenceFlow(fromElement, toElement)* exist. The first method returns an *Element* and takes as input the type of the *Element* (i.e. *MISTask* as a task of the MIS pool, *PartnerTask* as a task in the partner pool, *EndEvent*, *StartEvent* or *ParallelGateway*). The second method takes two *Elements* as input: the source and the target of the sequence flow.

In order to illustrate this algorithm step-by-step, the Figure 4.3 presents a simple case with five *PartnerCapabilities* that have been selected by the previous *Exploration* step and should now order into a *Process*. All these *PartnerCapabilities* have one or two *Flows* either composed of a single *BusinessField* ("BF" in the Figure 4.3), or of an intersection of two *BusinessFields* (e.g. PC4). The *Objective* of the collaboration has two domains: one in the intersection of "BF3" and "BF4", and the other concerning "BF5".

**First step : right-to-left construction step** The Algorithm 3, presents the right-to-left first step of the *Construction* algorithm. First, a new *Process* is created and stored in the variable *process*. An end event is added to the *process*, with *objectiveDomainList* as an input and no output.

Then, for each input domain *inputDomain*, of each *element* of *process* the algorithm tries to match all the output *Flows* of the *PartnerCapabilities* of *pCapaSet* with the input of *element*. As soon as a *pCapa* of *pCapaSet* has an output *Flow* that has (i) the same type as the type of *inputDomain* of the *element* and that and (ii) the same *BusinessField(s)* as *inputDomain*'s *BusinessFields*, a new MIS task is created and a sequence flow is generated between this MIS task and *element*. As such, the corresponding *pCapa*'s MIS task is added to the *Elements* of the *Process*, and, as such its input *Flows* can now be used to find other predecessors. Note that

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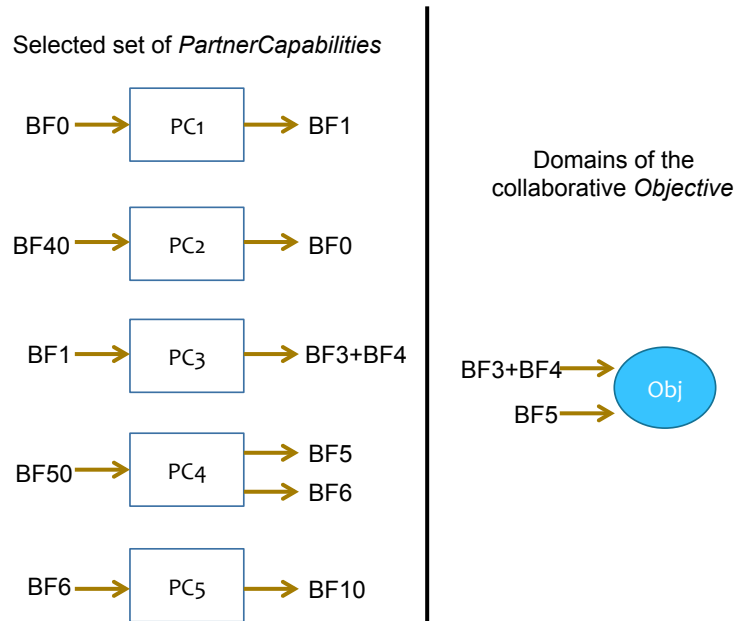


Figure 4.3 – Initial state of the construction algorithm illustrative case.

the IF condition prevents *element* from being linked to itself in the case it has similar input and output flows.

Finally the variable *condition* takes *true* as an initial value. Then, as soon as the *PartnerCapabilities* are tested, it turns to *false*. And, only if during the whole process, one *PartnerCapability* has been linked, it takes back *true* as value. Hence, this variable allows to know if there are still *Elements* to create, if not, the algorithm finishes.

Note that, at this step, if the domains of the *Objective* of collaboration have not all been linked to any *Flows of PartnerCapabilities*, then the *process* can be considered as not feasible.

Back in the illustrative case, Figure 4.4 shows the state of the collaborative *Process* after this right-to-left construction step. First, as “PC3” and “PC4” both have output *Flows* which *BusinessFields* are included in the domain of the collaborative *Objective*, they are directly linked to the end event of the *Process*. Then, as “PC1” output *Flow* has the same *BusinessField* as the input *Flow* of “PC3”, “PC1” is directly linked to “PC3”. The logic is the same for “PC2”.

**Second step : left-to-right construction step** This step aims at trying to involve the remaining *PartnerCapabilities* of *pCapaSet* that have not been used in the previously generated *process*, and it is detailed in Algorithm 4.

The logic of this left-to-right construction step is the exact mirror to the right-to-left step. Indeed, instead of considering the input *Flows* of each *Element* of the *process* and trying to find

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**Algorithm 3** Right-to-left OpenPaaS's ACO construction sub-algorithm.

```

1: procedure CONSTRUCTIONSTEP1(objectiveDomainList, pCapaSet)
2:   Create new empty Process process
3:   process.createElement(EndEvent, objectiveDomainList, null)
4:   condition=true
5:   while condition=true do
6:     for all pCapa in pCapaSet do
7:       condition= false
8:       outputList ← the output flows list of pCapa
9:       inputList ← the input flows list of pCapa
10:      for all element in the elements of process do
11:        for all inputDomain in the element's input list do
12:          for all pCapaOutputFlow in outputList do
13:            if pCapaOutputFlow.type = inputDomain.type AND the Busi-
            nessField list of inputDomain contain all the BusinessFields of pCapaOutputFlow
            AND element does not correspond to pCapa then
14:              condition=true
15:              newElement ← process.createElement(MISTask,inputList,outputList)
16:              process.createSequenceFlow(newElement, element)
17:            end if
18:          end for
19:        end for
20:      end for
21:    end for
22:  end whilereturn process
23: end procedure

```

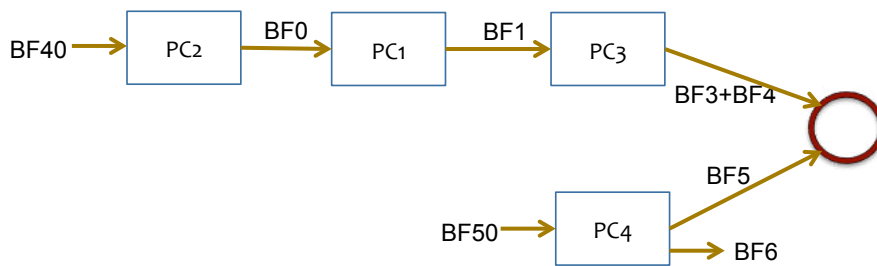


Figure 4.4 – Collaborative process state after the right-to-left step of the construction algorithm.

a *PartnerCapability* with the same *BusinessFields* in its output *Flows*, the goal, here, is to find *Elements* of the *process* with the same *BusinessFields* in their output *Flows* as the *BusinessFields* in the input *Flows* of the remaining *PartnerCapabilities*.

The variable *pCapaSetRemaining* refers to the list of *PartnerCapabilities* that have not been used in the *process* generated during the first step.

Note that, if at the end of this step, there remain *PartnerCapabilities* in *pCapaSetRemaining*

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that have not been used, then the *process* can be considered as not feasible.

**Algorithm 4** Left-to-right OpenPaaS's ACO construction sub-algorithm.

```

1: procedure CONSTRUCTIONSTEP2(process, pCapaSetRemaining)
2:   condition=true
3:   while condition=true do
4:     for all pCapaRemain in pCapaSetRemaining do
5:       condition= false
6:       outputList ← the output flows list of pCapaRemain
7:       inputList ← the input flows list of pCapaRemain
8:       for all element in the elements of process do
9:         for all outputDomain in the element's output list do
10:          for all pCapaInputFlow in inputList do
11:            if pCapaInputFlow.type =outputDomain.type AND the Busi-
            nessFields of pCapaInputFlow contain all the BusinessField list of outputDomain
            AND element does not correspond to pCapaRemain then
12:              condition=true
13:              newElement ← process.createElement(MISTask,inputList,outputList)
14:              process.createSequenceFlow(element, newElement)
15:            end if
16:          end for
17:        end for
18:      end for
19:    end for
20:  end while return process
21: end procedure

```

Figure 4.5 shows the result of this right-to-left step of the *Construction* algorithm. Here, one can see that the *BusinessFields* of “PC4” task’s output *Flows* are effectively included in the input *Flows* of “PC5”. Hence, “PC5” was linked as a successor of “PC4”.

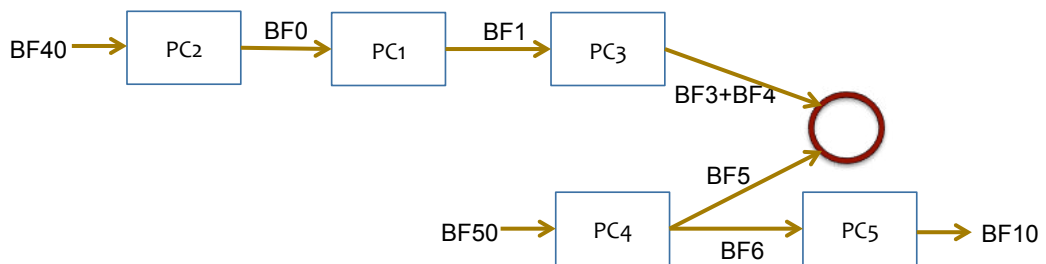


Figure 4.5 – Collaborative process state after the right-to-left step of the construction algorithm.

**Third step : end events and start event generation** At this time, all the tasks of the collaborative *Process* have been found and linked. Consequently, the process is already considered as feasible. Now, the start event and the optional remaining end events need to be generated.



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This step is very simple:

1. Creating the start event of the *Process*
2. Find the tasks of the *Process* that have no predecessor, and link them to the start event.
3. Find the tasks of the *Process* that have no successor, create an end event for each of them, and link them to the corresponding end event.

Figure 4.6 illustrates this step: as “PC2” and “PC4” have no predecessor, they are directly linked to the created start event. “PC5” has no successor, hence, a new end event is created and “PC5” is linked to this end event.

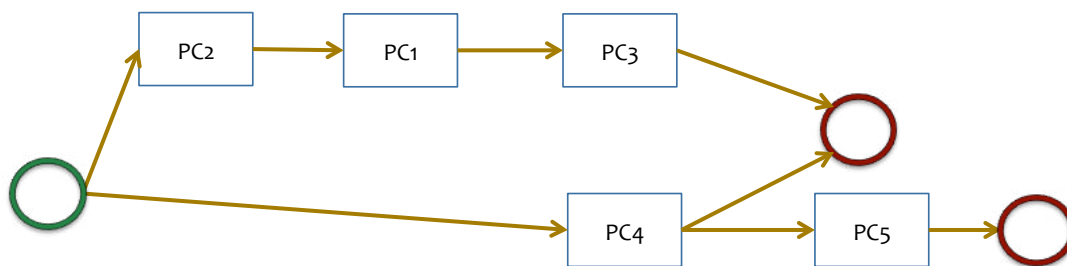


Figure 4.6 – Collaborative process state after start event and end events generation step of the construction algorithm.

**Fourth step : gateways generation** In order to obtain an acceptable BPMN model of the process skeleton, one last thing remains: creating the appropriate gateways. As explained, due to the context of this PhD thesis, the only gateways generated are parallel gateways. This step can be explained as follows:

1. Find the tasks that have several direct successors and for each of them, create a parallel gateways that takes this task as an input and its successors as output.
2. Find the tasks that have several direct predecessors and for each of them, create a parallel gateways that takes this task as an output and its predecessors as input.

Within the illustrative case, one can see in Figure 4.7 that three parallel gateways were generated: for example, one directly parallelizes “PC2” and “PC4” that both succeed to the start event. Nevertheless, a last human “cleaning” step is required: for instance, in Figure 4.7, there are two end events, and one of them is useless because when “PC3” is finished, “PC5” should also finish to end the process. Here, “PC5” can directly follow “PC4” and the first gateway could be closed after “PC5” by reuniting “PC3” and “PC5” before ending the process. In this case, this cleaning is due to the fact that there is a “longer” path in parallel of the one that fulfill the collaborative objective’s domains.

#### 4.5. Exploitation of the collaborative ontologies by an Ant Colony Optimization

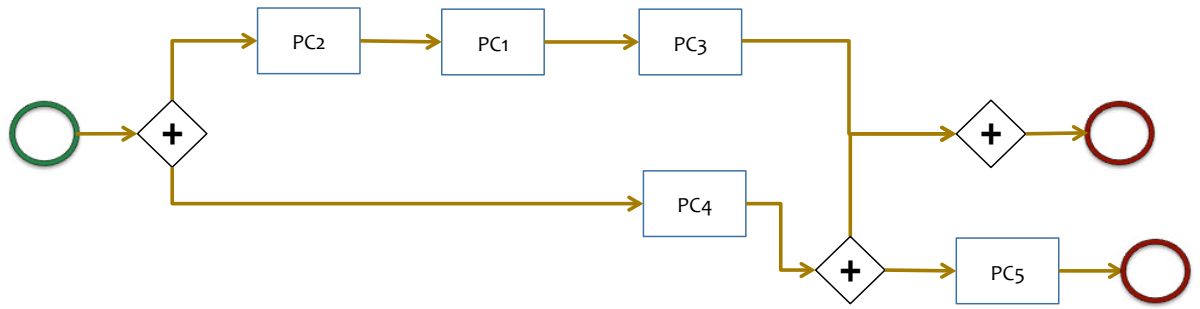


Figure 4.7 – Collaborative process state after parallel gateways generation step of the construction algorithm.

#### Evaluation

Now that the process has been built, and consequently fits the functional needs of the broker, it must now be evaluated according to the non-functional objectives  $P = p_1, \dots, p_n$  expressed and weighted by  $W = w_1, \dots, w_n$  in the Objective Modeler, and associated with *objective* the objective of the collaboration.

The method applied here is synthesized by Berrah et al. [253]. The expression of the performance of a system can be expressed in two basic ways, directly when the performance can be defined through a single expression and indirectly when the performance is the combination of several elementary expressions and especially in the case if these expressions do not have the same dimensions. The indirect expression of the global performance of a system is concretely applied by Cliville et al. [254], for instance.

Here the variable *process* represents the deduced process in the Construction step. The performances of *process* are evaluated according to the  $n$  non-functional dimensions and are stored in the vector  $v = v_1, \dots, v_n$ . Then, these scores are normalized according to their corresponding non-functional objective and are calculated as follows:  $s = \frac{v_1}{p_1}, \dots, \frac{v_n}{p_n}$ . Finally all these unitary elementary performances are aggregated according to the corresponding weights and the final global score is  $S_{process} = \sum_{i=1}^n (s_i \cdot p_i)$ .

This approach corresponds to Algorithm 5.

#### Improved Exploration

A first Exploration algorithm is presented in the Section 4.5, which can be improved. In order to improve the readability for the readers, the first “functional” algorithm was presented, which is now improved. The weakness of the first algorithm is indeed due to the structure of CO. To understand this fact, the hypothesis of total random choices (*i.e.* independant of the Equation 4.5) must be made. In this case, because of the decomposition of *Objectives* into *SubObjectives* (cf. Fig. 2), the probability for an ant is higher to choose a *Capability* of a high-level *Objective* than

**Algorithm 5** OpenPaaS's ACO Evaluation algorithm.

```

1: procedure EVALUATION( $process, P, W$ )
2:   Initialize  $S_{process} = 0$ 
3:    $n$  the size of  $P$ 
4:   Initialize  $v$  and  $s$ 
5:   for  $i = 1$  to  $n$  do
6:      $v_i \leftarrow$  Performance of  $process$  according to  $P_i$ 
7:      $s_i \leftarrow \frac{v_i}{p_i}$ 
8:      $S_{process} \leftarrow S_{process} + (s_i \cdot p_i)$ 
9:   end for
10:  return  $S_{process}$ 
11: end procedure

```

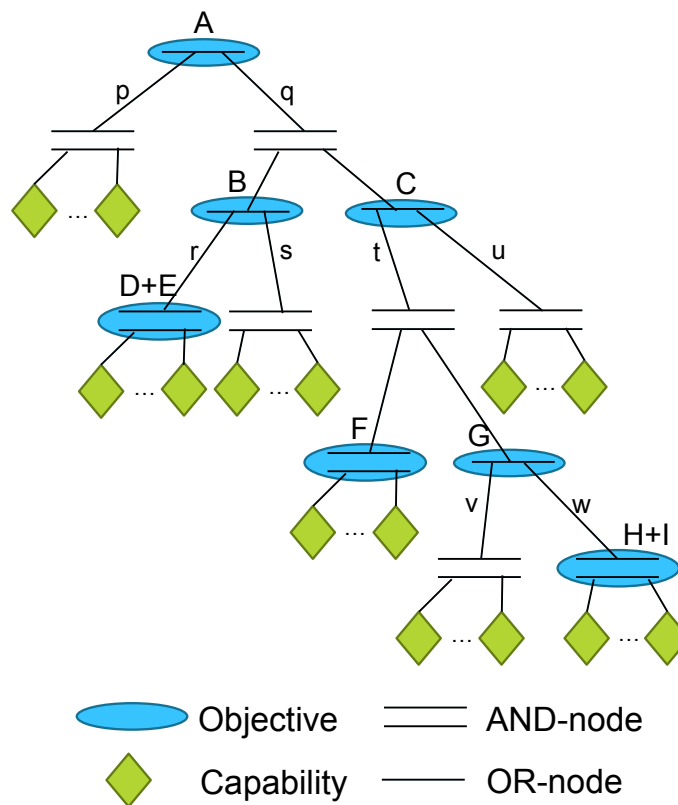


Figure 4.8 – Weighted CO's logical graph.

of a low-level *SubObjective*. For instance, on the Fig. 4.8 the probability for an ant to choose a *Capability* of A is  $p$ , and the probability to choose a *Capability* of (H+I) is  $w \cdot t \cdot q$ . In the simple algorithm of Fig. 2, the weights  $p, \dots, w$  are all equals to 0,5. Thus the comparative chance to choose a *Capability* of A is 0,5 against 0,125 for (H+I).

We propose to balance the weights of all the arcs established from OR-nodes (*i.e.* between

#### 4.5. Exploitation of the collaborative ontologies by an Ant Colony Optimization

*Objectives* and their *Capabilities* or their *SubObjectives*), except if the *Objective* is at the lowest-level decomposition in order to ensure a better equi-probability. As for each OR-node, there are always two arcs possible: (i) the AND-node of a decomposition into *Capabilities* or (ii) the AND-node of a decomposition into *SubObjectives*, then, for any OR-node, exactly two children arcs exist. The probability to take one or the other is 1, which means that the two children arcs are complementary (for instance,  $p + q = 1$ ).

As it comes to the rest of the equations to state, the approach begins with the lowest-level of *Objective* i.e. (H+I). The closest parent OR-node is G, from which the two children can be similarly chosen:  $v + w = 1$ . Then, in order to ensure the equi-probability, the two longest paths starting from each of the children OR-node arcs should be also similarly chosen. Here, the second closest parent OR-node is C. Each of the children longest arcs of C should be similarly chosen, which means that  $u = t \cdot v$ . In the same way, for the A OR-node, it can be stated that  $p = q \cdot t \cdot v$ . Finally, for the B OR-node, only two single-level arcs exist, therefore  $r = s$

This leads to the following equation system:

$$\left\{ \begin{array}{l} p + q = 1 \\ r + s = 1 \\ t + u = 1 \\ v + w = 1 \\ r = s \\ v = w \\ u = t \cdot v \\ p = q \cdot t \cdot v \end{array} \right. \quad (4.8)$$

The result, for this example is:

$$\left\{ \begin{array}{l} p = 1/4 \\ q = 3/4 \\ r = 1/2 \\ s = 1/2 \\ t = 2/3 \\ u = 1/3 \\ v = 1/2 \\ w = 1/2 \end{array} \right. \quad (4.9)$$

Note that, for instance, there is twice more chance to choose the F decomposition ( $q \cdot t = 0,5$ ) than the (H+I) ( $q \cdot t \cdot v = 0,25$ ). Nevertheless, this phenomena is quite normal since the F node is necessarily visited if the ant finishes with one or the other children connections of G. The F node is indeed part of two potential solutions: it has consequently twice more chance to be used.

This approach has been generally applied to the whole ECO. Assuming that the *rank* of an

## Chapter 4. Knowledge Exploitation: Collaborative Business Processes Deduction

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*Objective* determines its maximum number of decomposition (for instance,  $rank_G = 1$  since it can only be decomposed one time into *SubObjectives*,  $rank_C = 2$  since it can be at most decomposed two times into *subObjectives* and  $rank_B = 1$ ), then it is easily verifiable that:

- The probability coefficient of an arc to be chosen, between an *Objective* OR-node and its *SubObjectives* decomposition is  $coefficient_{arc} = \frac{rank_{Objective}}{1+rank_{Objective}}$ .
- The probability of an arc to be chosen, between an *Objective* OR-node and its *Capabilities* decomposition is  $coefficient_{arc} = \frac{1}{1+rank_{Objective}}$ .

Hence, as these coefficients are independent of the *Objective* chosen by the broker for the collaboration, ECO has been initially updated and each arc between two *Objective* OR-node now embeds its corresponding  $coefficient_{arc}$ .

Note that the specific choice among the children paths explained in the Equation 4.5 was momentarily forgotten. Now that the equi-probability has been resolved, it can be re-introduced. In order to balance the choices of the arcs all along the Exploration algorithm, it has been decided to apply these equi-probability coefficients directly to the amount of pheromone of the corresponding arc. Thus the new pheromone amount of a arc  $new\tau_{arc}$  becomes  $new\tau_{arc} = \tau_{arc} \cdot coefficient_{arc}$ , with  $\tau_{arc}$  the “basic” amount of pheromone and  $coefficient_{arc}$  the equi-probability coefficient of the *arc*, in Equation 4.5. However, in order to be efficient, this coefficient should be applied only on this Equation 4.5. The rest of the algorithms must remain unchanged, so that the pheromone can naturally evolve, otherwise, the current equi-probability method would become wrong.

## 4.6 Performances

In order to evaluate the performances of this ACO, it has been decided to assess the global score all along the iterations (*i.e.* ants cycles). For this purpose, different scenarios were set up by varying some of the parameters. First, the four chosen scenarios are described, and then the performance of the ACO on each of them are detailed.

### 4.6.1 Test scenarios

The scenarios have been chosen so that the behavior of the ants could be assessed, depending on two main parameters: the number of decomposition of *Objectives* into *SubObjectives*, which will be called *nbObjLevels* and the number of *PartnerCapabilities* available for each *Capability* of ECO, which corresponding variable is *nbPartnerCap*. The number of *Capabilities* per *Objective* has been set to 2, and the number of *SubObjectives* per *Objective* is also 2.

Hence, four ECOs have been generated along these parameters:

- ECO#1:  $nbObjLevels = 2$  and  $nbPartnerCap = 10$ .
- ECO#2:  $nbObjLevels = 2$  and  $nbPartnerCap = 20$ .
- ECO#3:  $nbObjLevels = 3$  and  $nbPartnerCap = 10$ .
- ECO#4:  $nbObjLevels = 3$  and  $nbPartnerCap = 20$ .

As a non-functional *Objective*, the top-level *Objective* of each ECO was always chosen - which is consistent with the choice of  $nbObjLevels$ . As it comes to the non-functional objectives, they depend on two non-functional criteria, which are the *global cost* and the *global time of delivery* of the solution. Both objective values have been selected so that they could not be reached, in order to evaluate the convergence of the ACO, with a weight of 0,8 for the cost and 0,2 for the time.

Hence, the cost *cost* and the time of delivery *time* of each *PartnerCapabilities* of the ECOs were randomly generated according to the level of the *Objective* their corresponding *Capability* fulfills, which is called here *partnerCapLevel* (otherwise the best solution would always directly answer the top-level *Objective*, which would go against the equi-probability of the edges):

- If  $partnerCapLevel = 1$  then  $cost \in [40;80]$  and  $time \in [0;20]$
- If  $partnerCapLevel = 2$  then  $cost \in [20;40]$  and  $time \in [0;20]$
- If  $partnerCapLevel = 3$  then  $cost \in [0;20]$  and  $time \in [0;20]$

All the *PartnerCapabilities* have been generated with the same input and output flows, as such, even if the calculation of the global time of delivery of a process corresponds to the maximum time of the *PartnerCapabilities*, the time assessment algorithm is still the same: it has no impact on the evaluation of each candidate solution, but it is quite convenient to generate viable (and consequently assessable) processes.

Eventually, the intrinsic parameters of the ACO were set along the recommendation of the literature [231, 255]:

$$\left\{ \begin{array}{l} numberofcyclesN = 100 \\ numberofantspercycleA = 10 \\ \alpha = 1 \\ \beta = 2 \\ \rho = 0,1 \\ \tau_0 = 0,1 \\ q_0 = 0,7 \end{array} \right.$$

### 4.6.2 Results

The ants' behavior was observed for each of the four ECOs, and, finally, the four graphs in Figure 4.9 were obtained. One can see on these graph that the ACO is rightly converging towards 1, when minimizing the function  $\frac{0,8*cost}{costObjective} + \frac{0,2*time}{timeObjective}$  for the best process found at each iteration.

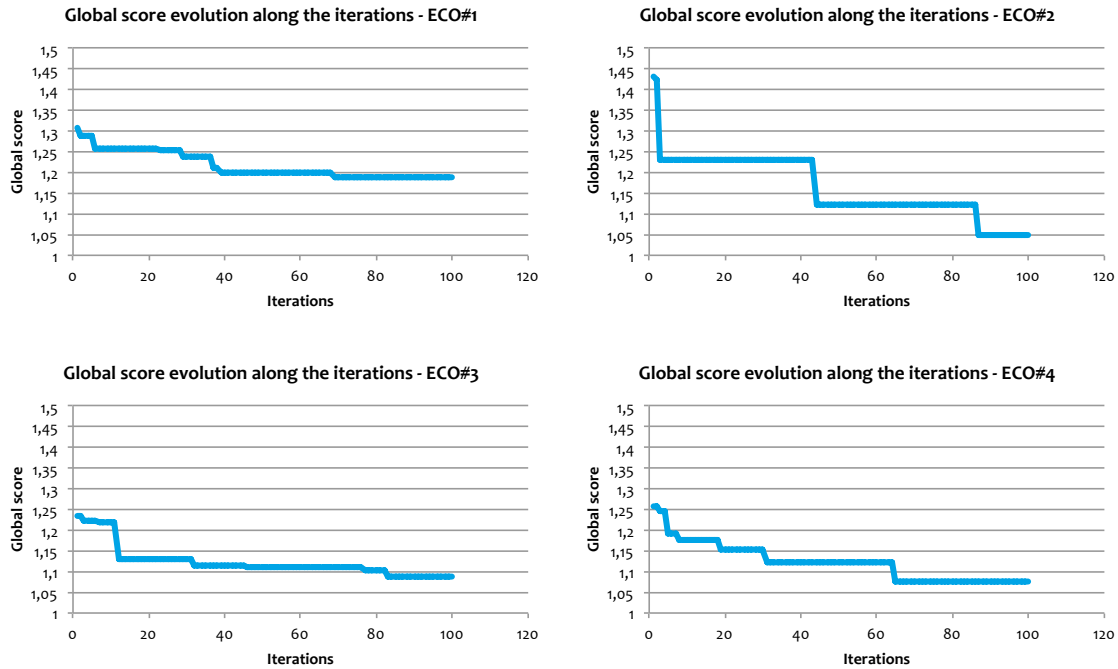


Figure 4.9 – Results of the test scenarios on the four generated ECOs.

As it comes to the time of computing, ECO#1 was processed in 452 seconds, ECO#2 in 767 seconds, ECO#3 in 1835 seconds and ECO#4 in 2216 seconds.

## 4.7 Contributions, discussion and perspectives

### 4.7.1 Contributions

This Chapter proposes a contribution that could be detailed along two axes: a scientific contribution and an applicative contribution.

**The scientific contribution** relies on the utilization of an ACO algorithm to a graph made of AND-nodes and OR-nodes. Due to the CO structure, this specific type of graph makes the application of an ACO more complex than a basic graph. Thus, the behavior of the ants has been adapted in consequence by constraining the paths they can choose at each level of CO.

Besides, such structure leads to unbalanced probabilities for all the edges of the graph to be chosen by ants. An improved exploration algorithm has therefore been implemented.

**The applicative contribution** relies on a new way to exploit a collaborative ontology. Limitations of ontology inferences and queries were highlighted in Part 4.2, however, ontologies are still very powerful tools. First, in the continuation of MISE project and in an easy integration concern, it was chosen to go on working with ontologies. But the main reason is rather the flexibility it brings to the IT system. Effectively, ontologies are a very widespread tools both in academic and industrial worlds. As such, implementing a surrounding intelligence allows the users to bring their own ontologies even with their own inferences rules as long as the knowledge structure described in Chapter 3 is respected. Besides, in comparison with exact methods, this ACO provides limited time response with good quality results. Nevertheless, considering that there are very few works in the literature that also offer to answer collaborative opportunities without knowing either the partners of the collaboration nor a high-level pattern to follow (*i.e.* macro-process), it is quite hard to compare these works with other approaches.

### 4.7.2 Discussions and perspectives

There are several points that could be discussed within this ACO algorithm to exploit the collaborative ontologies. Some of them lead to further ideas that could improve this DSS.

#### Improvement of the construction algorithm

The construction algorithm in Part 4.5 is somehow time-consuming because it builds the process before knowing if it is viable or not - because of input and output matching. As such, there is a non-negligible probability for each *pCapaSet* not to lead to any candidate solutions. However, it is hard to know if the process will be viable before trying to build it. For this reason, and for this step not being a loss of time and resources, it could be interesting to exploit the “non-viable” process. Thus, a reparation algorithm would allow to discard the *PartnerCapabilities* that do not fit into the process and choose concurrent ones that matches the right input and output.

Besides, using only *BusinessDomains*, even if they are quite detailed in BFO, seems not always realistic to describe the flows of the *PartnerCapabilitiesOne*. Thus, it could be interesting to associate a name to each flow. But consequently, it could become hard to find viable processes that respect an exact syntactic matching between the input name of a *PartnerCapability* (*i.e.* an activity of the process here) and the output name of its predecessor. In fact, this aspect has deliberately not been considered since the works of Tiexin Wang [200] (cf. the perspectives of Chapter 3) provide such semantic reconciliation: it needs now to be integrated.



### ACO parameters study and refinement

Since the broker chooses an *Objective* of collaboration in CO, this *Objective* could be a high-level or a low-level one. This means that, depending on the *Objective*, the part of CO exploited by the ACO varies and includes more or less decomposition levels. Thus, the parameters of the ACO, particularly the number of ants per cycle and the number of cycles, could be studied according to the complexity of the part of CO studied. In such a way, the parameters could be dynamically chosen for each opportunity so that the final solution is good enough and the time and resources consumed to find it are reasonable. Besides, such study would also allow to adapt the parameters whatever the ontologies directly brought by users and not only the provided CO.

## 4.8 Conclusion

As a conclusion, this Chapter presents in detail an ACO that has been adopted to exploit the ECO. Over the broad scope of metaheuristics, the ACO was chosen because of their ability to deal with acyclic directed graph such as ECO. Hence, ECO was transformed into a AND/OR graph corresponding to the *Objectives* and their decomposition into complementary *Capabilities* or into complementary *SubObjectives*. The ants of the ACO can therefore travel all along the edges and replicate if arriving to a AND node, or choosing one of the path if arriving to a OR node.

This approach shows good results, by converging fastly enough within 100 cycles of ants. Besides, the time of computing is quite fair compared to the time it actually would take when assessing all the candidate solutions. As a result, this ACO allows to offer the users a good manner to set up their collaboration, since it brings as efficient solution to deduce quasi-optimal inter-organizational collaborative processes only from ECO within good computing times.

Now that the whole theory has been explained, and that it has been assessed on “randomly” generated ECOs, it is time to apply this approach to a more practical use-case, so that the readers could better see how the users can really use this decision support system.

The ACO approach and the behavior of the ants have been presented in the proceedings of the Pro-VE 2014 Conference [202].

## 4.9 Résumé en français

Alors que le Chapitre 3 visait à représenter et acquérir des connaissances sur les collaborations à supporter, ce chapitre a pour but de développer un système d'aide à la décision basé sur des ontologies, afin d'exploiter ces connaissances pour en déduire des processus collaboratifs quasi-optimaux. Cela nécessite trois éléments: (i) trouver les *Capacités* devant être réalisées afin de remplir les *Objectifs* de la collaboration, (ii) trouver l'ensemble des "meilleurs" partenaires capables de réaliser ces *Capacités* et (iii) ordonner ces *Capacités* afin d'obtenir un processus. Néanmoins, le choix de l'ensemble des partenaires ne peut pas être fait de façon atomique, car, par exemple, le temps de réalisation d'un processus ne peut être évalué qu'une fois tous les partenaires choisis et leurs *Capacités* ordonnées (pour des questions de parallélisation des *Capacités*). Des calculs simples montrent que tester l'ensemble des processus pouvant potentiellement répondre à une opportunité résulte en un problème hautement combinatoire, amenant des temps de traitement irréalistes dans le contexte de ce RSE. Ainsi, les outils habituellement utilisés pour exploiter les ontologies, comme le raisonnement à base de règles logiques (*i.e.* inférences) et les requêtes en langage SPARQL, ne peuvent pas être utilisés directement ici.

Ce chapitre décrit donc l'exploitation d'une ontologie en la considérant comme un graphe de connaissances dont les noeuds représentent les individus de l'ECO résultant du Chapitre 3, et les arcs, les liens entre les différents individus de l'ontologie (*i.e.* lien d'*Objectif* à ses *SousObjectifs* complémentaires, d'*Objectif* à ses *Capacités* à réaliser complémentaires et des *Capacités* aux *Capacités d'organisations* correspondantes). Le graphe obtenu est donc un graphe orienté, acyclique et chacun de ses noeuds peut être assimilé à un noeud ET ou un noeud OU (ex. relation ET entre un *Objectif* et ses *SousObjectifs* complémentaires, relation OU entre une *Capacité* et les *Capacités d'organisations* concurrentes correspondantes). Devant le problème combinatoire posé par l'exploitation de ce graphe, l'approche menée s'est portée sur l'utilisation de métaheuristiques, et plus particulièrement d'un algorithme d'optimisation par colonies de fourmis.

Concrètement, cet algorithme peut être décrit selon trois étapes répétées sur plusieurs cycles, afin d'affiner les solutions trouvées: (i) exploration du graphe, (ii) construction d'une solution candidate et (iii) évaluation de cette solution. Initialement, chaque fourmi du cycle est déposée sur le noeud correspondant à l'*objectif* de la collaboration, et tous les arcs se voient attribuer une quantité de phéromone initiale. La première étape consiste, pour chaque fourmi du cycle, à explorer l'ensemble du graphe dans le respect des contraintes des noeuds de type ET/OU. Chaque arc utilisé par les fourmis est dévalué (*i.e.* diminution de la quantité de phéromone) afin d'éviter une convergence trop rapide des fourmis vers une solution unique (et donc de déversifier les solutions candidates). De plus lorsqu'une fourmi arrive sur un noeud de type ET, elle se réplique, tandis que sur un noeud OU, elle choisit l'un des arcs qui s'offre à elle. Une fois obtenu un ensemble de *Capacités d'organisations*, la deuxième étape de construction, permet de les ordonner en un processus, en réalisant des correspondances entre les flux en entrée et en sortie des *Capacités d'organisations* trouvées. Finalement, l'évaluation ne se fait qu'après avoir vérifié la viabilité du processus candidat obtenu, et consiste à comparer cette solution aux

## Chapter 4. Knowledge Exploitation: Collaborative Business Processes Deduction

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“meilleures” solutions obtenues par les fourmis précédentes. Si le processus candidat évalué est l’un des deux “meilleurs” processus trouvés par l’ensemble des fourmis du cycle, les arcs parcourus pour l’obtenir se voient intensifiés (*i.e.* augmentation de la quantité de phéromone). Le terme “meilleur” fait ici référence à l’évaluation d’une solution candidate vis-à-vis d’objectifs non-fonctionnels déclarés dans le modèle d’opportunité défini dans le Chapitre 3.

Par l’alternance entre diversification à chaque fourmi et intensification des meilleures solutions trouvées à chaque fin de cycle, cet algorithme permet finalement de trouver un processus quasi-optimal, en répondant simultanément aux questions *Quoi?/Qui?/Quand?* évoquées dans l’introduction de cette thèse. Une évaluation des performances sur des ontologies de différentes complexités a montré que l’algorithme présente de bonnes performances tant sur la qualité des solutions obtenues que sur le temps de calcul requis.

L’algorithme d’optimisation par colonies de fourmis détaillé dans ce chapitre amène deux contributions principales: l’adaptation de ce type de métaheuristique à un graphe ET/OU orienté et acyclique nécessite un soin particulier dans le choix des paramètres initiaux du graphe (par exemple le taux de phéromone initiale sur les arcs) mais aussi une nouvelle possibilité pour exploiter des ontologies dans le cas où requêtes et inférences ne se montreraient plus assez efficaces en terme de temps de traitement. En outre, l’intelligence est indépendante de la connaissance stockée dans l’ECO. Ainsi, les utilisateurs pourraient amener leur propres ontologies de collaboration sans changer les étapes d’acquisition des profils et opportunités, ni d’exploitation pour la déduction de processus collaboratifs quasi-optimaux.

# 5 Final Implementation and Illustrative Case

“We are stuck with technology when what we really want is just stuff that works.”

– Douglas Adams, *The Salmon of Doubt*

## 5.1 Introduction

In the previous Chapters, the theoretical solution was explained: from the acquisition of users’ needs on functional and non-functional axes, to the response to these needs based on the exploitation of the knowledge contained in ECO, with an ACO algorithm. Up to here, the acquisition and the exploitation of the collaborative knowledge can remain somewhat abstract. Hence, this Chapter aims at bringing a concrete point of view of the system through an illustrative case. Besides, as part of the OpenPaaS project, the whole system was implemented as user interfaces. Section 5.2 details the choices that have been made for developing such collaborative platform, from the IT technologies used, to the types of user interfaces offered. Then Section 5.3 gives a concrete illustrative case by simulating the interactions of the users with the system in a specific context.

## 5.2 Implementation

### 5.2.1 Functional architecture

The functional architecture of the implemented software actually fits exactly the way the users interact with it. Those interactions are of three types: either to (i) define a profile, (ii) bring a new collaborative opportunity or (iii) visualize and optionally adapt the final collaborative process.

## Chapter 5. Final Implementation and Illustrative Case

Following the MDA approach as mentioned in Chapter 3, the implementation has been made as modelers *i.e.* user-friendly interfaces that allow users to easily use it.

Figure 5.1 was already used in Chapter 1 in order to introduce the whole articulation of this PhD thesis. Actually, the logic followed by the IT system is the same. First, as a front door, the users model their profile via a Profile Modeler. Then a broker propose a new collaborative opportunity through the Objectives Modeler. Then, backyard, once the knowledge and the needs are acquired from these two models, the ACO algorithm is able to exploit both collaborative ontologies (*i.e.* CO and BFO, also mentioned as ECO), which enables to find a quasi-optimal set of organizations' capabilities and order them into an inter-organizational business process. Back to the front door, a third modeler the Collaborative Business Process Modeler allows the broker to visualize the final deduced process and optionally to adapt it to special needs.

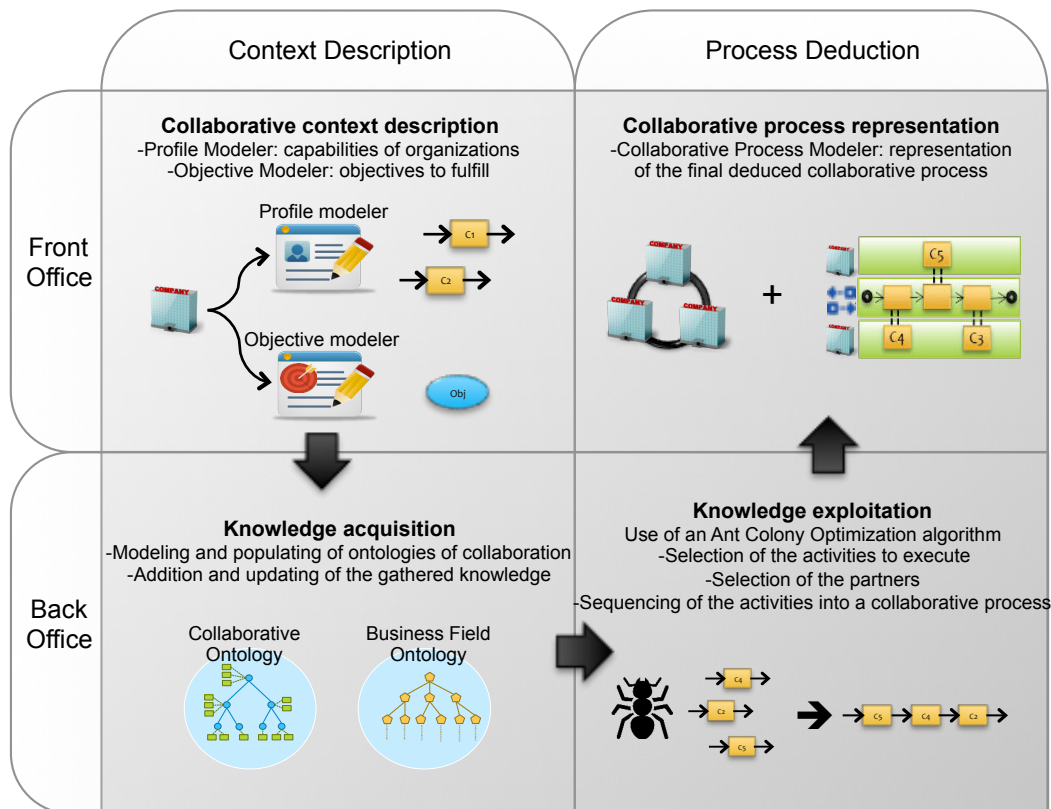


Figure 5.1 – Functional architecture.

As part of the OpenPaaS project, these three modelers have been plugged on the ESN implemented by the whole consortium, and which brings the users other collaborative tools rather oriented towards coordination needs (*i.e.* shared calendar, instant messaging...). Figure 5.2 shows that on the one hand, the three modelers rely on the collaborative ontologies CO and BFO, and are called as web services from the ESN, at each step.

The three further parts aims at bringing an overview on the tools developed in each of these

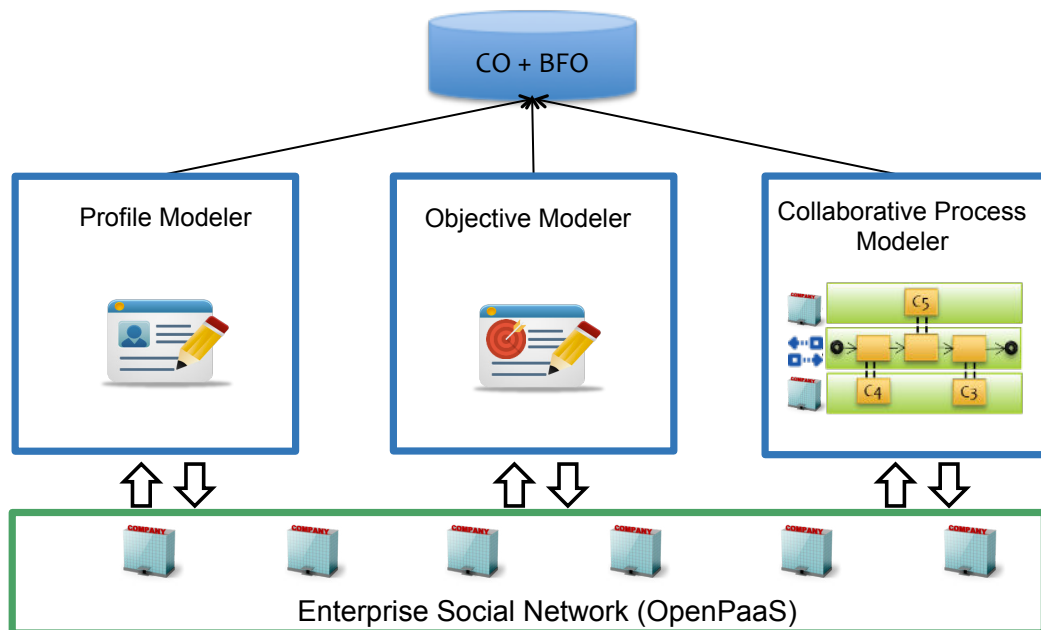


Figure 5.2 – Modelers overview.

modelers.

### Profile modeler

Figure 5.3 presents the different tools implemented within the Profile Modeler:

- The Palette enables to model the different concepts available. As stated in Chapter 3, for the Profile Modeler, these concepts correspond to (i) the organizations' capability (*i.e.* PartnerCapability in the metamodel presented in Chapter 3), (ii) the flows input and output and (iii) the relationships HasInput and HasOutput to link the capability with its flows.
- The File menu allows to manage the model file. Basically, it can be stored in the browser cache, or exported to the client workstation. A model that has been previously exported can also be imported. The button deploy allows to deploy the model in the server.
- The Action menu has a single button "populate ontology", which aims at acquiring the knowledge contained in the model and link it with the backyard ECO. Typically, this is the final button of the profile description step.

Beside these menus, shortcuts can directly be used to create the model, within the canvas. Figure 5.3 shows such basic model with a capability surrounded by its flows.

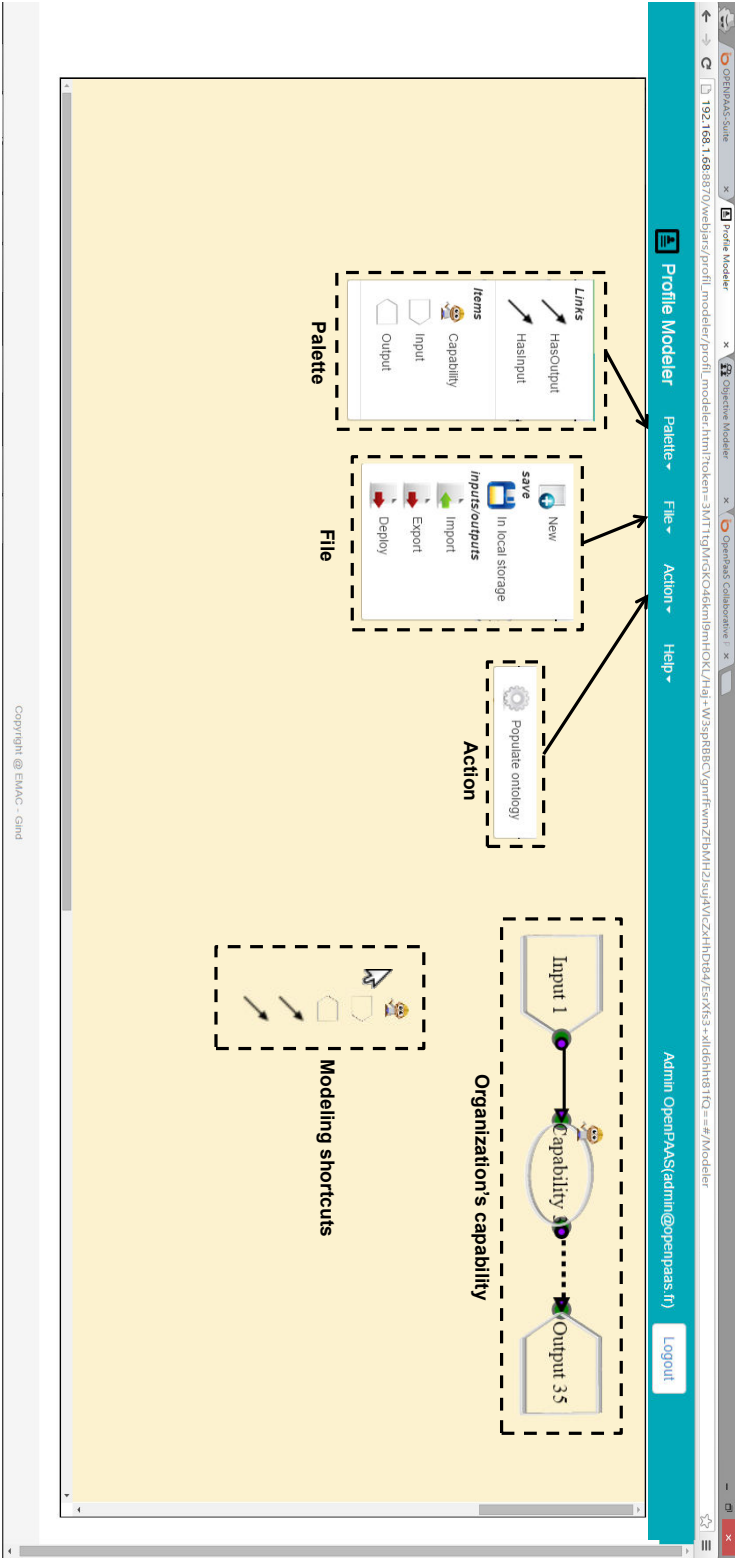


Figure 5.3 – Profile Modeller, modeling of a capability.

These links between the model and the CO and BFO are achieved by double-clicking on each instance. Then a box opens with all the possible details.

### **Objective modeler**

Figure 5.4 presents the different tools implemented within the Profile Modeler:

- The Palette enables to model the different concepts available. As stated in Chapter 3, for the Profile Modeler, these concepts correspond (i) the organizations' objective of collaboration, (ii) the business domains concerned by this objective and (iii) the relationship HasDomain that links the objective with its domain(s).
- The File menu is the same as for the Profile Modeler, except that there is no "deploy" button: the objectives are not stored in the server. These are one-shot objectives that are directly processed.
- The Action menu has a single button "deduce process", which goal is to call the ACO algorithm, and give it the objective model as an input.

Beside these menus, shortcuts can directly be used to create the model, within the canvas. Figure 5.4 shows such basic model with an objective and two linked business domains.

As in the Profile Modeler, when double-clicking on the instances they can be detailed.

### **Collaborative process modeler**

The Collaborative Process Modeler is basically a BPMN process modeler. Hence, the only menu that changes from the other modelers is the Palette, which contains all graphical BPMN elements classified as events, gateways, tasks, pools and flows. This modeler aims at offering a visualization of the final deduced collaborative process, but also allows the broker to adapt this deduced process if did not fit entirely exactly his/her expectations.

Let's now see these three modelers in action all along an illustrative case.



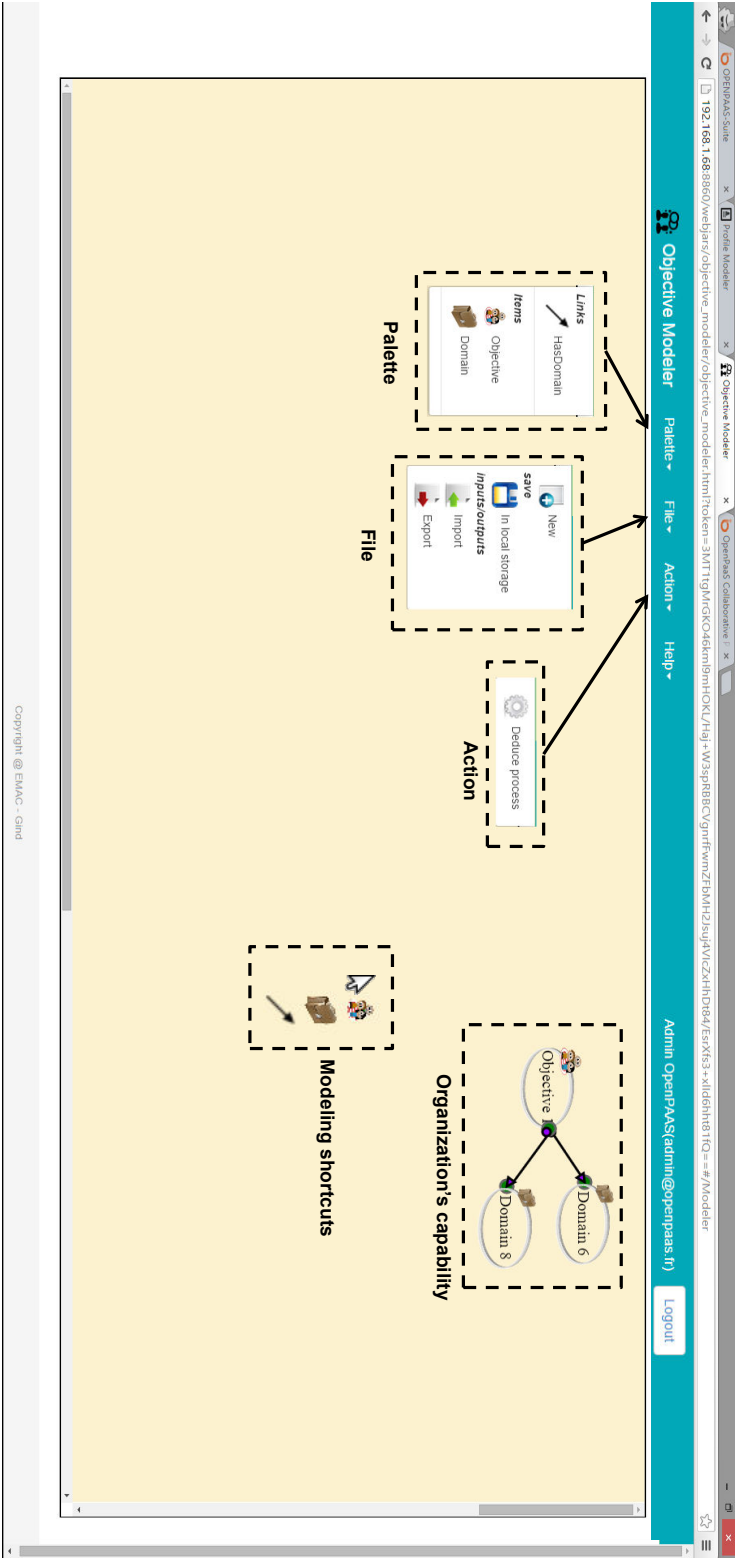


Figure 5.4 – Objective Modeler, modeling of an objective.

### 5.2.2 Technological choices

The development of this system has gone through two phases the front door modelers, and the background algorithms:

- Modelers: the modelers have actually been set up based on a generic modeler that has been developed within the Industrial Engineering Center at Mines Albi. This generic modeler can be adapted, by providing specific *xml* files that embeds the meta-model of the modeler. This meta-model specifies the Palette of the modeler but also the boxes open by double-clicking on the concepts drawn in the canvas.
- Background algorithms: they are called by clicking on the menu buttons. For this PhD thesis and the project OpenPaaS, three buttons have been specifically developed: (i) the “deploy” button to save the model file on the OpenPaaS server, (ii) the “populate ontology” button that takes the model as an input, and extract its knowledge to add it to the ECO in background and (iii) the “deduce process” button to run the ACO.

Java was used to develop the whole system, including the ACO. Moreover, all the interactions performed with ontologies have been implemented by using the Java API for OWL format, OWL API [171]. Note that the OWL API built-in StructuralReasoner<sup>1</sup> provides methods to implement basic queries, which were sufficient for the ACO algorithm.

## 5.3 Illustrative case and results

### 5.3.1 Presentation of the illustrative case

In this beginning of November, while the weather forecasts announced increasingly cold days for the months to come, John, young entrepreneur and happy owner of a wholesale distribution start-up is shopping in the streets of Albi. He suddenly realizes that Christmas decorations and objects are just about to arrive in shops and malls. This idea making its way, John thinks about those funny Christmas cheap hats and decides that it may become a new business to take in Albi area. The only problem is that those products are expected to be ready for the store shelves at the beginning of December. This means that John can really not afford wasting too much time for the establishment of the Supply Chain: he has to quickly find competitive collaborators that will be able to work with him. Once back home, he discovers the OpenPaaS platform and decides to create a profile for his business, and see if it could help him set up this new collaboration.

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<sup>1</sup>Site web page: <http://owlapi.sourceforge.net/javadoc/org/semanticweb/owlapi/reasoner/structural/StructuralReasoner.html>

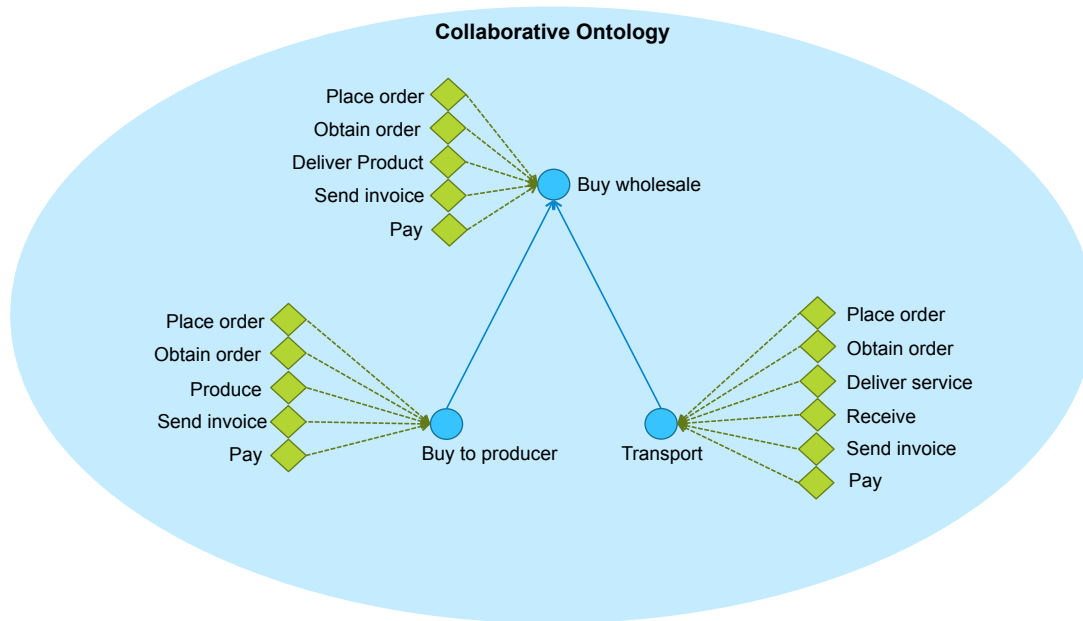


Figure 5.5 – Adapted CO for the use-case.

### 5.3.2 Collaborative Ontology for the illustrative case

For this specific illustrative case, a specific CO has been developed based on the MIT Process Handbook [71]. This CO is limited to two levels: the top-level objective is “Buy wholesale”, which can be decomposed into two complementary sub-objectives “Buy to producer” and “Transport”. Figure 5.5 illustrates this adapted CO. For each objective of the ontology, the capabilities to execute to fulfill it are given.

In fact, the top-level consists in a turnkey solution, while the decomposition brings a bit more complexity by decomposing the solution into a “composite” one. Note that some capabilities should be used to fulfill several objectives (e.g. “place order”), which is rather intuitive in this case. However for readability reasons, they have been repeated for each corresponding objectives.

It is crucial to note the convenience of this decomposition of objectives into sub-objectives: it indeed allows to fit several granularity levels, depending on the needs of the users. Hence, with this CO, the users can either choose “buy wholesale” for which they will almost have nothing to deal with; or they can choose “buy to producer”, in which case they will have to arrange the transportation themselves.

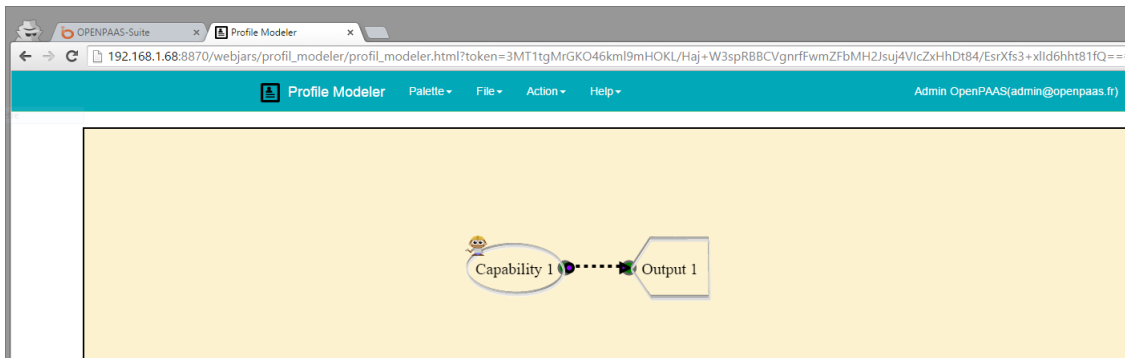


Figure 5.6 – Basic capability modeling.

### 5.3.3 Acquisition of the collaborative knowledge via human interactions

#### Profiles of organizations

The first step John has to fulfill is creating a new profile for his start-up on the Profile Modeler. For this purpose, he has to follow the profile modeling described in Chapter 3. He needs to describe his capabilities and link them to those contained in CO and precise their flows by linking them to BFO. The first capability that John creates is “Place order”.

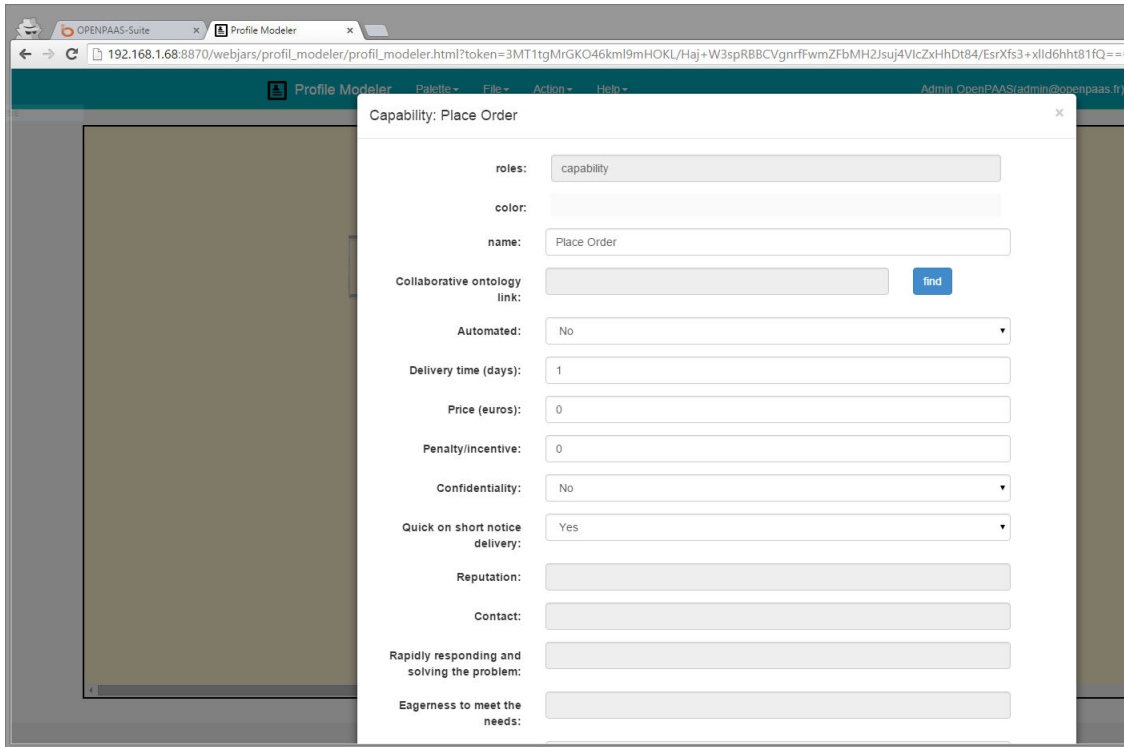
As a start, he creates a basic model with a capability and its expected flows: a single output, as described in Figure 5.6.

By double-clicking on the “Capability 1”, John can change the details of the capability as in Figure 5.7: its name, its associated non-functional criteria, and link it to the CO by clicking on the “find” box. Here, John has no access to the non-functional criteria that should be informed by further partners (*e.g.* reputation), but he details the following:

- Delivery time (days): 1 day.
- Price (euros): 0 euro.
- Penalty/incentive: 0.
- Confidentiality: no.
- Quick on short notice delivery: yes.

Note that an “automated” box is provided: it aims at defining if the capability is a human-task or basically a web service. If it is a web service: the capability could be linked with a SaaS deployed on the PaaS (either provided by OpenPaaS collaborative services -*e.g.* an automated form for administrative services- or directly by the organization). Here, John defines the capability as a human task.

## Chapter 5. Final Implementation and Illustrative Case



The screenshot shows a web browser window with the URL `192.168.1.68:8870/webjars/profil_modeler/profil_modeler.html?token=3MT1tgMrGKO46kml9mHOKL/Haj+W3spRBBcVgnrfwmZFbMH2Jsu4VlcZxHdTB4/Esrxfs3+xlld6hht81fQ==#`. The browser title is "Profile Modeler". The main content area displays a modal window titled "Capability: Place Order". The form contains the following fields:

- roles:
- color:
- name:
- Collaborative ontology link:
- Automated:
- Delivery time (days):
- Price (euros):
- Penalty/incentive:
- Confidentiality:
- Quick on short notice delivery:
- Reputation:
- Contact:
- Rapidly responding and solving the problem:
- Eagerness to meet the needs:

Figure 5.7 – Capability “Place order” description.

Now that the capability has been detailed, it must be linked to the CO by clicking on the “find” button in Figure 5.7. A list of all the capabilities contained in CO arises, with an input field to make a quick search. John searches “Place order” and selects it as in Figure 5.8.

As it comes to describe the flows, the approach is quite the same: John double-clicks on the “Output 1” and details the flow name. With a “find” button, he accesses all the business field contained in BFO, and he can link the output to a business domain. In Figure 5.9, John links the output to “8211 - Combined office administrative service activities”.

When the capability has been properly described, John can populate ECO with the knowledge contained in his capability model. Hence, he clicks on the “Populate ontology” button.

In background, the OWL2 file `co_test.owl` is updated, and a new individual appears with its corresponding data properties. The code presented in Figure 5.10 corresponds to the code updated with “Capability\_1”, which is John new capability.

### 5.3. Illustrative case and results

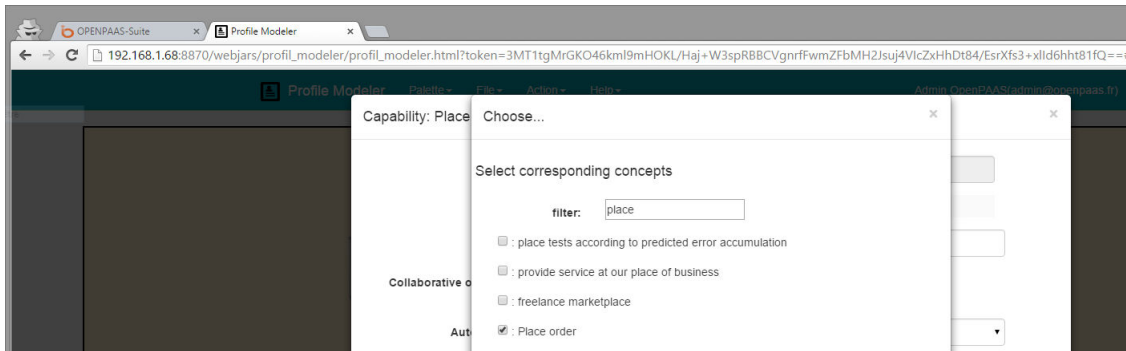


Figure 5.8 – Linking the capability to the CO.

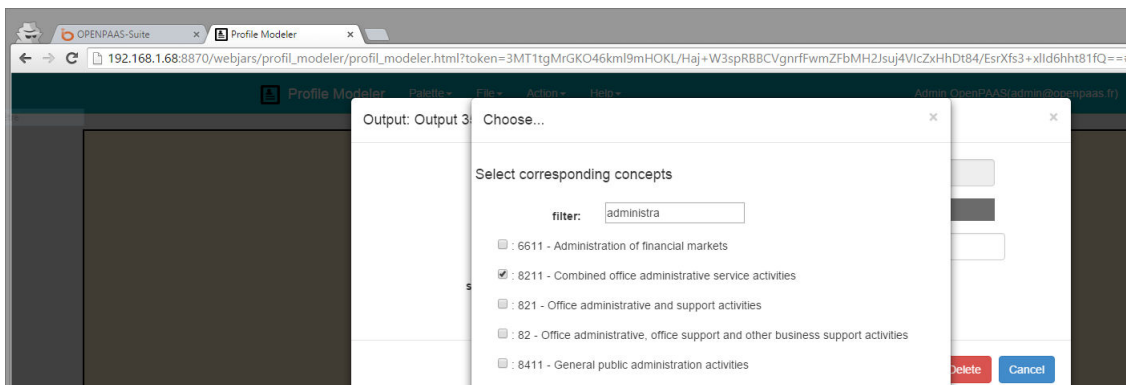


Figure 5.9 – Linking the capability output to the BFO.

<pre> 1216 &lt;ClassAssertion&gt; 1217   &lt;Class IRI="Flow"/&gt; 1218   &lt;NamedIndividual IRI="#Output_33"/&gt; 1219 &lt;/ClassAssertion&gt; 1220 &lt;DataPropertyAssertion&gt; 1221   &lt;DataProperty IRI="#hasDomain"/&gt; 1222   &lt;NamedIndividual IRI="#Output_33"/&gt; 1223   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;8211 - Combined office administrative service 1224   activities&lt;/Literal&gt; 1225 &lt;/DataPropertyAssertion&gt; 1226 1227 &lt;ClassAssertion&gt; 1228   &lt;Class IRI="PartnerCapability"/&gt; 1229   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1230 &lt;/ClassAssertion&gt; 1231 &lt;DataPropertyAssertion&gt; 1232   &lt;DataProperty IRI="#instantiates"/&gt; 1233   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1234   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;Place order&lt;/Literal&gt; 1235 &lt;/DataPropertyAssertion&gt; 1236 1237 &lt;ObjectPropertyAssertion&gt; 1238   &lt;ObjectProperty IRI="#hasFlow"/&gt; 1239   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1240   &lt;NamedIndividual IRI="#Output_33"/&gt; 1241 &lt;/ObjectPropertyAssertion&gt; 1242 1243 &lt;ClassAssertion&gt; 1244   &lt;Class IRI="Partner"/&gt; 1245   &lt;NamedIndividual IRI="#John"/&gt; 1246 &lt;/ClassAssertion&gt; 1247 &lt;ObjectPropertyAssertion&gt; 1248   &lt;ObjectProperty IRI="#provides"/&gt; 1249   &lt;NamedIndividual IRI="#John"/&gt; 1250   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1251 &lt;/ObjectPropertyAssertion&gt; 1252 1253 &lt;DataPropertyAssertion&gt; 1254   &lt;DataProperty IRI="#hasShortNoticeDelivery"/&gt; 1255   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1256   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;Yes&lt;/Literal&gt; 1257 &lt;/DataPropertyAssertion&gt; 1258 &lt;DataPropertyAssertion&gt; 1259   &lt;DataProperty IRI="#hasTotalCost"/&gt; 1260   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1261   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;0&lt;/Literal&gt; 1262 &lt;/DataPropertyAssertion&gt; 1263 &lt;DataPropertyAssertion&gt; 1264   &lt;DataProperty IRI="#isAutomated"/&gt; 1265   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1266   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;No&lt;/Literal&gt; 1267 &lt;/DataPropertyAssertion&gt; 1268 &lt;DataPropertyAssertion&gt; 1269   &lt;DataProperty IRI="#isConfidential"/&gt; 1270   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1271   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;No&lt;/Literal&gt; 1272 &lt;/DataPropertyAssertion&gt; 1273 &lt;DataPropertyAssertion&gt; 1274   &lt;DataProperty IRI="#hasDeliveryLeadTime"/&gt; 1275   &lt;NamedIndividual IRI="#Capability_1"/&gt; 1276   &lt;Literal datatypeIRI="http://www.w3.org/2001/XMLSchema#string"&gt;1&lt;/Literal&gt; 1277 &lt;/DataPropertyAssertion&gt; 1278 </pre>	<p>Create the Flow Details its relative domain</p> <hr style="border-top: 1px dashed #000;"/> <p>Create the PartnerCapability Details its relative CO individual</p> <hr style="border-top: 1px dashed #000;"/> <p>Link PartnerCapability with its Flow</p> <hr style="border-top: 1px dashed #000;"/> <p>Create the Partner Link it to its PartnerCapability</p> <hr style="border-top: 1px dashed #000;"/> <p>Detail the PartnerCapability's non-functional criteria</p>
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Figure 5.10 – Population of ECO updated with the “Populate ontology” button.

#### Objective of the collaboration

After having completed his profile, John decides to create his new collaborative opportunity through the Objective Modeler.

As a start, similarly to the Profile Modeler, John creates a basic model with an objective and three linked business domains as in Figure 5.11.

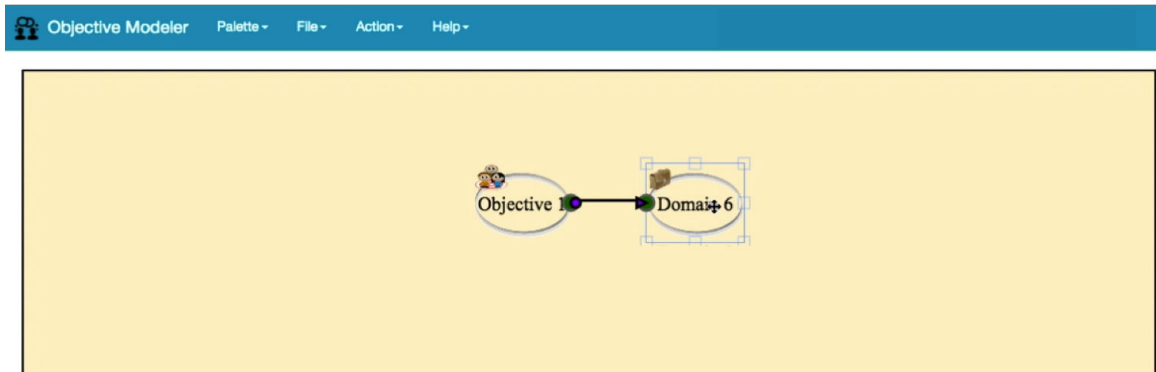


Figure 5.11 – Basic objective modeling.

Then, John details the objective he wants to propose: in Figure 5.12 he summarizes his needs through the non-functional criteria:

- Delivery time (days): 20 days.
- Total cost (euros): 5000 euros.
- Quantity: 15000.
- Quick on short notice delivery: yes.

For the remaining criteria, he has no specific expectations, that is why they are left in their default values (which are the minimal possibilities).

The objective should then be linked to the BFO, by clicking on the “find” button. Here, John selects “Buy wholesale” as it is his objective as in Figure 5.13.

Finally, John needs to precise the flows concerned by his opportunity. In this case, he has one business domain. Figure 5.14 shows that John links it at the intersection of two business domains with the individuals “1410 - Manufacture of wearing apparel, except fur apparel” and “4923 - Freight transport by road” in the BFO, with a physical type of flow, to express that he is interested in buying wearing apparels with a final transportation of the products by road accommodation.



Chapter 5. Final Implementation and Illustrative Case

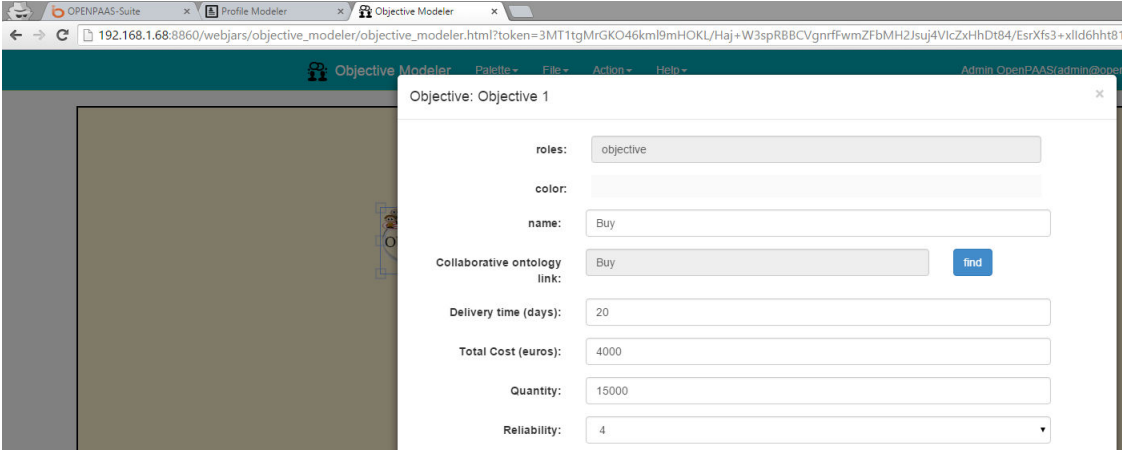


Figure 5.12 – Objective “Buy wholesale” description.

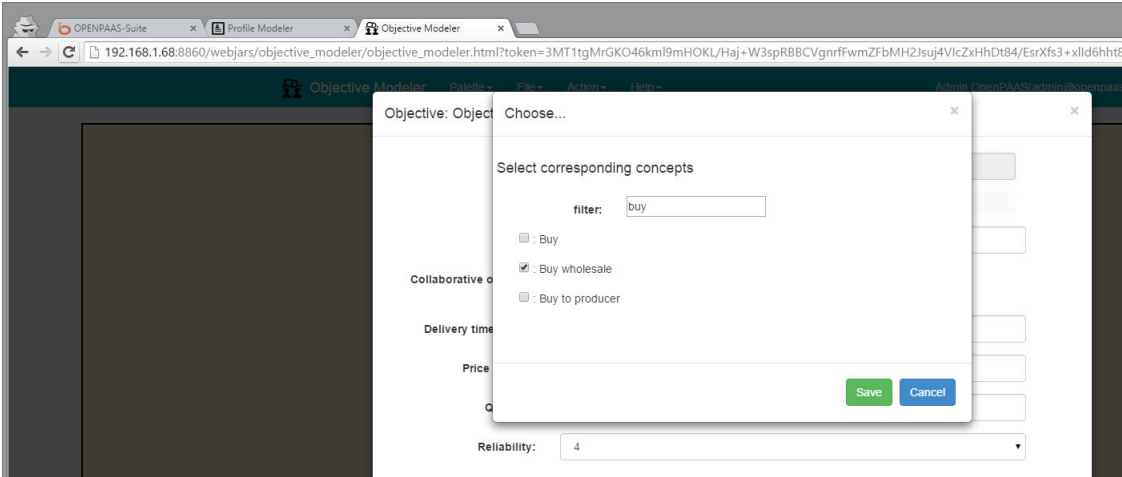


Figure 5.13 – Linking the objective to the CO.

The image shows a software interface window titled "Domain: Domain 6". It contains the following fields and controls:

- roles:** A text input field containing the word "domain".
- color:** An empty text input field.
- name:** A text input field containing "Domain 6".
- Domain ontology link:** A text input field containing "1410 - Manufacture of wearing apparel, except fur apparel,4923" and a blue "find" button to its right.
- type:** A dropdown menu currently displaying "Physical".
- Buttons:** At the bottom right, there are three buttons: a green "Save" button, a red "Delete" button, and a blue "Cancel" button.

Figure 5.14 – Linking an objective business domain to the BFO and apply a type.

### Creation of a set of profiles

For the convenience of this illustrative case a whole set of profiles has been generated. This illustrative case basically deals with three specific rules: wholesalers, manufacturer and carrier. Each of them actually have typical capabilities:

- Wholesalers have the following capabilities: “Obtain order” and “Deliver product” and “Send invoice”.
- Manufacturer have the following capabilities: “Obtain order”, “Produce” and “send invoice”.
- Carriers have the following capabilities: “Obtain order”, “Deliver service” and “send invoice”.

Besides, five different business fields are involved:

- 8211 class: “Combined office administrative service activities”
- 4923 class: “Freight transport by road”
- 4641 class: “Wholesale of textiles, clothing and footwear”
- 1410 class: “Manufacture of wearing apparel, except fur apparel”
- 13 class: “Manufacture of textiles”

Table 5.1 presents the different type of profiles that have been generated, with their corresponding capabilities and their flows.

The ten profiles of each type have been generated, with random values as non-functional criteria.

#### 5.3.4 Results

Once John has created its opportunity by defining the objective “Buy wholesale”, he can click on the button “deduce process”. The ACO algorithm finds a nearly-optimal collaborative process, as explained in Chapter 3. As a result, a *.pco* file is downloaded on the client workstation, which contains the whole deduced process.

In order to visualize this process, this file should be imported into the Collaborative Process Modeler. Figure 5.15 shows this process. One can note that the chosen solution by the ACO consists in the decomposition into “Buy to producer” and “Transport”. The process indeed embeds a manufacturer pool, with the “Produce” activity.

Type of profile	Co's corresponding capability	Input flows	Output flows
Manufacturer	Obtain order	8211 type: informational	Flow1. (8211+1410) type: informational
	Produce	Flow 1. 13 type: physical	Flow1. (1410+8211) type: informational
		Flow 2. (8211+1410) type: informational	Flow2. 1410 type: physical
	Send invoice	(1410+8211) type: informational	(1410+8211) type: informational
Carrier	Obtain order	8211 type: informational	Flow1. 4923 type: informational
	Deliver service	Flow1. 1410 type: physical	Flow2. (4923+8211) type: informational
		Flow2. 4923 type: informational	(1410+4923) type: physical
	Send invoice	(4923+8211) type: informational	(8211+4923) type: informational
Wholesaler	Obtain order	8211 type: informational	(8211 + 4923) type: informational
	Deliver product	Flow1. 1410 type: physical	Flow1. 1410 type: physical
		Flow2. (8211 + 4923) type: informational	Flow2. 4923 type: informational
	Send invoice	(8211 + 4923) type: informational	(8211 + 4641) type: informational

Table 5.1 – Generated types of profiles for the illustrative case.

On the ten manufacturers and ten carriers, Manufacturer8 and Carrier5 have been chosen as partners to work with John, to provide him wholesales of wearing apparels.

### 5.3.5 Highlighted limitations

The concrete explanation of this illustrative case leads to highlight two limitations. First, when choosing partners, the ACO could provide a candidate process in which Manufacturer3 deals with the Produce task, but the other tasks “Send invoice” or “Obtain order” could be achieved by any of the other Manufacturers, which is a problem. In order to solve it, it could be convenient to constraints the behavior of the ants of the ACO, so that each time they select a *PartnerCapability*, they remember the corresponding *Partner*, and when choosing other *PartnerCapability*, they prefer those provided by this partner.

Moreover, one can note that, here, for instance, the task “Deliver service” has, as input and output flows, ’ *BusinessField* “Manufacture of wearing apparel, except fur apparel”, which is not really intuitive: a carrier able to transport wearable apparels could also transport a lot of other products. The reason here is that the *Construction* algorithm does not take into account the *transverse* nature of some *PartnerCapability*. In order to resolve that, a study of the *transverse* nature of each *PartnerCapability* should be made: if a *PartnerCapability* is considered as transverse, then it conveys automatically its input flows’ *BusinessFields*. The question remains how to define the transverse nature of a *PartnerCapatbility*, especially if it depends on the context of the collaboration.

## 5.4 Conclusion

In this Chapter, a use-case was presented, which allows the readers to concretely imagine how to use the implemented DSS. Now that the inter-organizational business process has been deduced as a BPMN 2.0 process, it can be easily orchestrated: each of the activities contained in the MIS Pool is thus going to call the corresponding activities in the Partners’ pools. When situated on parallel sequences after a AND gateways, the activities will be called simultaneously. Many BPMN 2.0 orchestration engines exist, one of the must famous is for example Activiti [256].

Nevertheless, one can note that the whole system relies on the knowledge brought by the users in their profile models. Hardly avoidable at this time, it leads to make the assumption that the collaborative ontologies (*i.e.* CO and BFO) are understandable enough by the users and adapted to their point of view - since they have to link their concepts with CO’s individuals. Already observed by Wenxin Mu in her PhD thesis [220], the lack of freely exploitable collaborative knowledge is still here. This brings back to the discussions of Chapter 3: the integration of a tool for aligning heterogeneous knowledge bases, as the one developed by Tiexin Wang in his PhD thesis becomes crucial for making such system viable.

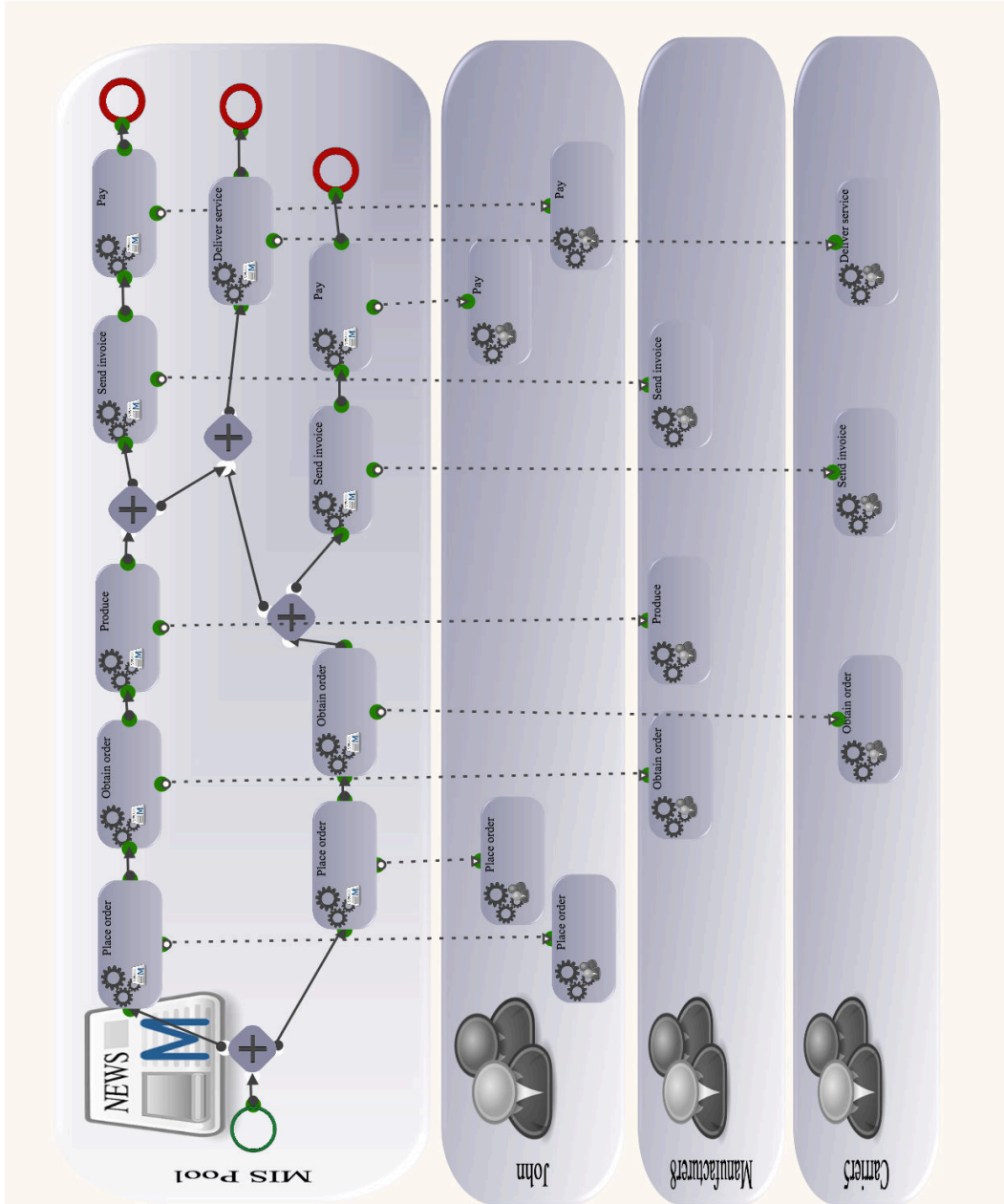


Figure 5.15 – Collaborative process deduced by the ACO within the illustrative case.

### 5.5 Résumé en français

Après avoir détaillé les mécanismes d'exploitation des ontologies de collaboration dans le Chapitre 4, ce chapitre vise à décrire le système qui a été effectivement implémenté, et à amener une illustration concrète du RSE implémenté dans le cadre de cette thèse. Trois éditeurs ont été développés: (i) un éditeur de profil, permettant aux organisations de décrire leurs capacités, (ii) un éditeur d'opportunité, permettant aux utilisateurs de proposer de nouvelles opportunités et (iii) un éditeur de processus collaboratif permettant de visualiser et éditer le processus collaboratif finalement obtenu. Les deux premiers éditeurs sont basés sur le principe décrit lors de l'acquisition des connaissances, dans le Chapitre 3.

Un cas d'illustration permet de montrer, en pratique, les interactions entre les utilisateurs du RSE et les trois éditeurs mis à disposition, dans le cadre d'une opportunité de type chaîne logistique virtuelle "one-shot" d'achat en gros, amenée par un grossiste dont le métier est d'acheter des larges lots et de les revendre à des distributeurs. Après passage de l'algorithme d'optimisation par colonies de fourmis, un processus métier collaboratif inter-organisationnel est déduit et présente les performances non-fonctionnelles désirées par le demandeur.

# Conclusion and Perspectives

“Every real story is a never ending story.”  
– Michael Ende, *The Neverending Story*

In today’s economic context, the ability to create inter-organizational collaborations is a key success factor for any enterprise. These collaborations need to be always faster, but they consist, most of the time, in ephemeral organization networks developed for one-shot opportunities. Such behavior is widely permitted by the recent advances made in computer and management sciences. However, the enthusiasm for inter-organizational collaborations is such that the need of more flexible, fast and efficient solutions is stronger than ever. In this context, this PhD thesis aims at automating the design-time of inter-organizational collaborations by providing an inter-organizational collaborative process as an answer to collaborative opportunities. Based on an Enterprise Social Network, the IT system that has been implemented around the acquisition and the exploitation of collaborative knowledge aims at addressing three issues: (i) which business services should be performed in order to achieve the objectives? (*What?*), (ii) who could provide these business services to obtain the best results (in terms of criteria such as time of completion, or cost)? (*Who?*), (iii) when should each organization execute its business services? (*When?*).

## Main results and contributions of the thesis

After having presented the context of these research works both from Management and Computer science perspectives, a three-time approach was adopted in these PhD research works to address the problematic identified in Chapter 1.

The first step provides a wide scope on the non-functional criteria usually taken into account within partner selection context, and, as such, has been based on a broad literature review within Management and Computer sciences. It has led to the establishment of a three-dimensional framework applied to the specific context of Enterprise Social Networks, but which can also be used for any partners selection context. Moreover, all the non-functional requirements of the resulting framework are associated to their adapted metrics.



## Conclusion and perspectives

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The second step focuses on the development of a knowledge-based system to allow for further deduction of collaborative business process. To this purpose, two ontologies have been structured, implemented and populated. The Collaborative Ontology (CO) focuses on the decomposition of collaborative objectives into sub-objectives and capabilities. The Business Field Ontology (BFO) provides a hierarchy of business domains. The organizations describe their capabilities through profile models, by affecting them at the intersection of both ontologies, and can as well propose a new opportunity. Both capabilities and opportunities descriptions are also extended with the non-functional criteria identified in the first phase. The main contributions of this part rely on the adaptation of a collaborative metamodel to fit the context of an Enterprise Social Network intended for the automation of the design-time of the collaboration. They also build on the mechanisms used by the organizations to describe themselves and their needs by using collaborative ontologies. The strength of these ontologies lies on that they are already populated with huge amount of individuals.

Deducing a “good” (*i.e.* regarding non-functional criteria) collaborative process may not be the same as finding each single best partner for each capability required to reach the collaborative objective (because of time concerns for example). Hence, the usual tools for exploiting ontologies are not sufficient enough, and an Ant Colony Optimization (ACO) algorithm has been implemented and adapted to the specific structure of the CO, to address simultaneously the previous *What? Who? When?* questions. As a result, two contributions are identified: the scientific one relies on the adaptation of an ACO algorithm to a very particular type of structure (which could be defined as an acyclic directed graph), while the applicative contribution consists in providing a new efficient way to exploit ontologies, to resolve combinatorial problems.

## Discussions and perspective of the present work

The research works conducted during this PhD have shown several limitations, which led to think of new high-level perspectives to give. There are often other related works within the MISE project that can provide a part of the answer, and it is thus interesting to confront MISE’s other PhD current research works.

### Short term perspectives

#### Lack of semantic reconciliation

On the one hand, one of the main limitations identified in the second and third phases of this PhD project (*i.e.* knowledge representation, acquisition and exploitation) is the lack of a semantic reconciliation service that would give a better experience to the users. It concerns the partner’s capabilities and opportunities description (*i.e.* when linking them to already existing individuals in the collaborative ontologies), which could be seen as laborious steps.

On the other hand, the difficulty to find freely available knowledge bases to describe inter-

organizational collaborations has been highlighted. The limitations of the chosen knowledge bases (*i.e.* MIT Process Handbook [71] and ISIC Classification [197]) to populate the collaborative ontologies have been also identified, and the ability of the system to work with any CO directly brought by the users would be a significant improvement.

Both can be fulfilled by integrating the works on semantic reconciliation of model and meta-model levels of Tiexin Wang's PhD thesis [200] in the frame of the MISE 3.0 project. This integration constitute one of the main short-term perspectives that will be given to these PhD works.

### **Comparison to other works**

There are not many research works oriented towards the automation of the design-time of inter-organizational collaborations. It has therefore been hard to compare the results of the ACO algorithm in this context. Hence, it is interesting to note that, within the MISE 3.0 project, Loïc Bidoux [257] is currently working on the automation of the design-time of inter-organizational collaboration. The main differences with these works are that Loïc Bidoux's PhD thesis is on the line of crisis management, and priorities are therefore different. Above all, the collaborative process should be deduced quickly even if it needs to be slightly adapted humanly, since time is the most critical dimension in such a context. Moreover, his thesis focuses as well on the resources availability. If the firemen of a specific area are already putting out a fire, then the available firemen of the closest other area should be called. Loïc Bidoux's works are oriented towards a planning algorithm.

As a perspective of both theses, it is planned to compare the response quality and computing time of the two algorithms in similar contexts. The goal is to find which algorithm should be applied, depending on the context and user needs, and thus to obtain a high-level decision support system that would allow to relevantly choose on of the two optimization algorithm, or mix both approaches.

### **Mid-term and long-term perspectives**

The current implemented system could be also extended with several complementary features, as explained in the two further Parts.

### **Automated emergence of organizations' profiles and opportunities**

For the users, establishing their profiles and new opportunities could be seen as a laborious step, because they need to find themselves each corresponding individual in the collaborative ontologies, which is not always convenient.

It is interesting to think of a way to automate the emergence of new organizations' profiles and

## Conclusion and perspectives

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opportunities:

- The emergence of new profiles can be seen as an intelligent extraction of the organizations' data. As an example, Van Der Aalst [258] has introduced the concept of process mining. The goal is, from data-set and machine learning adapted rules, to deduce the processes of an organization. This discipline is now more and more used in the industrial world to compare the effective processes of the organizations, with the theoretical designed processes. Hence, any organization that has deployed such technology is therefore able to automatically generate its internal processes. Each of those processes could then be seen as a capability that the organization is able to provide, and then automatically added to its profiles. In addition, the flows of the capability could also be deduced from the generated processes.
- The emergence of new opportunities can be seen as an intelligent extraction of the organizations' data within specific collaborative contexts (*i.e.* economic context for business opportunities, or even crisis context, in crisis management response). In the frame of her PhD thesis and the MISE project, Anne-Marie Barthe-Delanoë [259] has developed a Complex Event Processing (CEP) that allows, from logic rules, to analyze data flows and to provide an agility service to the whole MISE scheme.

Hence, by comparing an expected model (which has been generated by the automated design-time) and a field model (what is really happening), her research works allow to detect differences, and to consequently dynamically adapt the collaboration, (i) either by calling again the automated design-time, (ii) or by only changing the task of the business processes that are no more appropriate, (iii) or by changing technical services that are no longer appropriate. Hence, it brings three dynamic feedback loops. Imagine now that this field model corresponds to the current economic context. By applying specific rules, a change in the economic context model could then be detected (e.g. detection of a new privileged market). A link could therefore be made with some of the organizations' profiles stored in the Extended Collaborative Ontology of the system (*i.e.* CO extended with the partners' capabilities), and an opportunity could thus be automatically proposed to these profiles.

## Towards a knowledge management tool

More generally, this PhD thesis juggles with the three concepts: *data*, *information* and *knowledge*. Both of these three levels bring a transitory state from the basic field observation (*data* level), or the contextualized *information* to the structured *knowledge*. For example, each of the previously given perspective can be mentioned as a state transition between these three levels: the emergence of new profiles transform gathered data into information about the organization (*i.e.* its capabilities, which become knowledge once linked to the CO); the semantic reconciliation of Tiexin Wang can take two knowledge bases as input and merge them into another knowledge

base, which is a transformation from knowledge to knowledge.

Figure 5.16 does not aim at being exhaustive but rather gives a point of view on how data, information and knowledge can be manipulated, and the transition between the different states could be achieved. This Figure is broken down into the three levels, associated respectively to model designing (from data to information), semantic (from information to knowledge) and exploitation (from knowledge to new generated knowledge). For each of these three steps, some relevant tools are given, that could allow the transition between the different states.

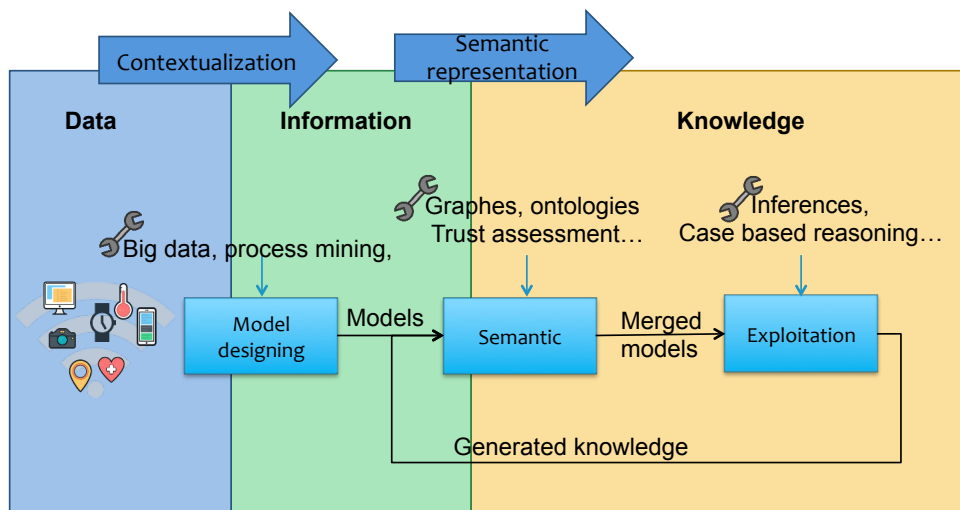


Figure 5.16 – From data to knowledge through information.

It is interesting to think of a new research program entirely centered around the three terms. A core of this system could be a basic interface to manipulate knowledge. This core could be extended on three research/development axes that are: (i) data mining and its related disciplines (from data to information and knowledge), (ii) knowledge bases alignment and (iii) knowledge exploitation towards various purposes (among others, collaborative process deduction). Technically, this core could be gradually enriched on these three axes, with surrounding plug-ins that would allow achieving specific state transitions across the three data, information and knowledge dimensions.



# Conclusion et Perspectives

Dans le contexte économique actuel, la capacité à créer des collaborations inter-organisationnelles se révèle être un facteur clé de succès pour toute entreprise. Ces collaborations doivent être toujours plus rapides, mais, la plupart du temps, elles consistent aussi en des réseaux d'organisations éphémères développés pour des opportunités uniques (*i.e.* de type *one-shot*). Cependant, l'engouement pour les collaborations inter-organisationnelles est tel que le besoin de solutions plus flexibles, rapides et efficaces est plus grand que jamais. Ainsi, cette thèse vise à automatiser le *design-time* de ces collaborations en déduisant un processus collaboratif inter-organisationnel en réponse à des opportunités de collaboration. Basé sur un Réseau Social d'Entreprises (RSE), ce système d'information, implémenté autour de l'acquisition et de l'exploitation des connaissances sur la collaboration, répond à trois questions: (i) quels sont les services métiers qui devraient être effectués pour réaliser les objectifs de la collaboration (*Quoi?*) (ii) quelles sont les organisations capables de réaliser ces services métier? (*Quoi?*) et quand est-ce que chaque organisation doit réaliser ses services métier? (*Quand?*)

## Principaux résultats et contribution de la thèse

Après avoir présenté le contexte de ces travaux de recherche à la fois d'un point de vue orienté génie industriel et systèmes d'information, une approche en trois étapes a été adoptée dans cette thèse, pour répondre aux problématiques identifiées au Chapitre 1.

Tout d'abord, la première étape a consisté à donner une vision large sur les critères habituellement utilisés pour sélectionner des partenaires, et, en tant que telle, a été basée sur une vaste revue de littérature entre génie industriel et informatique. Cette étude a mené à la création d'un cadre non-fonctionnel à la fois appliqué au contexte des RSEs, mais pouvant aussi être utilisé dans n'importe quel contexte de sélection de partenaires. De plus, tous les critères non-fonctionnels du cadre non-fonctionnel défini sont associés à des métriques qui leur sont adaptées.

Puis, la seconde étape a été centrée sur le développement d'un système à base de connaissances pour permettre une future déduction de processus métier collaboratif. Pour cela, deux ontologies ont été structurées, implémentées et peuplées. La Collaborative Ontology (CO) se concentre sur la décomposition d'objectifs de collaboration en sous-objectifs ou en capacités. La Business Field

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Ontology (BFO), quant à elle, propose une hiérarchie de domaines métiers. Ainsi, les organisations décrivent leurs capacités grâce à des modèles de profil, en les affectant à l'intersection des deux ontologies. De la même manière, elles peuvent aussi définir de nouvelles opportunités. Les capacités et les opportunités sont aussi définies selon les critères non-fonctionnels définis en Chapitre 2. Les principales contributions de cette partie résident dans l'adaptation d'un méta-modèle de collaboration au contexte spécifique d'un RSE dont le but est d'automatiser le *le design-time* des collaborations. Elles s'appuient, en outre, sur les mécanismes utilisés par les organisations pour décrire leurs profils et leurs besoins, en utilisant des ontologies de collaboration. La force de ces ontologies repose sur le fait qu'elles sont déjà peuplées avec de nombreuses instances.

Déduire un "bon" (i.e. selon des critères non-fonctionnels) processus collaboratif n'est pas forcément la même chose que trouver tous les meilleurs partenaires un-à-un pour chaque capacité requise dans la réalisation d'un objectif de collaboration (à cause de l'évaluation du temps de réalisation d'un processus par exemple). Ainsi, les outils habituellement utilisés pour exploiter les ontologies ne suffisent plus. Un algorithme par colonies de fourmis a donc été adapté à la structure de l'ontologie CO et implémenté: il permet de répondre simultanément aux trois questions *Quoi?/Qui?/Quand?*. Il en résulte deux contributions: une scientifique qui s'appuie sur l'adaptation d'un algorithme par colonies de fourmis à la structure très particulière de l'ontologie CO (pouvant être définie comme un graph orienté acyclique), alors qu'une deuxième, applicative, consiste en l'obtention d'un nouveau moyen efficace pour exploiter des ontologies en réponse à des problèmes à forte combinatoire.

## Discussions et perspectives des travaux actuels

Les travaux de recherche conduits durant cette thèse ont montré plusieurs limites, ce qui a amené à penser à des perspectives à plus ou moins longs termes. La plupart de ces perspectives peuvent être conduites dans le cadre du projet interne MISE, dont les différents éléments actuels, une fois intégrés, peuvent amener de nouvelles solutions innovantes ou encore d'intéressantes confrontations dans les démarches mises en oeuvre.

### Perspectives à court terme

#### Le manque d'une réconciliation sémantique

D'une part, une des principales limites mises en avant dans cette thèse, dans les Chapitres 3 et 4 (i.e. représentation, acquisition et exploitation des connaissances) est le manque d'un service de réconciliation sémantique qui permettrait d'offrir une meilleure expérience aux utilisateurs. Cela concerne en particulier la description des capacités et des opportunités (i.e. lors de la création de liens avec les instances déjà existantes dans les ontologies de collaboration) qui peut être perçue comme une étape laborieuse.

D'autre part, la difficulté à trouver des bases de connaissances librement accessibles pour décrire les collaborations inter-organisationnelles a aussi été mise en avant. La limite intrinsèque aux bases de connaissances choisies (i.e. MIT Process Handbook [71] et Classification ISIC [197]) pour peupler les ontologies de collaboration a aussi été identifiée: le fait que le système puisse travailler avec n'importe quelle CO directement fournie par les utilisateurs selon leurs besoins serait une amélioration significative à amener au système.

Ces limites rencontrées pourraient être toutes deux atténuées par l'intégration des travaux de thèse de Tiexin Wang [200] sur la réconciliation sémantique de modèles et de méta-modèles, dans le cadre de MISE 3.0. Cette intégration constitue une des principales perspectives à court terme qui seront données à ces travaux de recherche.

### Comparaison à d'autres travaux

Peu de travaux de recherche sont orientés vers l'automatisation du *design-time* des collaborations inter-organisationnelles. Ainsi, il a été difficile de comparer les résultats offerts par l'algorithme d'optimisation par colonies de fourmis dans ce type de contexte. C'est pourquoi il est intéressant d'évoquer les travaux de thèse réalisés par Loïc Bidoux [257] dans le cadre de MISE 3.0. portant aussi sur l'automatisation du *design-time* des collaborations inter-organisationnelles. La thèse de Loïc Bidoux s'intéresse, elle, à l'établissement de processus collaboratifs dans le cadre de la gestion de crise. Dans un tel contexte, les priorités sont différentes des collaborations inter-entreprises: les processus collaboratifs doivent être déduits rapidement mais cela requiert une légère adaptation finale, réalisée de façon humaine puisque le temps est une dimension cruciale. De plus, la thèse de Loïc Bidoux porte aussi sur la gestion des ressources associées à chaque partenaire: si les pompiers d'une région précise sont tous mobilisés pour éteindre un feu, par exemple, les pompiers de la région la plus proche doivent pouvoir être appelés en remplacement. Les travaux de Loïc Bidoux se sont, pour cela, orientés vers un algorithme de planification.

En tant que perspective des deux thèses, il est prévu de réaliser une étude comparative entre les deux algorithmes (en terme de qualité des solutions finales et de temps de calcul), dans des contextes similaires. L'objectif de cette étude serait de trouver quel algorithme des deux est le plus adapté selon les contextes et les besoins des utilisateurs, et, ainsi, obtenir un système d'aide à la décision qui permettrait de choisir l'un ou l'autre, ou encore utiliser les deux approches ensemble.

### Perspectives à moyen et long termes

Le système actuellement implémenté dans le cadre de cette thèse pourrait aussi être complété avec différents services, comme expliqué ci-dessous.



### Emergence automatisée de profils d'organisations et d'opportunités de collaboration

Pour les utilisateurs, établir leurs profils et décrire leurs opportunités peut être vu comme une étape laborieuse car il doivent eux-mêmes trouver les instances correspondantes dans les ontologies de collaboration, ce qui n'est pas toujours une tâche aisée. Il serait donc intéressant de proposer un moyen d'automatiser l'émergence de nouveaux profils et opportunités:

- L'émergence de nouveaux profils peut être vue comme une extraction pertinente de données provenant des entreprises. Par exemple, Van Der Aalst [258] a introduit le concept de *process mining*. L'objectif de cette nouvelle thématique est, à partir de jeux de données et de règles adaptées d'apprentissage automatique, de déduire des processus internes d'organisations. Le *process mining* est une discipline montante et de plus en plus d'entreprises s'intéressent à de telles solutions pour comparer les processus effectivement réalisés sur le terrain avec les processus *théoriques*. En conséquence, n'importe quelle organisation ayant développé un tel outil serait donc capable de générer automatiquement ses processus internes, et chacun de ces processus pourraient être exploités comme une capacité que l'entreprise pourrait fournir dans son profil. De plus, les flux de ces capacités pourraient aussi être déduits directement des processus générés.
- L'émergence de nouvelles opportunités peut être vue comme l'extraction pertinente de données d'entreprises selon des contextes de collaboration spécifiques (*i.e.* contexte économique pour de nouvelles opportunités économiques ou contexte de crise dans le cas de la gestion de crise). Dans le cadre de sa thèse et du projet MISE 2.0, Anne-Marie Barthe-Delanoë [259] a utilisé un Complex Event Processing (CEP) qui permet, sur la base de règles logiques, d'analyser des flux de données et a implémenté un service d'agilité s'appliquant à l'ensemble du schéma MISE (Figure ??). Ainsi, en comparant un modèle attendu (généralisé par le *design-time*) avec un modèle terrain mis à jour (ce qui arrive effectivement), ses travaux de recherche permettent de détecter les différences et d'adapter dynamiquement la collaboration, (i) soit en appelant à nouveau le service d'automatisation du *design-time*, (ii) soit en changeant uniquement les tâches du processus métiers qui ne sont plus appropriées, (iii) soit en changeant les services techniques qui ne sont plus appropriés. Cela permet donc d'amener trois boucles de rétroactions dynamiques au système. Nous pouvons maintenant imaginer que le modèle terrain correspond au contexte économique actuel. Sur la base de règles logiques, un changement de ce contexte économique pourrait être détecté (par exemple, détection d'un nouveau marché privilégié à exploiter). Un lien pourrait ensuite être fait avec certains profils d'organisations stockés dans l'Extended Collaborative Ontology (ECO) (*i.e.* la CO étendue avec les capacités d'organisations), et, ainsi, une nouvelle opportunité pourrait être proposée à ces profils.

La thèse d'Audrey Fertier, au sein de l'axe Intéropérabilité des Organisations, débutée en septembre 2015, vise d'ailleurs à mettre en place ces deux types d'émergences dans le cadre de la gestion de crise, ou comment connaître et exploiter en temps réel la situation terrain, à partir de

l'analyse de données provenant de capteurs, de réseaux sociaux, ou autres sources pertinentes. Cette thèse évoluera donc entre data mining, big data, et règles métier d'exploitation.

## Vers un outil de gestion de la connaissance

Plus généralement, cette thèse jongle essentiellement entre trois concepts: *données*, *information* et *connaissances*. Chacun de ces trois niveaux amène un nouvel état de transition, de l'observation basique (*données*), à l'*information* contextualisée puis la connaissance *structurée*. Par exemple, chacune des perspectives données précédemment peut s'inscrire dans ce schéma à trois niveaux: l'émergence de nouveaux profils collecte des données afin de les transformer en information sur les organisations (ie. les capacités des organisations, qui deviennent des connaissances une fois intégrées à l'ECO.); la réconciliation sémantique proposée dans les travaux de Tiexin Wang [200] peut prendre comme entrées deux bases de connaissances et les fusionner, ce qui représente une transformation de la connaissance vers la connaissance.

La figure 5.17 n'ambitionne pas d'être exhaustive mais plutôt de donner une point de vue sur comment données, information et connaissances pourraient être manipulées, et résume les transitions possibles dans les trois états. Cette figure est divisée en trois parties associées respectivement à la conception de modèles (des données à l'information); la sémantique (de l'information à la connaissance) et l'exploitation (de la connaissance à une connaissance nouvellement générée). Pour chacune de ces trois étapes, des outils pertinents sont proposés, qui peuvent permettre de franchir les différentes transitions entre les états.

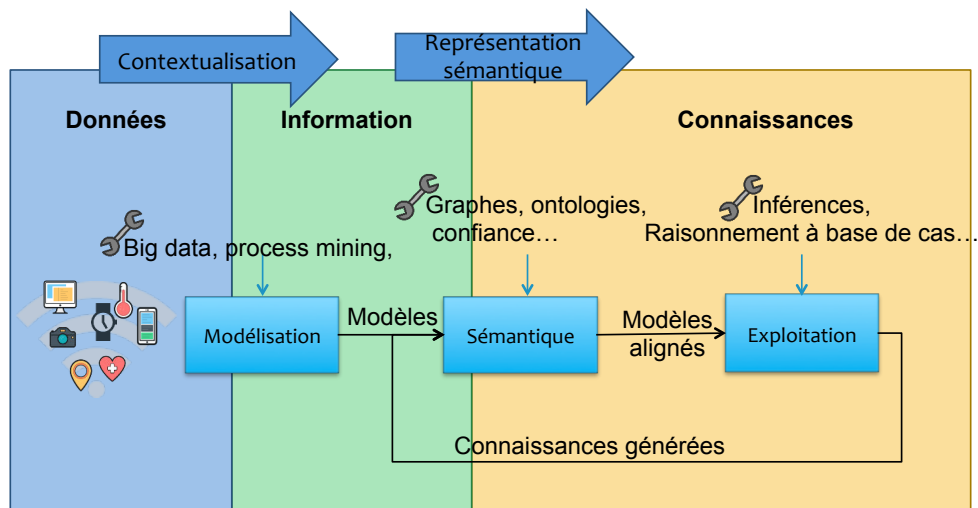


Figure 5.17 – Des données à la connaissances via l'information.

Il serait intéressant de centrer un nouveau programme de recherche autour de ces trois termes. En tant que coeur de ce système, une interface basique destinée à la manipulation de connaissances pourrait être développée. Puis, ce coeur pourrait être étendu: (i) à la discipline

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du *data mining* et ses disciplines connexes, (ii) à l'alignement de bases de connaissances et (iii) à l'exploitation de connaissances pour plusieurs objectifs (entre autre, la déduction de processus collaboratifs). D'un point de vue technique, un tel système peut se présenter comme une interface coeur développée petit-à-petit selon trois ces trois axes avec un système de plug-ins environnants, permettant de réaliser des transitions spécifiques entre les différents états.

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# Acronyms

<b>ACO</b>	Ant Colony Algorithm.
<b>API</b>	Application Programming Interface.
<b>B-OWL</b>	Business OWL.
<b>BFO</b>	Business Field Ontology.
<b>BO</b>	Business Opportunities.
<b>BPDM</b>	Business Process Definition Metamodel.
<b>BPEL</b>	Business Process Execution Language.
<b>BPM</b>	Business Process Management.
<b>BPML</b>	Business Process Modeling Language.
<b>BPMN</b>	Business Process Modeling Notation.
<b>CASE</b>	Computer Aided Software Engineering.
<b>CIM</b>	Computer Independent Model.
<b>CNO</b>	Collaborative Network of Organizations.
<b>CO</b>	Collaborative Ontology.
<b>DAML</b>	DARPA Agent Markup Language.
<b>DL</b>	Description Language.
<b>DSS</b>	Decision Support System.
<b>DTD</b>	Document Type Definition.
<b>ECO</b>	Extended Collaborative Ontology.
<b>EE</b>	Extended Enterprise.
<b>EPC</b>	Event-driven Process Chains.
<b>ESN</b>	Enterprise Social Network.
<b>GA</b>	Genetic Algorithm.
<b>HTN</b>	Hierarchical Task Network.
<b>IDE</b>	Integrated Development Environment.

## Acronyms

---

<b>IDEF</b>	Integrated DEFinition.
<b>ISIC</b>	International Standard Industrial Classification of all economic activities.
<b>KM</b>	Knowledge Management.
<b>KPI</b>	Key Performance Indicators.
<b>MDA</b>	Model Driven Architecture.
<b>MDE</b>	Model Driven Engineering.
<b>MIS</b>	Mediation Information System.
<b>MISE</b>	Mediation Information System Engineering.
<b>MOF</b>	Meta)Object Facility.
<b>NACE</b>	Statistical Classification of Economic Activities in the European Community.
<b>NAICS</b>	North American Industry Classification System.
<b>NIST</b>	Nation Institute of Standard and Technology.
<b>OASIS</b>	Organization for the Advancement of Structured Inrformation Standards.
<b>OIL</b>	Ontology Interface Layer.
<b>OMG</b>	Object Management Group.
<b>OML</b>	Ontology Markup Language.
<b>OWL</b>	Ontology Web Language.
<b>PaaS</b>	Platform as a Service.
<b>PCF</b>	Process Classification Framework.
<b>PIM</b>	Platform Independant Model.
<b>PM</b>	Platform Model.
<b>PSL</b>	Process Specification Language.
<b>PSM</b>	Platform Specific Model.
<b>QoS</b>	Quality of System.
<b>RDF</b>	Resource Description Framework.
<b>RDF-S</b>	Resource Description Framework (RDF) Schema.
<b>SA</b>	Simulated Annealing.
<b>SaaS</b>	Software as a Service.
<b>SADT</b>	Structured Analysis and Design Technique.
<b>SC</b>	Supply Chain.
<b>SCM</b>	Supply Chain Management.

<b>SCOR</b>	Supply Chain Operations Reference.
<b>SHOE</b>	Simple HTML Ontology Extension.
<b>SME</b>	Small and Medium Enterprise.
<b>SOA</b>	Service Oriented Architecture.
<b>SPARQL</b>	SPARQL Protocol And RDF Query Language.
<b>SQL</b>	Structured Query Language.
<b>SUMO</b>	Suggested Upper Merged Ontology.
<b>TS</b>	Tabu Search.
<b>UML</b>	Unified Modeling Language.
<b>VDO</b>	Virtual Development Office.
<b>VE</b>	Virtual Enterprise.
<b>VSC</b>	Virtual Supply Chain.
<b>WS-CDL</b>	Web Service Choreography Description Language.
<b>WSCl</b>	Web Service Choreography Interface.
<b>WSCL</b>	Web Service Conversation Language.
<b>WSFL</b>	Web Service Flow Language.
<b>XML</b>	eXtended Markup Language.
<b>XOL</b>	XML-based Ontology exchange Language.
<b>XPDL</b>	XML Process Definition Language.
<b>YAWL</b>	Yet Another Workflow Language.



# A BPM classification

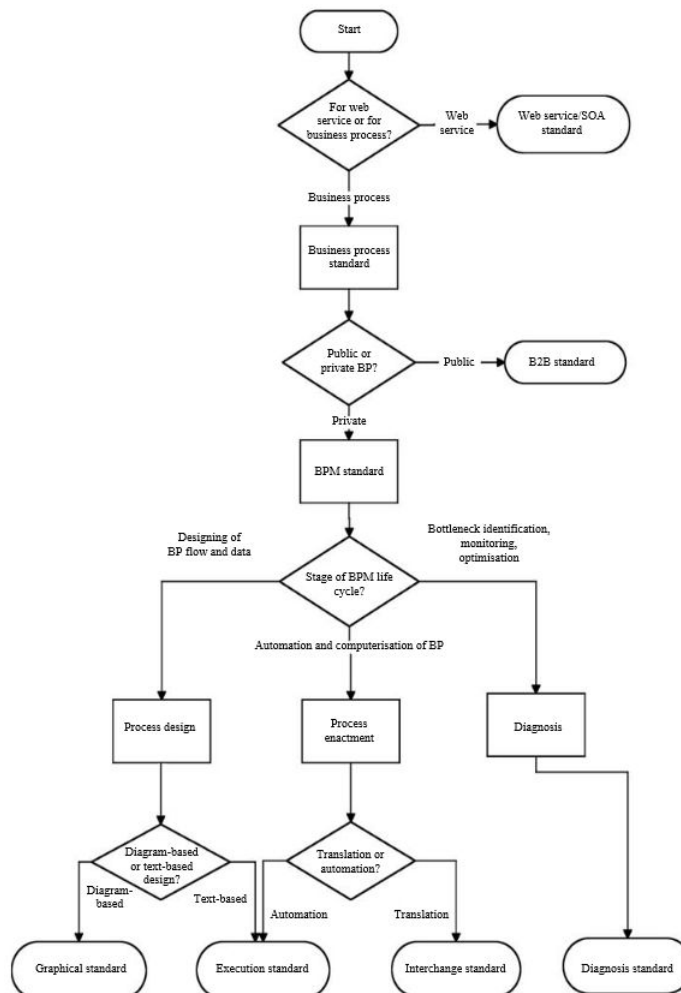
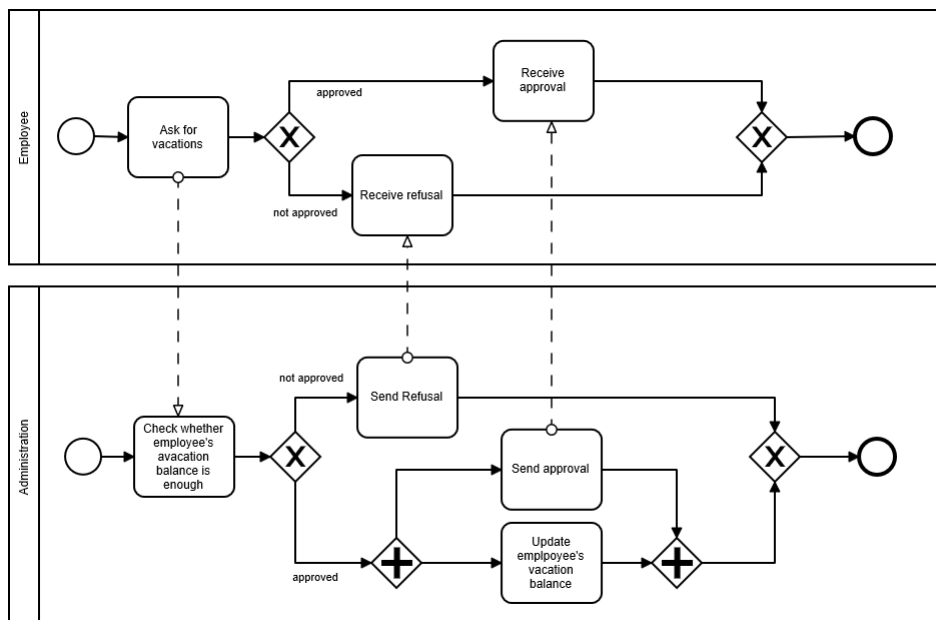


Figure A.1 – Classification diagram for choosing BPM standards, [58].



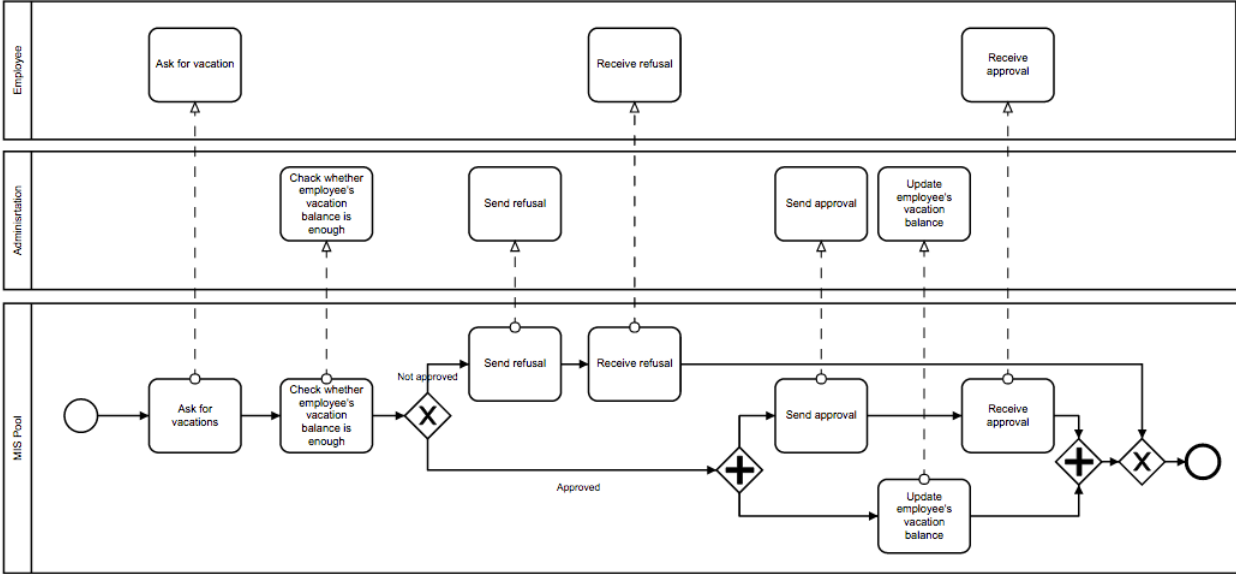


# B Business Process Modeling Notation



**BPMN model for taking vacation**

**Appendix B. Business Process Modeling Notation**



**Automated BPMN model for taking vacation with MIS pool**

## C Collaborative Ontology Sample

```
1 <?xml version="1.0"?>
2 <rdf:RDF xmlns="process_handbook.owl#"
3     xml:base="process_handbook.owl"
4     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
5     xmlns:owl="http://www.w3.org/2002/07/owl#"
6     xmlns:process_handbook="http://www.semanticweb.org/mise/process_handbook.owl#"
7     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
8     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
9   <owl:Ontology rdf:about="process_handbook.owl"/>
10
11
12
13   <!--
14   //////////////////////////////////////
15   //
16   // Object Properties
17   //
18   //////////////////////////////////////
19   -->
20
21
22
23
24   <!-- http://www.semanticweb.org/mise/process_handbook.owl#contributesTo -->
25
26   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/mise/process_handbook.owl
27     #contributesTo"/>
28
29
30   <!-- http://www.semanticweb.org/mise/process_handbook.owl#hasSubObjective -->
31
32   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/mise/process_handbook.owl
33     #hasSubObjective"/>
34
35
36   <!--
```

## Appendix C. Collaborative Ontology Sample

---

```
37  //////////////////////////////////////
38  //
39  // Data properties
40  //
41  //////////////////////////////////////
42  -->
43
44
45
46
47  <!-- http://www.semanticweb.org/mise/process_handbook.owl#name -->
48
49  <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#name"/>
50
51
52
53  <!--
54  //////////////////////////////////////
55  //
56  // Classes
57  //
58  //////////////////////////////////////
59  -->
60
61
62
63
64  <!-- http://www.semanticweb.org/mise/process_handbook.owl#Capability -->
65
66  <owl:Class rdf:about="http://www.semanticweb.org/mise/process_handbook.owl#
    Capability"/>
67
68
69
70  <!-- http://www.semanticweb.org/mise/process_handbook.owl#Objective -->
71
72  <owl:Class rdf:about="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
73
74
75
76  <!--
77  //////////////////////////////////////
78  //
79  // Individuals
80  //
81  //////////////////////////////////////
82  -->
83
84
85
86
87  <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_ANALYSIS -->
```

```

88
89 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_ANALYSIS">
90   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Capability"/>
91   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
    analysis Root&quot;</rdfs:label>
92   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot; All
    process activities are considered to be specialized types of Act. The first
    level of distinction below Act contains eight &apos;generic verbs&apos;
    into which we expect all other activities to be classified: The first four (
    Create, Destroy, Modify, and Preserve) focus on the input and output of a
    process and are roughly analogous to the computer commands of Write, Delete,
    Edit, Read. The next two (Combine and Separate) focus on multiple inputs or
    outputs. Decide is analogous to a decision box in a flow chart. Manage
    focuses on providing access to a scarce resource, such as capital, money,
    actors, etc.&quot;</rdfs:comment>
93   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;analysis Root&quot;</process_handbook:name>
94 </owl:NamedIndividual>
95
96
97
98 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-1 -->
99
100 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-1">
101   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
102   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;End
    state&quot;</rdfs:label>
103   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
    quot;</rdfs:comment>
104   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;End state&quot;</process_handbook:name>
105   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    COMMITMENT-1</process_handbook:name>
106 </owl:NamedIndividual>
107
108
109 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-182 -->
110
111 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-182">
112   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
113   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;flow
    is managed&quot;</rdfs:label>
114   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
    quot;</rdfs:comment>
115   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;flow is managed&quot;</process_handbook:name>
116   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    COMMITMENT-182</process_handbook:name>
117 </owl:NamedIndividual>
118
119
120
121
122 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-3 -->

```

## Appendix C. Collaborative Ontology Sample

```
123
124 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-3">
125   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
126   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
    Optimize &quot;</rdfs:label>
127   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;Optimize &quot;</process_handbook:name>
128   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;The
    goal of optimizing a given value.&quot;</rdfs:comment>
129   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    COMMITMENT-3</process_handbook:name>
130 </owl:NamedIndividual>
131
132
133
134 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-49 -->
135
136 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-49">
137   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
138   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
    Prevent state&quot;</rdfs:label>
139   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
    quot;</rdfs:comment>
140   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;Prevent state&quot;</process_handbook:name>
141   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    COMMITMENT-49</process_handbook:name>
142 </owl:NamedIndividual>
143
144
145
146 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-51 -->
147
148 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-51">
149   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
150   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
    Maintain state&quot;</rdfs:label>
151   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
    quot;</rdfs:comment>
152   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
    quot;Maintain state&quot;</process_handbook:name>
153   <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    COMMITMENT-51</process_handbook:name>
154 </owl:NamedIndividual>
155
156
157
158 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-53 -->
159
160 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
    owl#MPH_COMMITMENT-53">
161   <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
    Objective"/>
```

```

162     <rdfs:label rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;Create
163         state&quot;</rdfs:label>
164     <rdfs:comment rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
165         quot;</rdfs:comment>
166     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&
167         quot;Create state&quot;</process_handbook:name>
168     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">
169         COMMITMENT-53</process_handbook:name>
170 </owl:NamedIndividual>
171
172 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-73 -->
173 <owl:NamedIndividual rdfs:about="http://www.semanticweb.org/mise/process_handbook.
174     owl#MPH_COMMITMENT-73">
175     <rdfs:type rdfs:resource="http://www.semanticweb.org/mise/process_handbook.owl#
176         Objective"/>
177     <rdfs:label rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
178         maintain resource uncorrupted in storage&quot;</rdfs:label>
179     <rdfs:comment rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
180         quot;</rdfs:comment>
181     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&
182         quot;maintain resource uncorrupted in storage&quot;</process_handbook:name>
183     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">
184         COMMITMENT-73</process_handbook:name>
185 </owl:NamedIndividual>
186
187 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_COMMITMENT-75 -->
188 <owl:NamedIndividual rdfs:about="http://www.semanticweb.org/mise/process_handbook.
189     owl#MPH_COMMITMENT-75">
190     <rdfs:type rdfs:resource="http://www.semanticweb.org/mise/process_handbook.owl#
191         Objective"/>
192     <rdfs:label rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
193         Physical infrastructure is maintained&quot;</rdfs:label>
194     <rdfs:comment rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
195         quot;</rdfs:comment>
196     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&
197         quot;Physical infrastructure is maintained&quot;</process_handbook:name>
198     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">
199         COMMITMENT-75</process_handbook:name>
200 </owl:NamedIndividual>
201
202 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_E-YJTEG4-1 -->
203 <owl:NamedIndividual rdfs:about="http://www.semanticweb.org/mise/process_handbook.
204     owl#MPH_E-YJTEG4-1">
205     <rdfs:type rdfs:resource="http://www.semanticweb.org/mise/process_handbook.owl#
206         Objective"/>
207     <rdfs:label rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;asker
208         process is performed&quot;</rdfs:label>
209     <rdfs:comment rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
210         quot;</rdfs:comment>
211     <process_handbook:name rdfs:datatype="http://www.w3.org/2001/XMLSchema#string">&
212         quot;asker process is performed&quot;</process_handbook:name>

```



## Appendix C. Collaborative Ontology Sample

---

```
201     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">E
202     -YJTEG4-1</process_handbook:name>
203 </owl:NamedIndividual>
204
205
206 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_E-YJTEG4-2 -->
207
208 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
209     owl#MPH_E-YJTEG4-2">
210     <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
211     Objective"/>
212     <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
213     process achieves optimal outcome&quot;</rdfs:label>
214     <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;&
215     quot;</rdfs:comment>
216     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
217     quot;process achieves optimal outcome&quot;</process_handbook:name>
218     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">E
219     -YJTEG4-2</process_handbook:name>
220     <process_handbook:hasSubObjective rdf:resource="http://www.semanticweb.org/mise
221     /process_handbook.owl#MPH_E-YJTEG4-1"/>
222 </owl:NamedIndividual>
223
224
225 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_E0 -->
226
227 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
228     owl#MPH_E0">
229     <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
230     Capability"/>
231     <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
232     Activity Root&quot;</rdfs:label>
233     <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot; All
234     process activities are considered to be specialized types of Act. The first
235     level of distinction below Act contains eight &apos;generic verbs&apos;
236     into which we expect all other activities to be classified: The first four (
237     Create, Destroy, Modify, and Preserve) focus on the input and output of a
238     process and are roughly analogous to the computer commands of Write, Delete,
239     Edit, Read. The next two (Combine and Separate) focus on multiple inputs or
240     outputs. Decide is analogous to a decision box in a flow chart. Manage
241     focuses on providing access to a scarce resource, such as capital, money,
242     actors, etc.&quot;</rdfs:comment>
243     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
244     quot;Activity Root&quot;</process_handbook:name>
245     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
246     process_handbook.owl#MPH_ENT-KHBCG4-1"/>
247 </owl:NamedIndividual>
248
249
250
251 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_E1109 -->
252
253 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
254     owl#MPH_E1109">
255     <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
256     Capability"/>
257     <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
258     Process&quot;</rdfs:label>
```

```

236     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
237     quot;Process&quot;</process_handbook:name>
238     <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;
239     Processing is a form of modification that is unspecified other than that the
240     modification will follow a predefined set of rules/steps.&quot;</rdfs:
241     comment>
242 </owl:NamedIndividual>
243 <!-- http://www.semanticweb.org/mise/process_handbook.owl#MPH_E1147 -->
244
245 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/process_handbook.
246     owl#MPH_E1147">
247     <rdf:type rdf:resource="http://www.semanticweb.org/mise/process_handbook.owl#
248     Capability"/>
249     <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;Manage
250     sharing&quot;</rdfs:label>
251     <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&quot;A
252     sharing dependency occurs when two or more activities use the same resource
253     .&quot;</rdfs:comment>
254     <process_handbook:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">&
255     quot;Manage sharing&quot;</process_handbook:name>
256     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
257     process_handbook.owl#MPH_COMMITMENT-184"/>
258     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
259     process_handbook.owl#MPH_ENT-T3QPTD4-4"/>
260     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
261     process_handbook.owl#MPH_ENT-TGSMF4-15"/>
262     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
263     process_handbook.owl#MPH_ENT-TH8IZD4-1"/>
264     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
265     process_handbook.owl#MPH_ENT-TH8IZD4-4"/>
266     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
267     process_handbook.owl#MPH_ENT-TQIYIE4-26"/>
268     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
269     process_handbook.owl#MPH_ENT-TQIYIE4-28"/>
270     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
271     process_handbook.owl#MPH_ENT-TRMXID4-7"/>
272     <process_handbook:contributesTo rdf:resource="http://www.semanticweb.org/mise/
273     process_handbook.owl#MPH_ENT-TRVFUD4-1"/>
274 </owl:NamedIndividual>

```

Code C.1 – Collaborative Ontology sample.



## D Business Field Ontology Sample

```
1 <?xml version="1.0"?>
2 <rdf:RDF xmlns="BFO.owl#"
3     xml:base="BFO.owl"
4     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
5     xmlns:BFO="http://www.semanticweb.org/mise/BFO.owl#"
6     xmlns:owl="http://www.w3.org/2002/07/owl#"
7     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
8     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
9   <owl:Ontology rdf:about="BFO.owl"/>
10
11
12
13   <!--
14   ////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
15   //
16   // Object Properties
17   //
18   ////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
19   -->
20
21
22
23
24   <!-- http://www.semanticweb.org/mise/BFO.owl#hasSubDomain -->
25
26   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/mise/BFO.owl#hasSubDomain
27     "/>
28
29
30   <!-- http://www.semanticweb.org/mise/BFO.owl#isSubDomainOf -->
31
32   <owl:ObjectProperty rdf:about="http://www.semanticweb.org/mise/BFO.owl#
33     isSubDomainOf"/>
34
35
36   <!--
```



```

88
89
90
91 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0113_-
    _Growing_of_vegetables_and_melons__roots_and_tubers -->
92
93 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0113_-
    _Growing_of_vegetables_and_melons__roots_and_tubers">
94   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
95   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0113 - Growing
    of vegetables and melons, roots and tubers</BFO:name>
96   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_011_-_Growing_of_non-perennial_crops"/>
97 </owl:NamedIndividual>
98
99
100
101 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0114_-_Growing_of_sugar_cane -->
102
103 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0114_-
    _Growing_of_sugar_cane">
104   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
105   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0114 - Growing
    of sugar cane</BFO:name>
106   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_011_-_Growing_of_non-perennial_crops"/>
107 </owl:NamedIndividual>
108
109
110
111 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0115_-_Growing_of_tobacco -->
112
113 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0115_-
    _Growing_of_tobacco">
114   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
115   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0115 - Growing
    of tobacco</BFO:name>
116   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_011_-_Growing_of_non-perennial_crops"/>
117 </owl:NamedIndividual>
118
119
120
121 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0116_-_Growing_of_fibre_crops -->
122
123 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0116_-
    _Growing_of_fibre_crops">
124   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
125   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0116 - Growing
    of fibre crops</BFO:name>
126   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_011_-_Growing_of_non-perennial_crops"/>
127 </owl:NamedIndividual>
128
129
130
131 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0119_-_Growing_of_other_non-
    perennial_crops -->
132

```

## Appendix D. Business Field Ontology Sample

```
133 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0119_-
134   _Growing_of_other_non-perennial_crops">
135   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
136   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0119 - Growing
137     of other non-perennial crops</BFO:name>
138   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
139     BFO_011_-_Growing_of_non-perennial_crops"/>
140 </owl:NamedIndividual>
141 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_011_-_Growing_of_non-
142   perennial_crops -->
143 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_011_-
144   _Growing_of_non-perennial_crops">
145   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
146   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This class
147     includes all forms of growing of cereals, leguminous crops and oil seeds in
148     open fields, including those considered organic farming and the growing of
149     genetically modified crops. The growing of these crops is often combined
150     within agricultural units.</rdfs:label>
151   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This class
152     includes the growing of non-perennial crops not elsewhere classified.</rdfs:
153     label>
154   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This class
155     includes:</rdfs:label>
156   <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This group
157     includes the growing of non-perennial crops, i.e. plants that do not last
158     for more than two growing seasons. Included is the growing of these plants
159     for the purpose of seed production.</rdfs:label>
160   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">011 - Growing
161     of non-perennial crops</BFO:name>
162   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
163     BFO_0112_-_Growing_of_rice"/>
164   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
165     BFO_0113_-_Growing_of_vegetables_and_melons__roots_and_tubers"/>
166   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
167     BFO_0114_-_Growing_of_sugar_cane"/>
168   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
169     BFO_0115_-_Growing_of_tobacco"/>
170   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
171     BFO_0116_-_Growing_of_fibre_crops"/>
172   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
173     BFO_0119_-_Growing_of_other_non-perennial_crops"/>
174   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
175     BFO_01_-_Crop_and_animal_production__hunting_and_related_service_activities"
176     />
177   <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
178     BFO_0111_-_Growing_of_cereals_(except_rice)__leguminous_crops_and_oil_seeds"
179     />
180 </owl:NamedIndividual>
181 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0121_-_Growing_of_grapes -->
182 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0121_-
183   _Growing_of_grapes">
184   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
```

```

166     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0121 - Growing
167         of grapes</BFO:name>
168     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
169         BFO_012_-_Growing_of_perennial_crops"/>
170 </owl:NamedIndividual>
171
172 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0122_-_
173     _Growing_of_tropical_and_subtropical_fruits -->
174 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0122_-_
175     _Growing_of_tropical_and_subtropical_fruits">
176     <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
177     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0122 - Growing
178         of tropical and subtropical fruits</BFO:name>
179     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
180         BFO_012_-_Growing_of_perennial_crops"/>
181 </owl:NamedIndividual>
182
183 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0123_-_Growing_of_citrus_fruits --
184     >
185 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0123_-_
186     _Growing_of_citrus_fruits">
187     <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
188     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0123 - Growing
189         of citrus fruits</BFO:name>
190     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
191         BFO_012_-_Growing_of_perennial_crops"/>
192 </owl:NamedIndividual>
193
194 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0124_-_
195     _Growing_of_pome_fruits_and_stone_fruits -->
196 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0124_-_
197     _Growing_of_pome_fruits_and_stone_fruits">
198     <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
199     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0124 - Growing
200         of pome fruits and stone fruits</BFO:name>
201     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
202         BFO_012_-_Growing_of_perennial_crops"/>
203 </owl:NamedIndividual>
204
205 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0125_-_
206     _Growing_of_other_tree_and_bush_fruits_and_nuts -->
207 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0125_-_
208     _Growing_of_other_tree_and_bush_fruits_and_nuts">
209     <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
210     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0125 - Growing
211         of other tree and bush fruits and nuts</BFO:name>
212     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
213         BFO_012_-_Growing_of_perennial_crops"/>

```



## Appendix D. Business Field Ontology Sample

---

```
208 </owl:NamedIndividual>
209
210
211
212 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0126_-
    _Growing_of_oleaginous_fruits -->
213
214 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0126_-
    _Growing_of_oleaginous_fruits">
215   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
216   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0126 - Growing
    of oleaginous fruits</BFO:name>
217   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_012_-_Growing_of_perennial_crops"/>
218 </owl:NamedIndividual>
219
220
221
222 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0127_-_Growing_of_beverage_crops
    -->
223
224 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0127_-
    _Growing_of_beverage_crops">
225   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
226   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0127 - Growing
    of beverage crops</BFO:name>
227   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_012_-_Growing_of_perennial_crops"/>
228 </owl:NamedIndividual>
229
230
231
232 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0128_-
    _Growing_of_spices__aromatic__drug_and_pharmaceutical_crops -->
233
234 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0128_-
    _Growing_of_spices__aromatic__drug_and_pharmaceutical_crops">
235   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
236   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0128 - Growing
    of spices, aromatic, drug and pharmaceutical crops</BFO:name>
237   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_012_-_Growing_of_perennial_crops"/>
238 </owl:NamedIndividual>
239
240
241
242 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0129_-
    _Growing_of_other_perennial_crops -->
243
244 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0129_-
    _Growing_of_other_perennial_crops">
245   <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
246   <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0129 - Growing
    of other perennial crops</BFO:name>
247   <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
    BFO_012_-_Growing_of_perennial_crops"/>
248 </owl:NamedIndividual>
249
250
251
```

```

252 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_012_-_Growing_of_perennial_crops
253 -->
254 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_012_-_
255 _Growing_of_perennial_crops">
256 <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
257 <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This class
258 includes:</rdfs:label>
259 <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This group
260 includes the growing of perennial crops, i.e. plants that lasts for more
261 than two growing seasons, either dying back after each season or growing
262 continuously. Included is the growing of these plants for the purpose of
263 seed production.</rdfs:label>
264 <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">012 - Growing
265 of perennial crops</BFO:name>
266 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
267 BFO_0121_-_Growing_of_grapes"/>
268 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
269 BFO_0122_-_Growing_of_tropical_and_subtropical_fruits"/>
270 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
271 BFO_0123_-_Growing_of_citrus_fruits"/>
272 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
273 BFO_0124_-_Growing_of_pome_fruits_and_stone_fruits"/>
274 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
275 BFO_0125_-_Growing_of_other_tree_and_bush_fruits_and_nuts"/>
276 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
277 BFO_0126_-_Growing_of_oleaginous_fruits"/>
278 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
279 BFO_0127_-_Growing_of_beverage_crops"/>
280 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
281 BFO_0128_-_Growing_of_spices__aromatic__drug_and_pharmaceutical_crops"/>
282 <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
283 BFO_0129_-_Growing_of_other_perennial_crops"/>
284 <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
285 BFO_01_-_Crop_and_animal_production_hunting_and_related_service_activities"
286 />
287 </owl:NamedIndividual>
288
289 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0130_-_Plant_propagation -->
290
291 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0130_-_
292 _Plant_propagation">
293 <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
294 <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0130 - Plant
295 propagation</BFO:name>
296 <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
297 BFO_013_-_Plant_propagation"/>
298 </owl:NamedIndividual>
299
300 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_013_-_Plant_propagation -->
301
302 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_013_-_
303 _Plant_propagation">
304 <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
305 <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">See class
306 0130.</rdfs:label>

```

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```

288     <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">This class
        includes the production of all vegetative planting materials including
        cuttings, suckers and seedlings for direct plant propagation or to create
        plant grafting stock into which selected scion is grafted for eventual
289     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">013 - Plant
        propagation</BFO:name>
290     <BFO:hasSubDomain rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
        BFO_0130_-_Plant_propagation"/>
291     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
        BFO_01_-_Crop_and_animal_production__hunting_and_related_service_activities"
        />
292 </owl:NamedIndividual>
293
294
295
296 <!-- http://www.semanticweb.org/mise/BFO.owl#BFO_0141_-_
        _Raising_of_cattle_and_buffaloes -->
297
298 <owl:NamedIndividual rdf:about="http://www.semanticweb.org/mise/BFO.owl#BFO_0141_-_
        _Raising_of_cattle_and_buffaloes">
299     <rdf:type rdf:resource="http://www.semanticweb.org/mise/BFO.owl#Domain"/>
300     <BFO:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0141 - Raising
        of cattle and buffaloes</BFO:name>
301     <BFO:isSubDomainOf rdf:resource="http://www.semanticweb.org/mise/BFO.owl#
        BFO_014_-_Animal_production"/>
302 </owl:NamedIndividual>

```

Code D.1 – Business Field Ontology sample.



## Deduction of inter-organizational collaborative business processes within an enterprise social network

**Abstract.** Especially in the context of collaborative supply chains and virtual enterprises, the step of designing the collaborative workflows remains laborious because either it is still carried out humanly or the methods lack of flexibility. Based on an enterprise social network, this thesis aims at facilitating this step by proposing a service for the deduction of collaborative processes. It raises three main issues: (i) finding the activities to execute that answer the objectives of the collaboration (What?), (ii) selecting the corresponding partners (Who?) and (iii) ordering the activities into a collaborative business process (When?). Moreover, it is expected that many companies could be able to provide the same activities, on the enterprise social network. In this competitive context, a global optimization should be set up in order to find the quasi-optimal collaborative process that answer these three questions simultaneously. A three-dimensional solution is proposed here. First, a non-functional framework has been set up in order to determine the criteria that make a « good » partner in a specific collaborative context. Then, collaborative ontologies have been implemented and enable the representation and the acquisition of collaborative knowledge, so that the IT system can understand (a) the users' needs when they model their objectives of collaboration and (b) the users' capabilities when they model their profiles on the enterprise social network. And finally, a tool for decision support has been implemented thanks to an ant colony optimization algorithm that exploits the collaborative ontologies in order to provide a quasi-optimal process that fits the context of the collaboration and answers its objective. The results are in line with the FUI French project OpenPaaS which aims at offering an enterprise social network to facilitate their collaborations.

**Keywords.** Inter-organizational collaboration, Interoperability, Business process deduction, Ontology, Ant Colony Optimization, Information system.

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## Déduction de processus métier collaboratifs inter-organisationnels au sein d'un réseau social d'entreprises

**Résumé.** Particulièrement lors de collaborations dans le cadre de chaînes logistiques ou d'entreprises virtuelles, établir les workflows collaboratifs est une étape laborieuse car souvent réalisée soit de façon humaine, soit avec des méthodes manquant de flexibilité. Sur la base d'un réseau social d'entreprises, cette thèse vise à faciliter cette étape en proposant un service de déduction de processus collaboratifs inter-organisationnels. Cela soulève trois problèmes: (i) trouver les activités qui doivent être exécutées pour remplir les objectifs de la collaboration (Quoi?), (ii) sélectionner les partenaires pouvant réaliser ces activités (Qui?) et (iii) ordonner ces activités en un processus métier collaboratif (Quand?). Dans le cadre d'un réseau social, il est attendu que plusieurs organisations soient capables de fournir les mêmes activités. Dans un tel contexte de concurrence entre les organisations, une optimisation globale permet de trouver un processus final quasi-optimal, en prenant en compte ces trois questions de manière simultanée: trouver l'ensemble des "meilleurs" partenaires et leurs activités dans un contexte de collaboration spécifique. A cette fin, des ontologies de collaboration ont été développées et permettent de représenter et collecter des connaissances sur les collaborations. Ainsi, quand les utilisateurs remplissent leurs profils sur le réseau social, le système peut comprendre (i) les attentes des utilisateurs lorsqu'ils fournissent leurs objectifs de collaboration et (ii) les capacités qu'ils peuvent fournir. Un outil d'aide à la décision, basé sur un algorithme d'optimisation par colonies de fourmis, permet ensuite d'exploiter les ontologies de collaboration afin de trouver un processus quasi-optimal répondant aux attentes et objectifs de la collaboration. Les résultats de cette thèse s'inscrivent au sein du projet FUI OpenPaaS dont le but est d'établir un nouveau réseau social d'entreprises visant à faciliter leurs collaborations intra et inter-organisationnelles.

**Mots-clés.** Collaboration inter-organisationnelle, Interopérabilité, Déduction de processus collaboratifs, Ontologie, Optimisation par colonies de fourmis, Système d'information.