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THESE

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A Contribution to Enterprise Interoperability Maturity Assessment

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To my parents, my husband
and my daughter.

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General Introduction

1. Background and Problems

Historically, progress occurs when entities communicate, share information, and together create something that could not be achieved alone. Moving beyond people to machines and systems, interoperability is becoming a key factor of success in all domains.

Growing globalization, competitiveness and rising environmental awareness are driving many companies to control their interoperability strategy. Interoperability between systems thus requires considerable attention to be assessed and continuously improved.

Numerous models, methodologies, tools and guidelines exist that can help an organization, an enterprise, or more generally a system, to develop interoperability and improve the way it operates with others. However, interoperability is not a binary state; it has various degrees. Specifically, the highest one is not necessarily, the main target of enterprises. Developing interoperability requires considerable costs and efforts. Characterizing and measuring different degrees of interoperability, allows an enterprise to define its needed interoperability and to plan the migration path to reach it. This has become a significant research challenge over the past few years and maturity models have been developed in response to this challenge. Numerous maturity models have been developed for different purposes, some of which are dedicated to the interoperability domain. A survey of the most known ones has revealed that, in most cases, existing maturity models focus on one single facet of interoperability (data, technology, conceptual, enterprise modeling, etc.). Measuring more than one facet of interoperability implies using multiple maturity models, which creates redundancies and incompatibilities and makes the aggregation process more difficult. However, investigations into this domain have shown that, existing maturity models are complementary rather than contradictory. Consequently it is necessary to structure them into a single complete interoperability maturity model to avoid repetition and ensure consistency.

Measuring interoperability, using maturity models, needs analysis and investigations among the considered enterprise to detect problems and improve the enterprise capability to interoperate. Enterprise interoperability maturity can be measured in two ways : *A priori* where the measure relates to the potential of a system to be interoperable with a possible future partner whose identity is not known at the time of evaluation, *A posteriori* where the measure relates to the compatibility measure between two (or more) known systems willing to interoperate. The most known interoperability maturity models deal with the *a posteriori* measure of interoperability and do not sufficiently address potential of interoperability with unknown partners. However, measuring interoperability *a priori*, promotes the detection of interoperability problems at an early stage, which helps companies to take right decisions and perform corrective actions before problems adversely impact their businesses.

More concretely, this thesis aims at tackling the following problems, seen as necessities and research priorities to consider:

- Lack of satisfactory Enterprise interoperability measurement approach and the necessity to elaborate a set of metrics (in the form of a maturity model) that allows measuring the enterprise interoperability potential, i.e. its ability to interoperate with a future unknown partner. The proposed metrics must allow an enterprise to manage its interoperability development according to its needs and cover various aspects and dimensions of enterprise interoperability.
- Lack of a shared understanding of Enterprise Interoperability (EI) and the necessity to base the enterprise interoperability measures development on a rigorous and unambiguous discourse of EI. In particular a comprehensive representation of the EI domain to cover the basic concepts already defined and identified in the existing relevant works should be conducted.
- Lack of scientific and theoretic foundation in EI research and the necessity to investigate and apply relevant concepts and principles from other existing scientific domains. The objective is to ground the enterprise measure development on a scientific basis and thus contribute to the on-going European initiative in this area to develop the Enterprise Interoperability Science Base (EISB)

2. Contributions of the thesis

The main contribution of this research is to define a maturity model for enterprise interoperability. The proposed model has to deal with the *a priori* measure of interoperability maturity and to cover the various interoperability facets studied by the main existing interoperability maturity models.

In order to define this maturity model, the most known interoperability maturity models such as: LISI (Levels of Information System Interoperability) (DoD, 1998), NMI (NC3TA reference Model for Interoperability) (NATO, 2003), OIM (Organizational Interoperability Model) (Clark and Jones, 1999), LCIM (Levels of Conceptual Interoperability Model) (Tolk and Muguira, 2003), and EIMM (Enterprise Interoperability Maturity Model) (ATHENA, 2005) were referred to. Moreover, in order to cover existing interoperability facets (i.e. conceptual, technical and organizational) (ISO 14258, 1999) and the four concerns of enterprise interoperability (i.e. business, process, service and data) (Chen and Daclin, 2007) and thus, go beyond existing approaches, MMEI was built using the Framework of Enterprise Interoperability (FEI) already published as an EN/ISO standard (Chen et al., 2005) (Chen, 2006).

A second contribution of this thesis is to develop a common understanding about the enterprise interoperability domain. In this context, the FIG-OOI (Focused Interest Group on Ontology of Interoperability) group of the INTEROP-NoE (INTEROP. European Network of Excellence) (INTEROP, 2003) provides a preliminary framework for managing interoperability problems: the Ontology of Interoperability (OoI). "The OoI aims at formally defining interoperability and providing a framework to describe problems and related solutions pertaining to the interoperability" (Rosener et al., 2005). This OoI is used as a starting point for the proposed approach. It is enhanced by a set of relevant concepts coming from existing enterprise interoperability models and frameworks to build the Ontology of Enterprise Interoperability (OoEI). This OoEI aims at providing a formal definition of EI and thus serves as a basis for defining the maturity model. The third contribution is to provide a scientific foundation to the development of EI. This issue has been discussed in a European Commission roadmap (EIR, 2006), where the use of the General System Theory (GST) has been considered to be most appropriate to define a science base for enterprise interoperability. GST has a holistic view that can exceed the limits of traditional theories in tackling complex problems such as enterprise systems. Considering the enterprise as a system, the GST brings rigorous and theoretical concepts and principles to the EI domain. These concepts are integrated, thereafter, in the OoEI and used to develop the maturity model.

The objectives of these research efforts include the following goals:

- Help enterprises to assess their strengths and weaknesses in terms of interoperability and to better define their interoperability development strategy.

- Allow enterprises to monitor their interoperability progress and to manage and plan the actions to implement in order to improve interoperability
- Promote the use of scientific approaches in dealing with enterprise interoperability problems and thus, contribute to develop verifiable and repeatable scientific methods.
- Have an improved understanding of enterprise interoperability problems, issues and possible solutions.

To achieve these goals, four steps have been carried out in this research. First, investigations have been performed in the GST in order to capture system concepts that are relevant to the interoperability domain. Next, the identified relevant system theory concepts are applied to enhance the OoI, allowing having a system view of interoperability. Thirdly, a survey about the measurement models and methods for interoperability was conducted to detect the gaps between existing maturity models and the defined enterprise interoperability domain. Based on that, a maturity model for enterprise interoperability was proposed grounded in the Framework of Enterprise Interoperability (FEI), formally represented in OoEI and taking into account existing maturity models.

To this end, a comprehensive literature review of the three domains covered by this thesis is conducted:

- Enterprise interoperability
- General system theory
- Interoperability maturity models

3. Organization of the thesis

This document is structured as follows.

- Chapter 1 presents the enterprise Interoperability problems, challenges and Research objectives. This includes the industrial and economic contexts of interoperability, interoperability definitions; and research challenges and priorities.
- Chapter 2 investigates and identifies relevant enterprise interoperability concepts from existing EI models and frameworks. The Ontology of Interoperability (OoI) as defined by INTEROP-NoE, is studied. An analysis of these is performed to choose concepts that are relevant to define the enterprise interoperability domain. Subsequently, the Ontology of Enterprise Interoperability (OoEI) is proposed.

- Chapter 3 reviews the General System Theory and demonstrates how it can be useful for developing enterprise interoperability. Relevant systemic concepts are identified and an enhanced OoEI, integrating GST concepts is proposed.
- Chapter 4 aims at defining the Maturity Model for Enterprise Interoperability (MMEI). The proposed model covers main existing maturity models and expands on this to define assessment methodology. In particular, a method based on fuzzy sets theory and linguistic variables is proposed. This is to ease the quantification using natural language in which MMEI users express their evaluations.
- Finally, in Chapter 5, a real case study is presented through a multinational company, in which the MMEI and its related methodology has been applied.

In summary, the overview of the research work and the contributions are illustrated in figure 1.

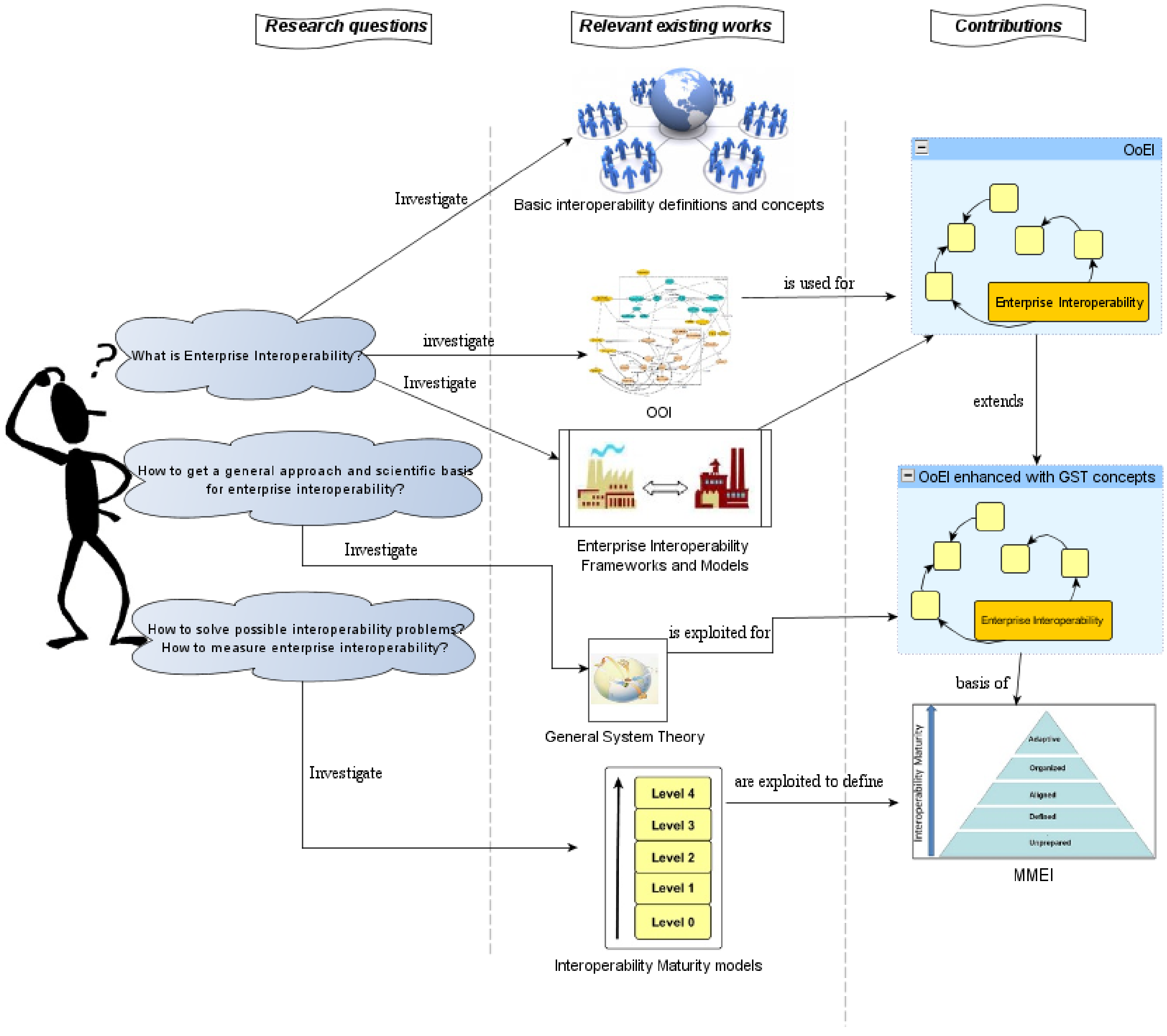

Figure 1. Research Context Overview

Chapter 1

Enterprise Interoperability:

Problems, Challenges and Research objectives

1.1. Introduction

Information Technology (IT) as well as human systems evolve in a worldwide heterogeneous environment and work in network. Operating in such an environment requires flexibility and cooperation between enterprises, sharing their core competencies in order to exploit the market opportunities. Exchanges are needed for both operational control, and to a larger extent for the decision making process during the establishment of cooperation, including opportunity exploration, planning and implementation.

It is acknowledged that one of the major issues in global collaboration and cooperation is the development of interoperability between enterprises. Hence, interoperability has become a key factor to success of enterprises and thus requires considerable attention. In order to provide a clear understanding of interoperability, it is important to study the various different interacting systems.

This chapter identifies and defines the framework of the research carried out in the thesis. The figure 1.1 gives an overview of the chapter.

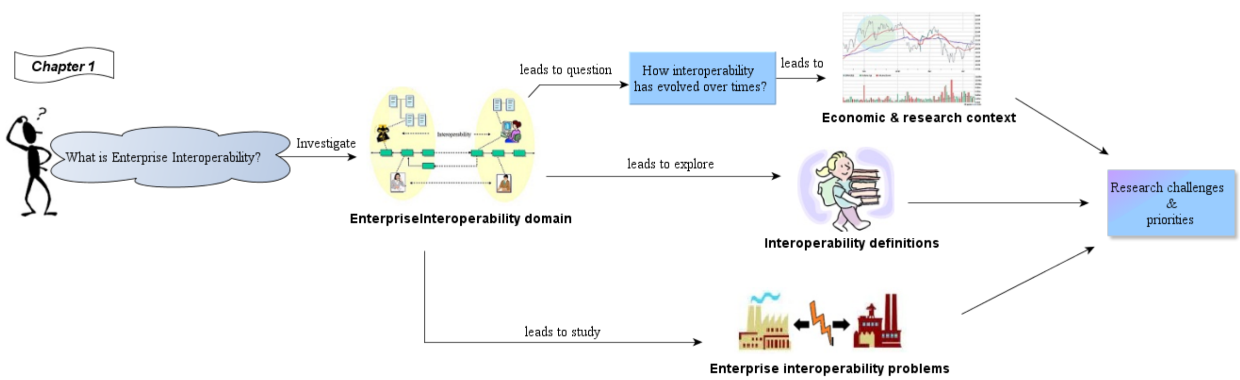

Figure 1.1. Overview of the chapter

Section 1.2 gives an overview of the economic and research contexts where interoperability has evolved. In section 1.3 basic definitions and concepts of Enterprise Interoperability (EI) are presented. Section 1.4 outlines problems that enterprises may face when interoperating or willing to interoperate. In section 1.5, basic concepts related to interoperability assessment approaches, allowing analysis of enterprise interoperability problems and evaluating EI capability are reviewed. Based on the literature review and the remaining issues to be solved, section 1.6 presents the research challenges and priorities, as well as the objectives of the thesis.

1.2. Enterprise Interoperability in the economic and research contexts

In order to understand the economic context in which interoperability challenges have emerged, this section reviews the economic stages which enterprises have had to cope with since the last century.

Existing work accurately presents these stages and the evolution of the enterprise in the economic context (O'Connor, 2004). The objective here is to explain the economic aspects and main reasons that led to the development of enterprise interoperability rather than provide a historical commentary.

In economic theory, the *law of supply and demand* is considered one of the fundamental principles governing an economy. Based on this principle, enterprises have evolved into three stages from the end of the last world war until the present time.

The first stage, known as the *Economic shortage*, covered the period between 1945 and 1975. It was characterized by a product demand which was, higher than the amount supplied in the market. The customer did not have any influence on the enterprise's manufacturing (i.e. products, quality, price, etc). The enterprise was in a strong position and imposed its products in the local market where competition between enterprises was weak. There was no need to develop partnerships and *interoperability* was not a subject that needed to be addressed.

The second stage, known as the *equilibrium* extended from 1975 until the beginning of the Nineties. It was characterized by a situation of balance between supply and demand. In such context, the enterprise didn't *sell what it produced*, but it *produced what it must sell*. It had to meet the needs expressed by customers, to sell its products. The markets were becoming more open, increasing the competition between enterprises. Partnerships between enterprises started, and some interoperations developed to cope with competition. However, this was still regarded as an option, not as an enterprise need. During this period, notions of *interoperability* were proposed in the literature (DoD, 1977; Elridge, 1978; Mc Cal, 1980) but this was limited to the IT systems domain.

The last stage called “surplus” started at the beginning of the nineties and has continued until the present time. It is characterized by a supply that exceeds demand forcing enterprises to become competitive.

Being in such a competitive industrial context has meant that enterprises must react swiftly to market changes and focus on their strategic production whilst subcontracting non-strategic parts to external partners and reducing costs. This potentially has led to an increased collaboration and a significant development of partnerships between enterprises (to develop interoperability).

Additionally research in the domain of enterprise modeling and integration has emerged (GRAI (Doumeingts et al., 1998), CIMOSA (AMICE, 1993), PERA (PERA, 2001)). This has made it easier for enterprises to enhance their productivity, flexibility and their capacity to evolve despite changes (Vernadat, 1996).

The concept of interoperability started to gain momentum in the 90s (Daclin, 2007) and hence the history of interoperability is recent. It is a key research issue in many domains, including the development of enterprise partnerships. In this context of emerging interoperability research and economic evolution, substantial interoperability research work is being reported in the literature.

In the 2000s, the European Commission sets up an expert group to identify processes to develop interoperability of enterprise software applications in Europe, and to make propositions to the Commission to launch projects in this domain (Chen and Doumeingts, 2003). Three main research domains addressing interoperability issues were identified:

- Enterprise modeling dealing with the representation of the inter-networked organization to establish interoperability requirements;
- Architecture & Platform defining the implementation solution to achieve interoperability
- Ontologies addressing the semantics necessary to assure interoperability.

Based on the recommendation of the expert group, a thematic network, named, Interoperability Development of Enterprise Applications and Software (IDEAS) was launched (July 2002–June 2003) to outline a roadmap to develop interoperability (IDEAS, 2003). Two main initiatives were then developed: ATHENA (ATHENA, 2003) and INTEROP Network of Excellence (INTERO, 2003) projects. Some other projects under SP6 and SP7 relating to enterprise interoperability continue this development, such as COIN[1] (FP7-216256) (Elvesæter et al., 2008) (COIN, 2008) and ENSEMBLE (ENSEMBLE, 2011). These research oriented projects have largely contributed to a better awareness and understanding of enterprise interoperability, and the search for solutions.

Nowadays, the growing globalization, competitiveness and rising environmental awareness are driving many companies to control their interoperability strategy and enhance their ability to interoperate. This is the new challenge that enterprises have to cope with: continually improving interoperability to maintain its competitiveness.

1.3. Basic definitions and concepts of Enterprise Interoperability

Interoperability is ubiquitous but not easy to understand due to its numerous definitions and interpretations. Ford et al. (2008) point out that according to their survey, thirty-four definitions of interoperability were proposed since 1977.

The most commonly acknowledged definition is provided by IEEE: *the ability of two or more systems or components to exchange information and to use the information that has been exchanged* (IEEE, 1990). The US Department of Defense (DoD), which deals with interoperability in the military domain, considers interoperability as *the ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services exchanged to enable them to operate effectively together* (DoD, 2001). In Europe, the definition issued from the Interop NoE (INTEROP, 2003) views interoperability as *the ability or the aptitude of two systems that have to understand one another and to function together* (Chen *et al.*, 2007). Conversely, IDEAS defines Interoperability as the *Capacity of an enterprise software or application to interact with others (...)* (IDEAS, 2003). Given the numerous definitions that exist, we may never have any agreement on a precise definition due to differing expectations that are constantly changing (Morris et al. 2004).

To better understand *Interoperability*, it is necessary to study and understand some concepts related to interoperability like integration, collaboration, cooperation and compatibility.

[1] COIN Enterprise Collaboration & Interoperability

1.3.1. Interoperability and Integration

Interoperability is sometimes distinguished from integration, but at other times the two terms are used interchangeably. Dictionary definitions suggest that any significant difference between them lies in the degree of coupling between the entities. Thus, an integrated system is sometimes considered to be more tightly coupled than a system composed of interoperable components (Pollock and Hodgson, 2004). Broadly speaking, interoperability has the meaning of coexistence, autonomy and federated environment, whereas integration refers more to the concepts of coordination, coherence and uniformity (Pollock, 2001). Chen et al. (2008) define *enterprise integration* and *enterprise interoperability* as follows:

- Enterprise integration is the process of ensuring the interaction between enterprise entities necessary to achieve domain objectives.
- Interoperability is the ability for two systems to understand one another and to use one another's functionalities. The word ''inter-operate'' implies that one system performs an operation for another system.

1.3.2. Collaboration, Cooperation and Interoperability

The ability of enterprises to collaborate and cooperate has been closely linked to the ability of enterprises to interoperate.

The literature presents different explanations of the collaboration concept. Most of the explanations acknowledge one form or another of sharing the work. Dillenbourg et al. (1995) make a distinction between cooperation and collaboration. They define cooperative work as "accomplished by the division of labor among participants, as an activity where each person is responsible for a portion of the problem solving (...)"; whereas a collaboration is defined as the "mutual engagement of participants in a coordinated effort to solve the problem together".

For both collaboration *and cooperation*, there is an engagement to work together towards a common goal. Interoperability is a prerequisite for enterprise collaborations (Mertins et al., 2007). However it is important to understand that interoperability can occur both in collaborative and non-collaborative (confrontational) ways. In the military domain, non-collaborative interoperability is called confrontational interoperability; it occurs when sets of opposing systems attempt to control each other (Ford, 2008).

1.3.3. Interoperability and compatibility

An interoperability problem occurs when two or more incompatible systems are put in relation (Naudet et al., 2008). Thus, in order to interoperate, systems have to be compatible. Kasunic and Anderson (2004) discuss the differences between interoperability and compatibility and state that "compatibility is something less than interoperability. It means that systems/units do not interfere with each other's functioning but it does not imply the ability to exchange services. To realize the power of networking through robust information exchange, we must go beyond compatibility". Hence interoperable systems are by necessity compatible, but the converse is not necessarily true.

Based on the definitions reviewed above, we can conclude that interoperability lies in the middle between compatibility and integration. However, it is clear that compatibility is a minimum requirement to achieve interoperability.

In common cases, interoperability involves two (or more) enterprises. These enterprises can be different: they may have different systems, models or organizations. These differences may be problematic if systems having to interoperate are incompatible. In order to avoid such problems, enterprises need to know types of problems that may occur when interoperating or willing to interoperate. The next section identifies these interoperability problems.

1.4. Problems of Enterprise Interoperability

In this section, the factors that make interoperability such a complex issue are considered. To this end, recent research related to interoperability problems is reviewed.

According to (Chen, 2006) (Ulberg et al., 2009), there are three kinds of interoperability problems, called also barriers that enterprises may face: conceptual, technological or organizational.

- *Conceptual problems* are mainly concerned with the syntactic and semantic incompatibilities of information to be exchanged or to be used during an interoperation. These problems concern the modeling at the higher level of abstraction (i.e. enterprise models) as well as the level of programming (i.e. low capacity of semantic representation of XML) (Chen and Daclin, 2007). Syntactic differences can be found whenever different structures are used to represent information and knowledge.

- *Technological problems* refer to the use of computer or ICT (Information and Communication Technologies) to communicate and exchange information (i.e. architecture & platforms, infrastructure…) (Chen, 2006). These problems concern the standards to use, store, exchange, processes or computerize information.
- *Organizational problems* relate to the definition of responsibilities and authorities so that interoperability can take place under good conditions. Responsibility needs to be defined in order to delegate tasks (process, data, software, computer…). If responsibility in an enterprise is not clearly and explicitly defined, interoperation between two systems is obstructed. Authority is an organizational concept which defines who is authorized to do what. For example, it is necessary to define who is authorized to create, modify, maintain data, processes, services, etc.

In order to quickly overcome these interoperability problems, enterprises need to be prepared to establish interoperability and initiate corrective actions before potential problems occur. To this end, an enterprise has to first assess its ability to interoperate. This is the purpose of the interoperability assessment which is studied in the next section.

1.5. Enterprise Interoperability assessment

Assessing interoperability allows enterprises to know their strengths and weaknesses and prioritize actions to improve interoperability.

Many methods are proposed in the literature to deal with interoperability assessment or contribute to it of which the maturity model is one common method. It is a framework that describes, for a specific area of interest, a number of levels of sophistication at which activities can be carried out (Alonso et al., 2010). It describes stages through which enterprises evolve in terms of interoperability and proposes plans of action in order to reach higher levels.

Generally speaking, enterprise interoperability maturity can be measured in two ways: a *priori* where the measure relates to the potential of a system to be interoperable with a possible future partner whose identity is not known at the moment of evaluation, *a posteriori* where the measure relates to the compatibility measure between two (or more) known systems willing to interoperate or to the measurement of the performance of an existing interoperability relationship between two systems.

The *a priori* assessment allows enterprises to prepare interoperability and to avoid potential problems when they need to collaborate together. Despite its importance, the most known interoperability maturity models such as NMI (NATO, 2003), OIM (Clark and Jones, 1999), LCIM (Tolk and Muguira, 2003), and EIMM (ATHENA, 2005), mainly deal with the *a posteriori* measure of interoperability and do not sufficiently address the potential of interoperability.

1.6. Research challenges and priorities

Although enterprise interoperability research has achieved significant results during the past ten years, many problems remain. Based on the literature review and the research context, the main research challenges and priorities that have been detected and considered as important are presented. The objectives and contributions of this thesis are then defined.

1.6.1. Lack of common and precise understanding of Enterprise Interoperability

Enterprise Interoperability seems to be a straightforward concept. However, there is no common definition or shared comprehension of it. Each expert defines and understands interoperability, according to his domain.

Since this is a gap in the research context, it is necessary to find a consensus about *enterprise interoperability*. This leads to the necessity of formalizing the enterprise interoperability domain concepts. However, as interoperability is a general issue that is tackled through many different domains such as military, software, information systems, modeling, organizations or health there is a need for a general consensus that is applicable to any interoperability domain.

1.6.2. Lack of a scientific foundation of Enterprise interoperability

According to LeMoigne (1994), the systemic approach is the trans-disciplinary study of the abstract organization of phenomena, independently of their substance, type, spatial or temporal scale of existence. It touches virtually all the traditional disciplines, from mathematics, technology, and biology to philosophy and social sciences, allowing a general approach, that could be applied across domains (Giachetti, 2010). This common base is necessary to avoid reinventing the wheel with every domain that is addressed. The general perspective provided by such a systemic approach is especially important when considering the different facets of interoperability: technical, organizational and conceptual (EIF, 2004; Chen, 2006). Indeed, the

same general approach and reasoning can be adopted whatever the considered system, be it technical (*e.g.* IT systems), organizational or conceptual (e.g. models), or a composition of these.
Based on this general theory, the objective is to define a conceptual model that provides a complete description and understanding of the EI domain. This will also be based on existing frameworks and models that have been defined for interoperability.

1.6.3. Insufficient assessment methods for EI potential

Growing globalization, competitiveness and rising environmental awareness are driving many companies to control their interoperability strategy and enhance their ability to interoperate. There is a need to take note of how things currently stand in order to progress, which is essential for controlling and improving the status quo of a company.
Widely used assessment methods utilize maturity models, many of which have been defined and described in the literature. They mainly deal with the *a posteriori* measure of interoperability and do not sufficiently address the *a priori* interoperability despite its importance to prepare and plan interoperability (Guédria et al., 2011). Moreover, they mainly focus on one single facet of interoperability (data, technology, conceptual, Enterprise modeling, etc.) and do not allow a global view of the enterprise interoperability domain. Therefore, when an enterprise needs to assess its whole interoperability, it has to use one maturity model for each interoperability field or concern (i.e. business interoperability, conceptual interoperability, technical interoperability, data interoperability, etc).

1.6.4. Objectives of the thesis

The review of current research has identified three main objectives to be investigated and reached. The first is to formalize the enterprise interoperability research domain, leading to a non-ambiguous understanding by providing explicit semantics of enterprise interoperability concepts. An explicit formal representation of the EI domain is elaborated through the OoEI (Ontology of Enterprise Interoperability), as presented in chapter 2.
The second objective is to devise a scientific base for enterprise interoperability. To this end, the use of the general system theory is investigated in order to ground the enterprise interoperability research on a more rigorous and scientific basis. Useful general concepts from GST to enterprise interoperability are identified and integrated into the OoEI.

Finally, the main objective of this research is to define a maturity model for enterprise interoperability that extends existing maturity models and focuses on potential interoperability assessment. This will allow enterprises to plan their future interoperations and correct interoperability problems before they occur, despite the challenging competitive environment.

In order to achieve this, an understanding of the interoperability domain is required and a general approach to take into account existing maturity models is also needed. Figure 1.2 summarizes the objectives of the thesis.

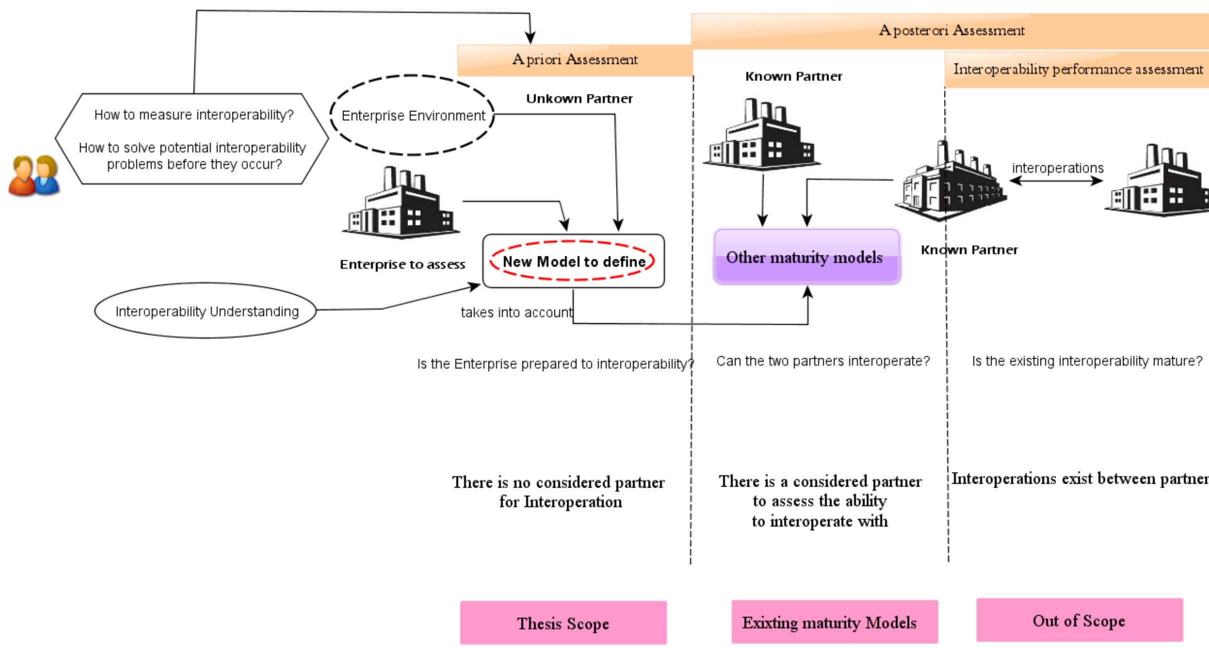

Figure 1.2. Thesis objectives

1.7. Conclusions

In this chapter, the economic and research contexts where interoperability problems have emerged and evolved were presented. Enterprise interoperability and related concepts were explored, and it is clear that there is yet to be a precise and common understanding about enterprise interoperability. Furthermore the development of enterprise interoperability is mainly driven by technology in pragmatic ways. The scientific foundation of enterprise interoperability is non-existent and the lack of measurement tools in this area is evident. Consequently defining metrics for measuring enterprise interoperability is seen as one of the research priorities in order to provide a more robust and scientific basis to this field.

Among the existing knowledge of sciences and theories, the General System Theory (GST) seems most relevant to provide a theoretical and scientific foundation for enterprise interoperability development. Based on the relevant concepts from the GST, a general formalization of the enterprise interoperability can be elaborated. To this end, it is necessary to study interacting enterprises and relevant capabilities which are defined through available interoperability frameworks and existing models through a comprehensive literature review.

Developing interoperability can raise many problems that have to be addressed to achieve targeted objectives. Solving interoperability problems is a long iterative process which can fail due to the lack of a consensus between partners or the high cost of the solution. Predicting and solving the interoperability problems before they occur is simpler than developing corrective actions. For that, enterprises need to plan and to be prepared for potential interoperations. To tackle the interoperability assessment issue, many maturity models have been proposed in the literature. However existing maturity models are insufficiently developed to deal with the interoperability *a priori* measurement, an issue which this thesis aims to address as a research priority.

Chapter 2

Enterprise Interoperability: Concepts formalization

2.1. Introduction

The main purpose of this chapter is to define and formalize the Enterprise Interoperability domain where the Maturity Model for Enterprise Interoperability (MMEI) is to be built. This formalization is necessary due to the lack of a common understanding and explicit semantics of Enterprise Interoperability concepts. The main objectives of this chapter are as follows:

1) Identify a set of key enterprise interoperability concepts to address any identified problems and solutions. This is done through the studies of existing frameworks and relevant interoperability models.
2) Devise a formalized representation of the identified concepts by developing an ontology of enterprise interoperability (OoEI). This is done based on the analysis of existing enterprise frameworks and with the help of an appropriate ontology modeling technique.

To this end, the operational entities where interoperations take place within an enterprise will first be studied. This aspect is mainly defined through various existing interoperability frameworks and models, which are reviewed in section 2.2. Section 2.3 presents a discussion and an analysis about these models and frameworks and highlights relevant underlying concepts. The objective of section 2.4 is to propose an ontology that takes into account the findings of the literature review and goes beyond to formalize identified key enterprise interoperability concepts. Finally, a concluding summary is given in section 2.5.

2.2. Existing enterprise interoperability models and frameworks

This section surveys known models and frameworks defined in the enterprise interoperability context. The main purpose of a framework is to provide an organizing mechanism so that concepts, problems and knowledge on enterprise interoperability can be represented in a more structured way (Chen et al., 2008).

2.2.1. The IDEAS Interoperability framework

The IDEAS ((Interoperability Developments for Enterprise Application and Software) interoperability framework was developed within the IDEAS project (IDEAS, 2003). It identifies three levels of interoperability: Business, knowledge and ICT systems. These three levels are related through a common semantic interface as shown in the figure 2.1.

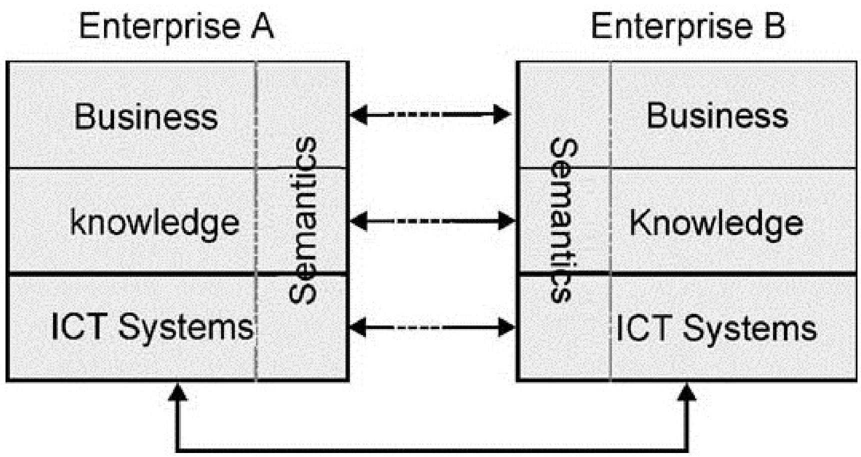

Figure 2.1. IDEAS framework overview (chen and Doumeingts, 2003)

- *Business level* is concerned with all issues related to the organization and the management of an enterprise (the way an enterprise is organized, how it operates to produce value, how it manages its relationships, etc). It includes the decisional model, the business model and business processes.
- *Knowledge level* is concerned with acquiring, structuring and representing the collective/personal knowledge of an enterprise. It includes knowledge of internal aspects such as products, the way the administration operates and controls, how the personnel are managed. It also includes external aspects such as partners and suppliers, laws and regulations, legal obligations and relationships with public institutions.
- *ICT systems level* is concerned with ICT solutions that provide interoperation between enterprise resources (i.e. software, machines and humans), allowing the enterprise to operate, make decisions and, exchange information within and outside its boundaries.

The semantic dimension cuts across the business, knowledge and ICT levels. It is concerned with capturing and representing the actual meaning of concepts and thus promoting understanding across the different levels (Chen and Doumeingts, 2003).

2.2.2. The Athena Interoperability Framework (AIF)

The main objective of the ATHENA (Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Application) Interoperability Framework (AIF) is to synthesize the research results of the ATHENA project (AIF, 2004). The framework aims at providing solution developers and integrators with guidelines on how to use the ATHENA solutions in addressing their business needs and technical requirements for interoperability (Berre et al., 2007).

The AIF is structured into three levels (Berre and Elvesæter, 2008):

- *Conceptual level* which allows identifying concepts, models, meta-models, languages and relationships required to develop interoperability.
- *Applicative level* which focuses on methodologies, standards and domain models. It provides guidelines, principles and patterns that can be used to solve interoperability problems.
- *Technical level* which focuses on the technical development and ICT environments. It provides ICT tools and platforms for developing and running enterprise application and software systems.

The AIF provides a reference model in which the modeling solutions coming from the three different research areas of ATHENA (i.e. enterprise modeling, architectures and platforms, and semantic mediation and ontology) can be related. Figure 2.2 illustrates the reference model that indicates the required and provided artefacts of two collaborating enterprises (Berre et al., 2007) (Del Grosso et al., 2011).

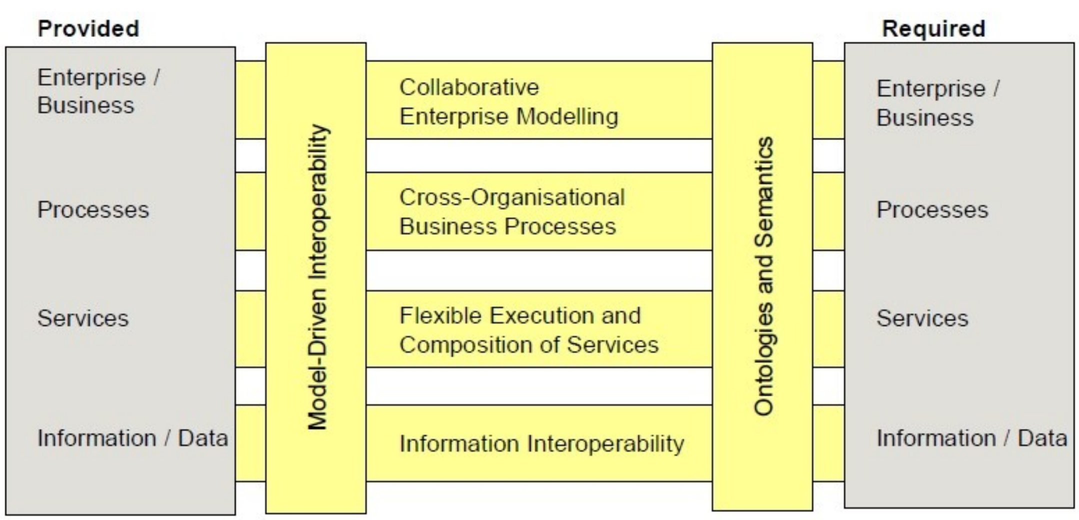

Figure 2.2. ATHENA Interoperability reference model (Berre et al., 2007)

Interoperations can take place at the various levels (enterprise/business, process, service and information/data):

- Interoperability at the *enterprise/business* level should be seen as the organizational and operational ability of an enterprise to factually cooperate with other, external organizations in spite of e.g. different working practices, legislations, cultures and commercial approaches.
- Interoperability of *processes* aims to make various processes work together. It is also concerned by connecting internal processes of two companies to create *cross-organizational business process*.
- Interoperability of *services* is concerned with identifying, composing and executing various applications (designed and implemented independently).
- Interoperability of *information/data* is related to the management, exchange and processing of different documents, messages and/or structures by different collaborating entities.

A *model-driven interoperability* approach that cuts across the four interoperability levels implies that models are used to formalize and exchange the provided and required artefacts that must be negotiated and agreed upon. ATHENA defines a set of meta-models and languages that can be supported by tools and methods to construct the models in question (Berre et al., 2007) (Del Grosso et al., 2011).

2.2.3. The European Interoperability Framework (EIF)

The EIF framework (EIF, 2004) was developed in the context of a research program funded by the European commission for the interoperability development. It aims at providing a set of recommendations and specifications to connect systems. Defined recommendations and guidelines may also be used for e-Government services so that public administrations, enterprises and citizens can interact across borders, in a pan-European context. EIF identifies three levels of interoperability: semantic, organizational and technical as illustrated in figure 2.3.

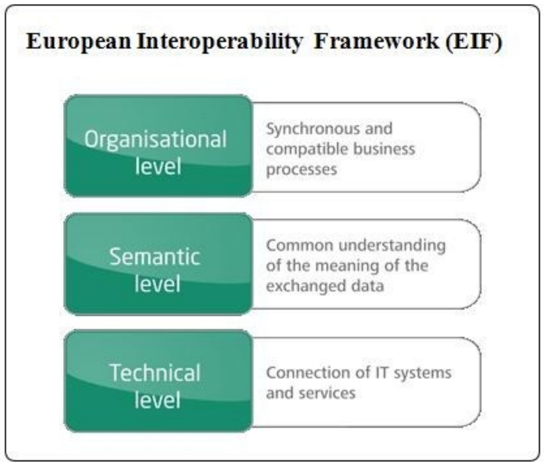

Figure 2.3. EIF framework overview

- Semantic *Interoperability* is concerned with ensuring that the precise meaning of exchanged information is understood by any application that was not initially developed for this purpose. Semantic interoperability enables systems to combine received information with other information resources and to process it in a meaningful manner.
- Organizational *Interoperability* is concerned with defining business goals, modeling business processes and bringing about the collaboration of administrations that wish to exchange information and may have different internal structures and processes.
- Technical *interoperability* covers the technical issues of linking computer systems and services. It includes key aspects such as open interfaces, interconnection services, data integration and middleware, data presentation and exchange, accessibility and security services.

2.2.4. The Framework for Enterprise Interoperability (FEI)

The Framework for Enterprise Interoperability (FEI) (Chen, 2006) was developed within the frame of INTEROP European Network of Excellence (NoE) (INTEROP, 2007). The purpose of this framework is to define the research context of the enterprise interoperability and help identifying and structuring the knowledge in this domain. FEI defines a classification scheme for interoperability knowledge according to three dimensions: *interoperability barriers*, *interoperability approaches*, and enterprise *interoperability concerns*, also called *enterprise levels*, (see figure 2.4).

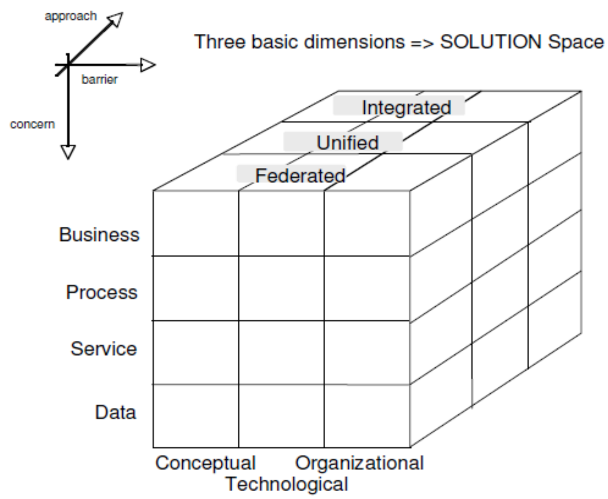

Figure 2.4. Enterprise Interoperability Framework (Chen, 2006)

- *Interoperability barriers*: According to the FEI, the establishment in interoperability consists in removing all the identified barriers. Interoperability problems exist when there are such barriers (Chen, 2006). Three kinds of barriers are identified, referring each to one of the identified interoperability levels: Conceptual, Technological, and Organizational.

    - C*onceptual* barriers relate to the syntactic and semantic differences of information to be exchanged during interoperation.
    - *Technological* barriers relate to the incompatibility of information technologies (architecture & platforms, infrastructure…).
    - O*rganizational* barriers relate to the definition of responsibilities and authorities.

- *Interoperability Concerns*: The establishment or diagnosis of enterprise interoperability leads to identify the different operational levels that are concerned. Four enterprise levels are defined in the FEI, namely *business, process, service* and *data*. They represent the areas concerned by interoperability in the enterprise.

    - *Interoperability of data* aims to make work together different data models with different query languages to share information coming from heterogeneous systems.
    - *Interoperability of services* aims at making it possible for various services or applications (designed and implemented independently) to work together by solving the syntactic and semantic differences.

- *Interoperability of processes* aims to make various processes work together. In the interworked enterprise, the aim will be to connect internal processes of two companies to create a common process.
- *Interoperability of business* aims to work in a harmonized way to share and develop business between companies despite the difference of methods, decision making, culture of the enterprises or, the commercial making.

- *Interoperability Approaches:* Deriving from ISO 14258 (ISO 14258, 1999), FEI considers the following three basic ways to relate entities together to establish interoperations:

  - *The Integrated approach* is characterized by the existence of a common format for all the constituents systems. This format is not necessarily a standard but must be agreed by all parties to elaborate models and build systems.
  - *The Unified approach*, also characterized by the existence of a common format but at a meta-level. This meta-model provides a mean for semantic equivalence to allow mapping between diverse models and systems.
  - *The Federated approach*, in which no common format is defined. This approach maintains the identity of interoperating systems; nothing is imposed by one party or another and interoperability is managed in an ad-hoc manner.

2.2.5. The E-health interoperability framework

The E-health interoperability framework (NEHTA, 2007) was developed by the National E-Health Transition Authority (NEHTA) initiatives in Australia. It defines three levels of interoperability across health organizations (see figure 2.5):

- *Organizational layer* which provide a shared policy and process framework across the E-Health interoperability agenda covering each NEHTA initiative. It includes the Business Processes, standards plan, security policies and Privacy.
- *Information layer* which provide shared building blocks for semantic (information) interchange including Foundation Components, Value Domains, Structures, common Assemblies, Relationships and Metadata.
- *Technical layer* is concerned with the connectivity of systems for information exchange and service use. Solutions are based on open standards providing a level playing field for competitive provision of technical solutions.

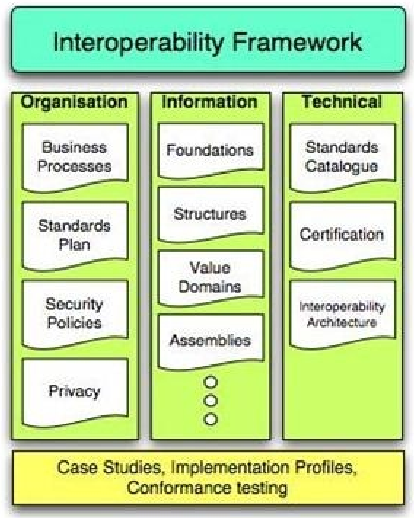

Figure 2.5. E-health interoperability framework (NEHTA, 2007)

2.2.6. Interoperability Conceptual Model (ICM)

The Interoperability Conceptual Model (ICM) is an ongoing work, developed by the MITRE Corporation (Rohatgi and Friedman, 2010) in the socio-technical context. Its purpose is to present the different interoperability dimensions (or types). ICM considers that interoperability can be classified as either technical or non-technical as shown in table 2.1.

Table 2.1. Interoperability Types (Rohatgi and Friedman, 2010)1

Technical Interoperability Types	Non Technical Interoperability Types
Data	Culture
Network	Programmatic
Service	Constructive
Application	Operational
Infrastructure	Policy
Security	Semantic (Conceptual)
Platform	Coalition
System	Organizational

In its final form, the ICM shows the nested nature of the interoperability space along with the interrelationships and interdependencies among various interoperability types in the form of UML class diagram as illustrated in figure 2.6.

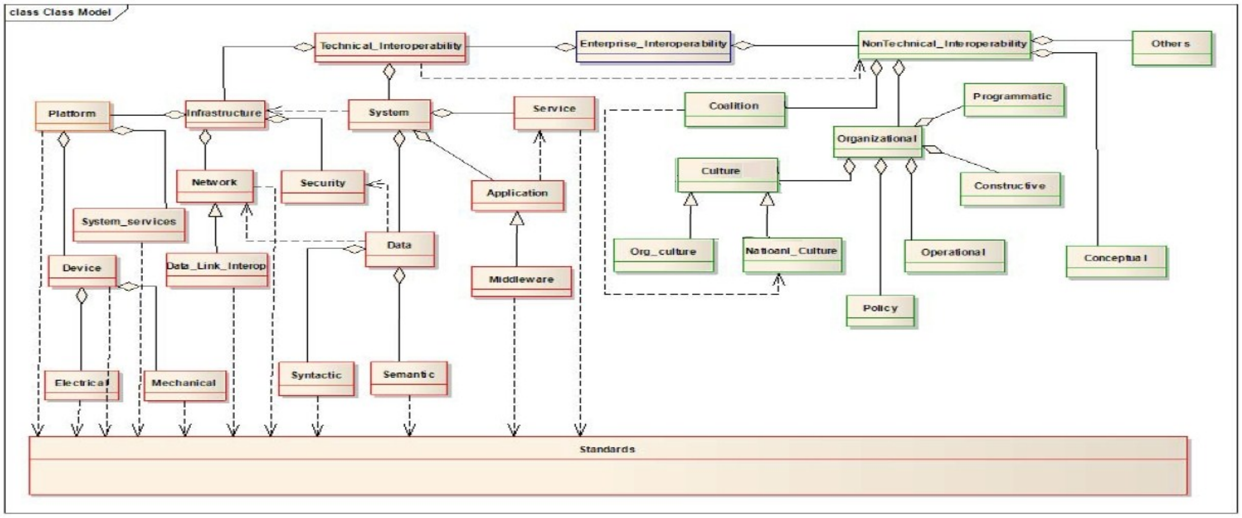

Figure 2.6. Interoperability Conceptual Model (Rohatgi and Friedman, 2010)

2.2.7. Ontology of Interoperability (OoI)

The first attempt to define the interoperability domain was made by Rosener et al. (2004), where a model for defining interoperability as a heterogeneous problem induced by a communication problem was proposed. This was followed by an enhanced model of interoperability based on three meta-models: decisional meta-model, resource composition meta-model and systemic meta-model (Rosener et al., 2005).

On the basis of these research efforts that lead, first, to a UML formalization of the Interoperability problem, the Ontology of Interoperability (OoI) (Naudet et al., 2006) was developed within the frame of INTEROP project (INTEROP, 2004), using the Ontology Web Language (OWL)[2]. This OoI aims at formally defining interoperability while providing a framework to describe problems and related solutions pertaining to the interoperability domain. It was progressively enhanced in (Ruokolainen and Kutvonen, 2006) and (Ruokolainen et al., 2007).

The approach adopted for building the OoI considers interoperability from a problem-solving perspective, not restricted to communication matters. Indeed, contrary to what can be found in most of the available definitions, interoperability is not only related to communication. The

[2] http://www.w3.org/TR/owl-features/

components of a system do not necessary have to communicate, but might simply have to be composed together for a specific purpose. This is illustrated by the following definition, proposed by Naudet et al. (2008), "*An interoperability problem appears when two or more incompatible systems are put in relation. Interoperability per se is the paradigm where an interoperability problem occurs*."

The latest version of OoI, as presented in figure 2.7 by Naudet et al. (2008), is mainly based on two models namely, the *systemic meta-model* which includes the resource composition model introduced by Rosener et al. (2005) and the *problem-solving* meta-model, also called *decisional meta-model*.

In the bottom part of the figure 2.7, the systemic model describes systems as interrelated subsystems. A *System* is composed of *SystemElement*, which are systems themselves, and *Relation*.

The *Relation* class formalizes the existing relationships inside a system, which is the source of the occurrence of interoperability problems.

The problem-solving model (in the top part of the figure 2.7) is designed within a problem-solving perspective. *Interoperability* is implemented as a subclass of the *Problem* concept. Problems of interoperability exist when there is a relation, of any kind, between incompatible systems in a super- system they belong to or system they will form (i.e. a system to build). *Incompatibility* concept is a subclass of a more generic *InteroperabilityExistenceCondition* class aiming at explicitly formalizing the fact that Incompatibility is the source of interoperability problems for systems of any nature, as soon as they belong to the same super-system and there is a relation of any kind between those systems. *Solutions* solve *problems* and can in turn induce new problems. Two kinds of solutions, namely *a priori* and *a posteriori* solutions are defined, with respect to the occurrence of the problem. Solutions solving problems by anticipation are *a priori* solutions. *A posteriori* solution can be used for solutions correcting problems after they occurred.

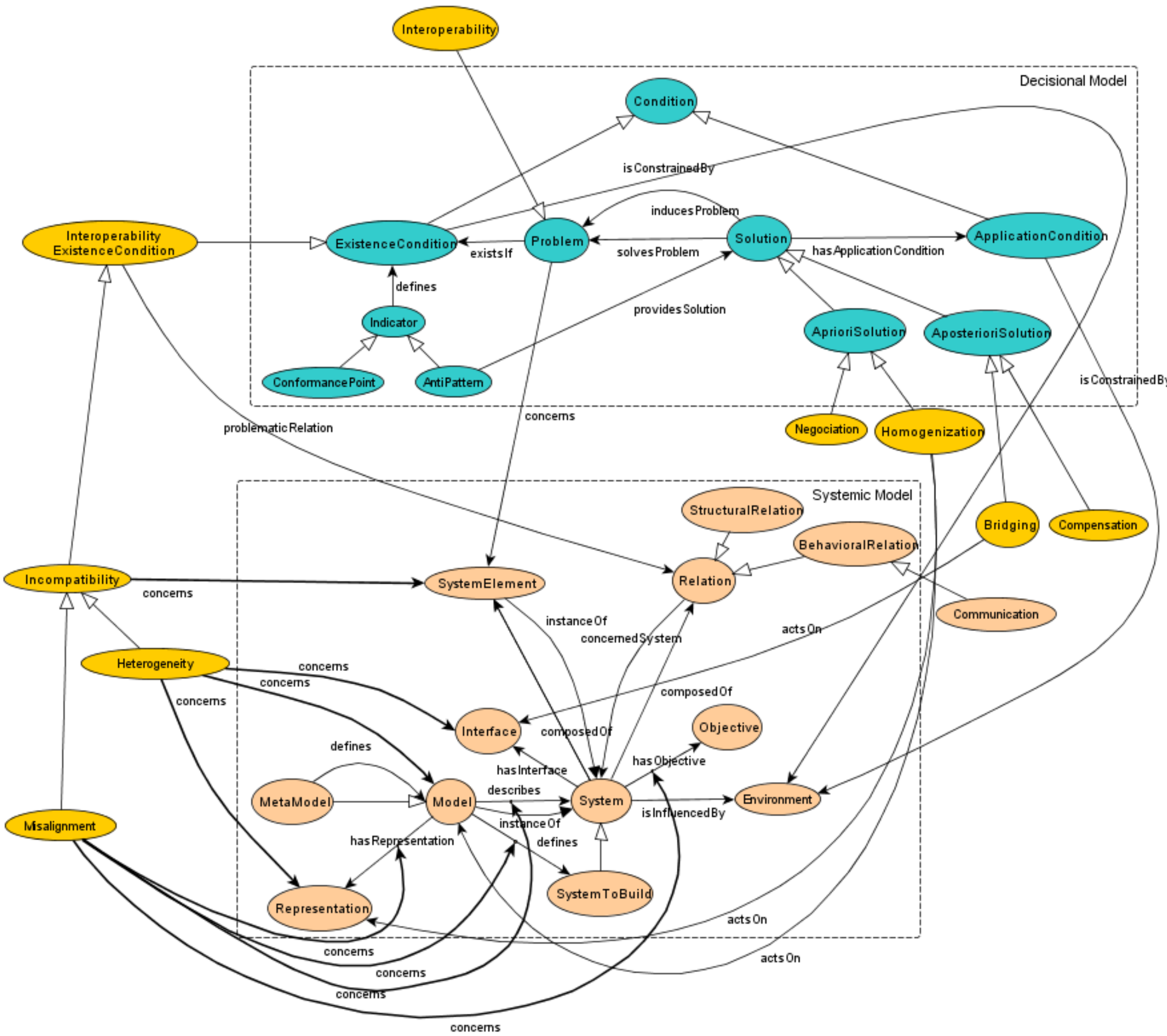

Figure 2.7. Ontology of Interoperability overview (Naudet et al., 2008)

2.3. Discussion and analysis

The IDEAS interoperability framework is the first initiative carried out in Europe to address enterprise interoperability issues. It was used as a basis to elaborate a roadmap to build ATHENA Integrated Project and INTEROP NoE. As stated by Chen et al. (2008), the IDEAS interoperability framework builds on the three relevant research domains (enterprise modeling, architecture and platform, and ontology) contributing to develop interoperability rather than on the interoperability domain itself.

Within the ATHENA project, the AIF proposes interoperability guidelines for enterprise business needs at different levels (conceptual, applicative, and technical). This reflects more interoperability solutions rather than operational entities interoperating within an enterprise. Within the same context, the ATHENA reference model defines four enterprise interoperating entities (business, process, service and data) (Berre et al., 2007). EIF and E-health frameworks propose an interoperability classification from the point of view of interoperability aspects. These interoperability aspects (semantic, technical, organizational, etc.) reflect more interoperability issues or problems rather than levels of operational entities where interoperation takes place (Chen et al. 2008). A differentiation by complementary interoperability classification was proposed by FEI by considering that interoperation concerns different levels of the enterprise namely: data, service, process and business (INTEROP, 2007). Compared to other interoperability frameworks, the FEI provides three explicitly defined interoperability dimensions (interoperability barriers, interoperability concerns and interoperability approaches) to allow defining interoperability research domain. It considers the hypothesis that interoperability problems exist because of incompatibility (i.e. obstacle to the establishment of seamless interoperation).

Although FEI aimed at defining the domain of enterprise interoperability, its main purpose remains to give a classification of the main issues in the Enterprise Interoperability (EI) domain.

In order to completely define the domain of EI, research work aiming at defining interoperability was looked into. The first attempt to define the interoperability domain is the OoI. Since then, some initiatives from the same perspective have been proposed, like e.g. the CIM model in 2010. However, as stated by its developers, CIM remains an ongoing research that requires further developments in order to be considered. Figure 2.8 summarizes the main frameworks in the enterprise interoperability context by their purpose.

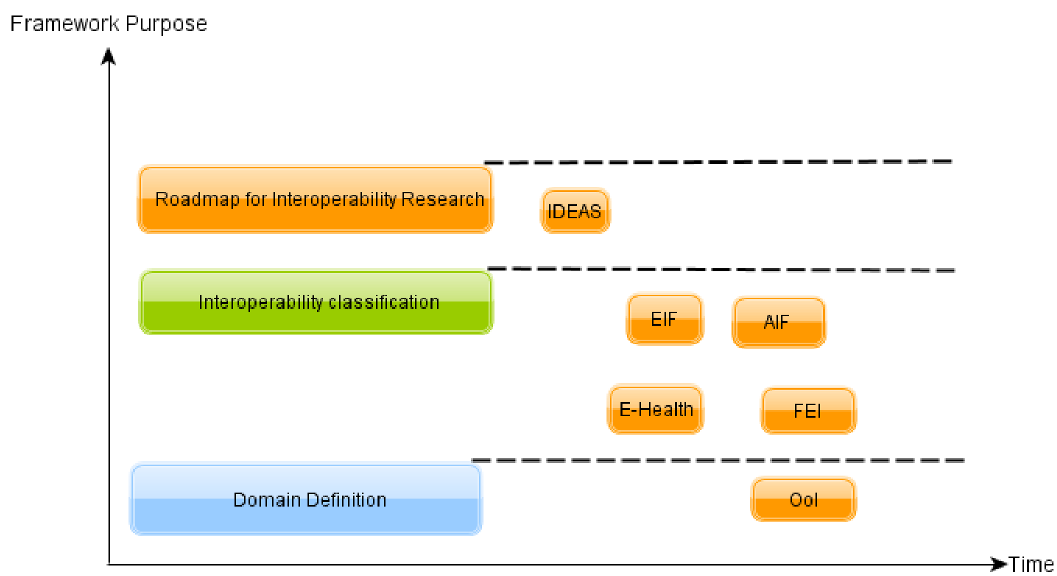

Figure 2.8. Enterprise Interoperability Frameworks Purpose

The OoI was proposed in the general context of Interoperability and needs to be tailored to a specific domain to be used (Naudet et al., 2008). Hence in order to deal with the enterprise interoperability, the OoI has to be extended to the enterprise interoperability domain. To this end, all the relevant concepts defined by the reviewed EI frameworks need to be taken into account. This is depicted by table 2.2.

FEI has a different view from other defined frameworks regarding the classification of interoperability. It considers that an interoperability problem exists because of incompatibilities, which form barriers to interoperability: conceptual, technological and organizational barriers. These barriers exist at all enterprise levels. Hence, removing them allows the establishment of conceptual, technical and organizational interoperability, respectively.

The Knowledge level proposed by IDEAS concerns collective/personal knowledge of an enterprise. It includes knowledge of internal aspects (i.e. products, the way the administration operates and controls, how the personnel is managed, etc.) and external aspects (i.e. partners and suppliers, laws and regulations, legal obligations and relationships with public institutions) (see section 2.2.1). This can be seen twofold i) the required knowledge to facilitate interoperability and ii) the required knowledge to solve interoperability problems. Knowledge is not an interoperating entity itself but a requirement within the enterprise. For that it is presented vertically with the two fields “interoperating entities” and “interoperability approaches” in the table 2.2.

Table 2.2. EI frameworks and chosen concepts for OoEI

	Ideas		***ATHENA***	***EIF***	***E-Health***	***FEI***	***Chosen Concepts for OoEI***	***Remarks***
Interoperability Classification	Semantic		Conceptual	Semantic	Information	Conceptual barrier	Conceptual Conceptual Barrier	Conceptual (semantic+ syntax) encompasses semantic and information.
	-		Applicative	Organizational	Organizational	Organizational barrier	Organizational Organizational Barrier	Applicative not relevant
	-		Technical	Technical	Technical	Technological barrier	Technical Technological barrier	
Interoperating Entities	Knowledge	Business	Business	-	-	Business	Business	Knowledge is a requirement for interoperating entities, ICT is covered by Data, service and process
			Process	-	-	Process	Process	
		ICT system	Service	-	-	Service	Service	
			Data	-	-	Data	Data	
Interoperability Approaches	Knowledge	-	-	-	-	Integrated	Integrated	Knowledge is a requirement to solve interoperability problems, approaches are only defined by FEI
		-	-	-	-	Unified	Unified	
		-	-	-	-	Federated	Federated	

Based on the chosen concepts in table 2.2, an integration of these concepts in the OoI is proposed, allowing to add a specific vocabulary, specializing the OoI in the enterprise domain and to define the Ontology of Enterprise Interoperability (OoEI), as depicted by figure 2.9. This is the purpose of the next section.

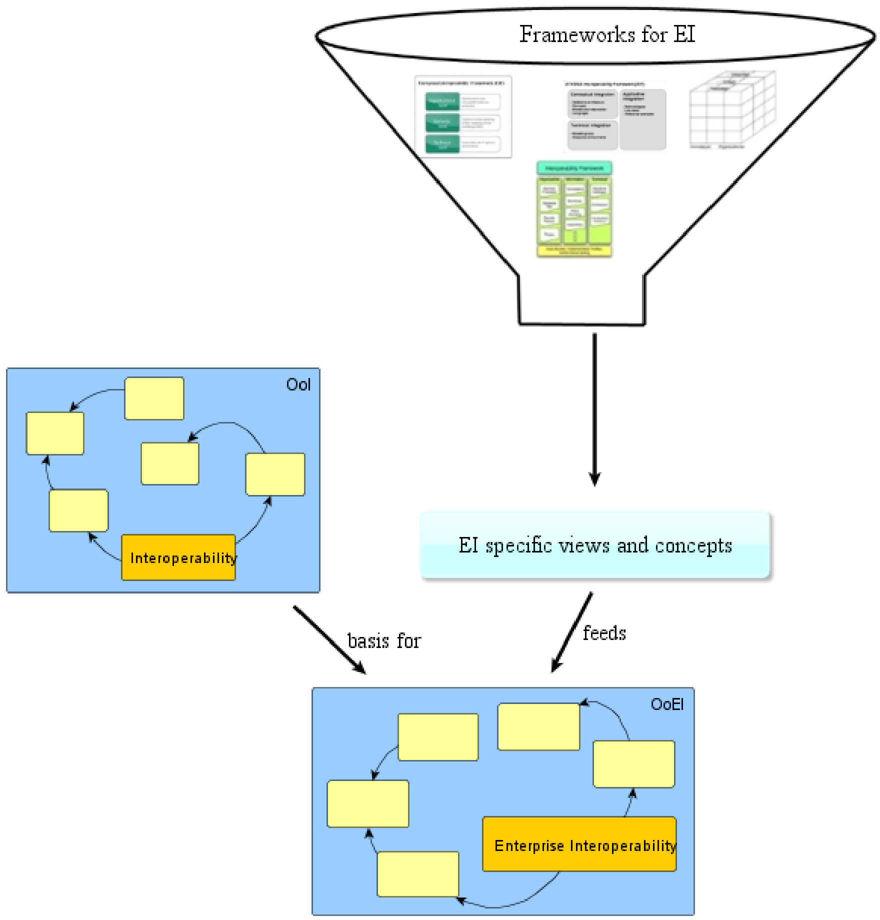

Figure 2.9. Inputs for the construction of OoEI

2.4. Towards Ontology of Enterprise Interoperability formalization (OoEI)

In this section, a definition of the Ontology of Enterprise Interoperability (OoEI) by using the OoI and relevant concepts from the existing EI frameworks is proposed. Based on the analysis completed in the previous section, concepts and properties (i.e. relations between concepts) related to the EI domain that can be integrated into OoI are defined. The different extensions are presented on conceptual graphs of the concerned OoEI part.

Before presenting this ontology, it is important to define what ontology is. There are various definitions of the modern notion of ontology. A widely adopted one is given by Gruber: "an ontology is a formal, explicit specification of a shared conceptualization" (Gruber, 1995). This definition regards the "conceptualization" as, something in the mind. Second, this conceptualization is supposed to be shared, which is the practical goal of ontologies. In this research work, the adopted view of ontology is the one used by Dietz (2006), where “the focus is on defining the core elements and their interrelationships in a most clear and extensive way” (Dietz, 2006). Nowadays, ontology has preserved its original meaning. It serves to provide a basis for the common understanding of some area of interest among a community of people who may not know each other at all, and who may have very different cultural backgrounds.

Recently, the notion of ontology has been addressed in the context of the World Wide Web, particularly in the context of the Semantic Web (Berners-Lee et al., 2001).

Based on the Enterprise Interoperability (EI) frameworks review and analysis (see section 2.3), three main dimensions of EI are considered: Interoperability aspects (conceptual, organizational and technical), Interoperating entities, also known as Enterprise Interoperability concerns in FEI (business, process, service and data) and Interoperability approaches (integrated, unified and federated). These are represented by the three concepts: *InteroperabilityAspect*, *InteroperabilityApproach*, and *InteroperabilityConcern* respectively. These are all modeled with their different constituents represented here as instances under the *EnterpriseInteroperabilityDimension* concept, as shown in figure 2.10. Added concepts are presented in green color.

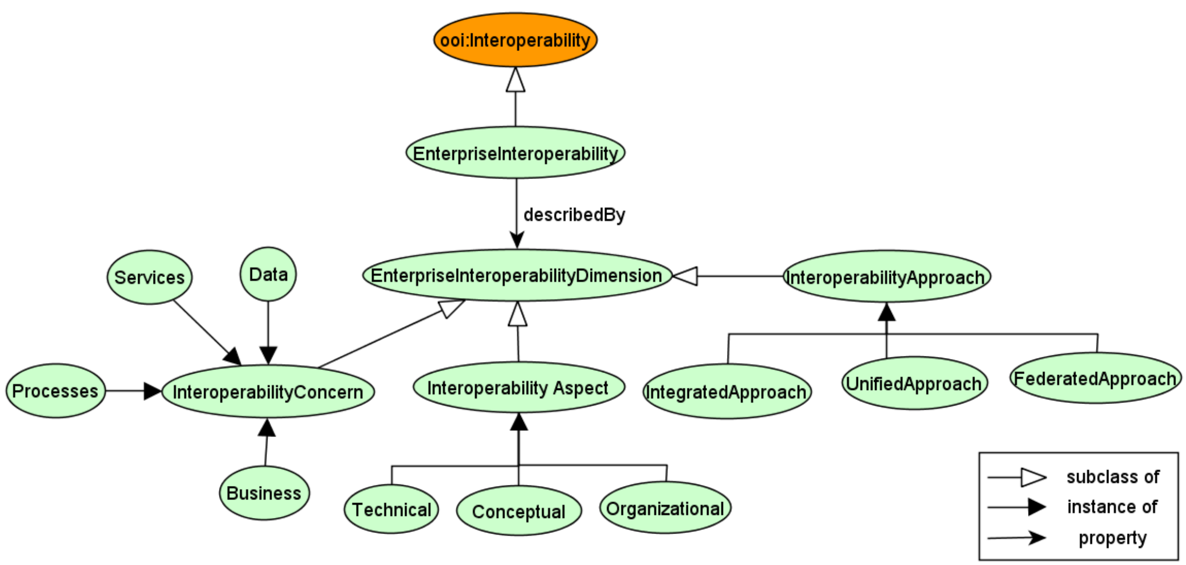

Figure 2.10. Extract from OoEI: EI dimensions’ integration into OoEI

Interoperability problems are represented by the *InteroperabilityBarrier* concept. The term barrier is defined as *an incompatibility, obstructing the sharing of information and preventing exchanging services* (Chen and Daclin, 2007). It is then assimilated (with the *equivalentClass* in figure 2.11) to the *ooi:Incompatibility* concept. The establishment of interoperability (with its three aspects) consists of removing identified barriers (conceptual barrier, organizational barrier or/and technological barrier). Hence each *InteroperabilityBarrier* is related to the corresponding *InteroperabilityAspect* (see figure 2.11).

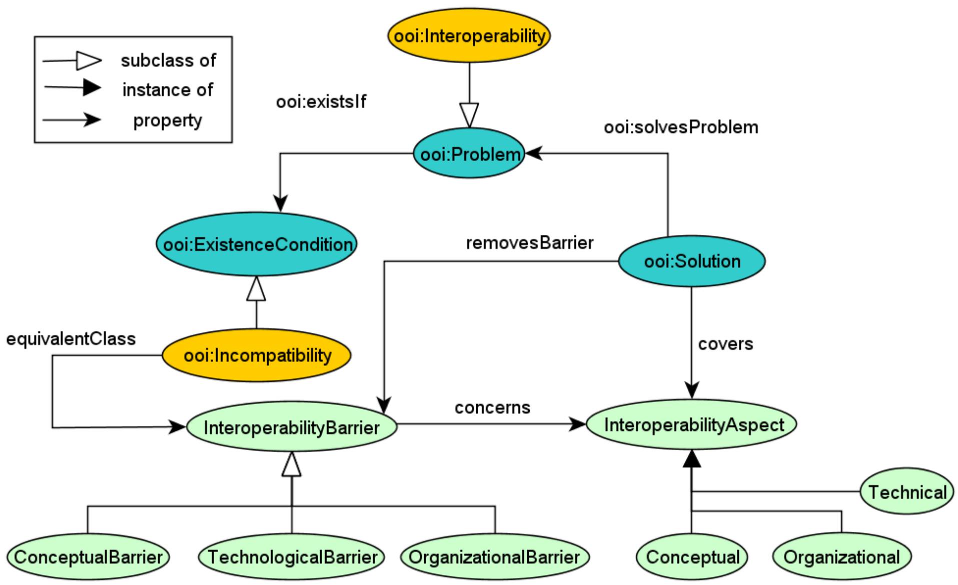

Figure 2.11. Extract from OoEI: Integration of interoperability barriers into OoEI

The inclusion of interoperability approaches (integrated, federated and unified) defines the way systems' relations causing the problems could be solved. This is modeled with the *defines* property that links *InteroperabilityApproach* to *ooi:Relation*.

Last, we consider *KnowledgeforInteroperability* concept, representing pieces of knowledge like *e.g.* PSL relevant to interoperability (INTEROP, 2007). *Knowledgeforinteroperability* instances provide solutions to remove barriers (*removes barrier* link to *InteroperabilityBarrier*) at a particular Enterprise interoperability concern (*concerns* link to *InteroperabilityConcern*), through a specific interoperability approach (*uses approach* link to *InteroperabilityApproach*). These concepts and the associated links are presented in figure 2.12.

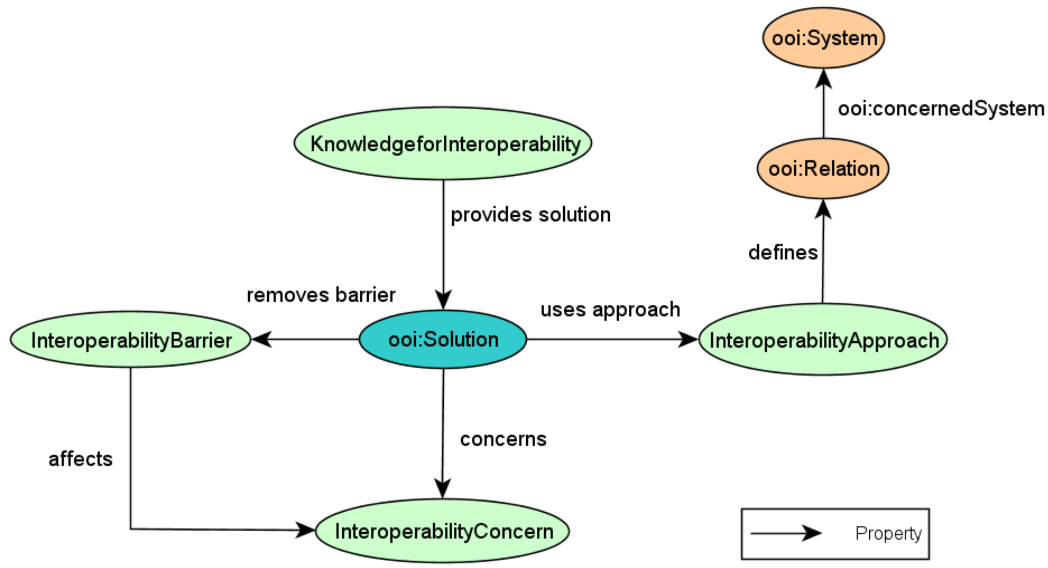

Figure 2.12. Extract from OoEI: Integration of the knowledge for interoperability into OoI

In summary, the OoEI is grounded on OoI concepts and some additional concepts specific to the EI domain that we have defined based on the review of the existing EI frameworks (see Table 2.2). Figure 2.13 gives an overview of the added concepts (i.e. in green color) of the OoEI.

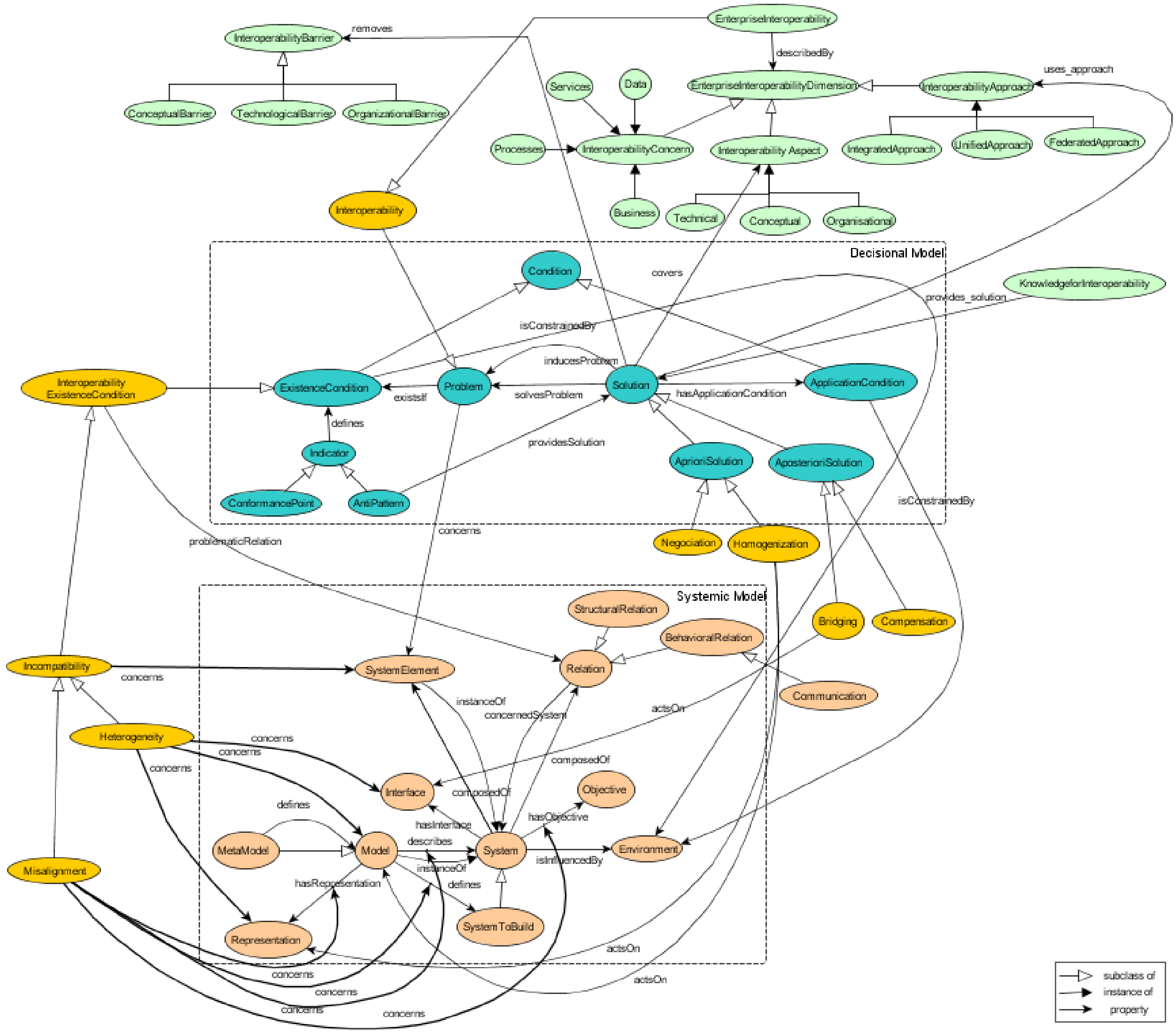

Figure 2.13. Overview of OoEI

2.5. Conclusion

This chapter has first presented a survey on frameworks and conceptual models related to the Enterprise Interoperability. An analysis of their underlying interoperability concepts has been performed with the aim of improving the understanding of enterprise interoperability and identifying a set of key EI concepts. The different operational levels of the enterprise that are concerned by interoperations, as well as the interoperability aspects and the problems that refer to them were then identified. Based on this, the OoI was extended to the enterprise domain, and the OoEI was proposed as a formal basis to represent enterprise interoperability domain.

Enterprise interoperations take place between enterprise systems. In order to ground the Maturity Model for Enterprise Interoperability on a scientific foundation, the proposed OoEI also needs to be further enhanced with additional system related concepts. To this end, a study of the general system theory that addresses the enterprise system structure and functioning is proposed. Hence, the OoEI would benefit from being further refined according to systemic elements. Indeed, enterprise interoperability concerns (also known as enterprise levels) defined in FEI can be considered as sub-systems of the enterprise containing specific elements. In the next chapter, the general system theory, considered as one of the relevant sciences for interoperability, is reviewed and relevant concepts for enterprise interoperability that can be integrated in OoEI are identified.

Chapter 3

General System Theory for Enterprise Interoperability

3.1. Introduction

Research has significantly advanced in the field of Enterprise Interoperability (EI) over the past ten years, and EI has become an important area of research, ensuring the competitiveness and growth of European enterprises. It studies the problems related to the lack of interoperability in organizations, and proposes novel methods and frameworks to contribute with innovative solutions to these problems.

However, in spite of the research developed so far, there is no established scientific foundation for EI. This is a deficit recognized by the EI research community (ENSEMBLE, 2011). The need to have an Enterprise Interoperability Science Base (EISB) was first tackled in the Enterprise Interoperability Research Roadmap, published by the European commission (EIR, 2006). The definition of an EISB was specified as one of the main challenges that needed to be addressed by researchers in the domain (ENSEMBLE, 2011) and was studied through sciences relevant to the interoperability domain.

This chapter deals with this issue and aims to contribute to developing a scientific foundation for Enterprise Interoperability. Two main objectives are defined as follows:

(1) Review existing scientific theories, in particular the system theory to identify relevant concepts and principles that can be used in the Enterprise Interoperability domain.

(2) Integrate the relevant theoretical concepts in OoEI presented in chapter 2 and propose an enhanced OoEI on which the Maturity Model for Enterprise Interoperability can be built.

The chapter is organized into 5 sections. Section 3.2 provides an outline of the scientific basis of interoperability where the choice to focus on the 'system theory' among others is discussed. Section 3.3 reviews the main system concepts, highlighting the system properties that are important for interoperability and solutions to deal with related issues from a system point of view. Then, section 3.4 proposes an enhanced OoEI including selected concepts from the general system theory and relevant systemic solutions. Finally conclusion is given in section 3.5.

3.2. Contribution to the science base for Enterprise Interoperability

The multi-disciplinary nature of the interoperability domain has led to research in various relevant sciences and scientific domains (i.e. called neighboring scientific domains in (Charalabidis et al., 2011), (ENSEMBLE, 2011)) for the establishment of the EISB. The study of neighboring scientific domains has shown that those most closely relevant to EI include social sciences and applied sciences, as well as formal sciences, represented by mathematics, systems science and computer science (ENSEMBLE, 2011). Within these domains, four scientific levels of interoperability are identified: semantics, models, tools and orchestration (Charalabidis et al., 2011), (ENSEMBLE, 2011), as shown in figure 3.1:

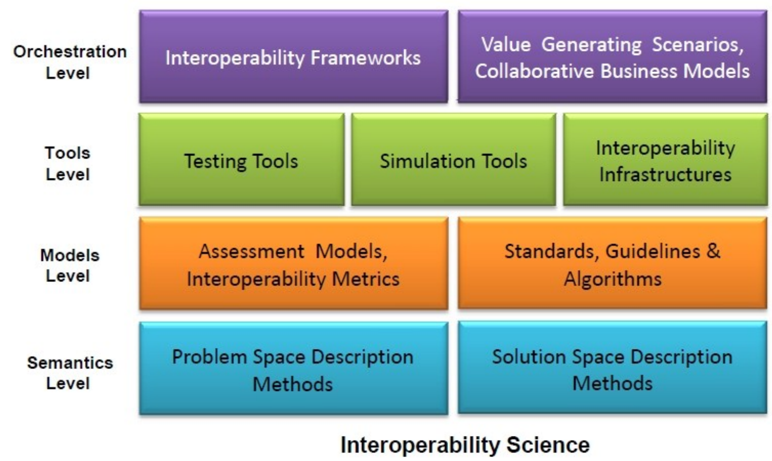

Figure 3.1. Scientific elements of Interoperability (charalabidis et al., 2011)

a) At the *level of semantics*, the mathematical domains of logic, set theory, graph theory and information theory seem to have practical applications for describing interoperability problems in a formal way. The use of patterns is also relevant in this area, both in the form of design patterns (Gamma et al., 1995) and also in the more mathematical form of general pattern theory (Grenander, 1996).

b) At the *level of models and tools*, existing knowledge in the neighboring domains of systems theory (Bertalanffy, 1968) (Lemoigne, 1990), systems engineering (Dennis, 1998), computer algorithms (Aho et al., 1974) and operational research (Ciriani et al., 1999) should be looked into. Service science (Spohrer, 2007) should also be considered in order to define models and tools for interoperability at this level.

c) At the *orchestration level*, where more generic formulations are needed, social sciences provides a sound scientific corpus, in face of economics, legal science or even public administration and management (Charalabidis et al., 2011).

In this research work, a major issue besides the EI formalization is to define a maturity model assessing EI (see Section 1.6), this can be situated at the *Models level* of interoperability (see

Figure 3.1), where the General System Theory (GST) is seen as the first theory in the list of those considered for EISB.

It is important to note that each of these neighboring sciences contributes to issues of understanding interoperability as well as setting up a science base foundation (ENSEMBLE, 2011). Among these sciences, the GST has been chosen as a basis to further define the enterprise interoperability domain. Indeed in the EI domain, there exist many systems, structures and relationships. Understanding their interactions from a system point of view is considered an important approach in developing interoperability solutions and evaluating the maturity of enterprise interoperability. The GST has a holistic view and can exceed the limits of classical theories in tackling complex problems (Naudet et al., 2009). It touches on virtually all the traditional disciplines, from mathematics, technology, and biology to philosophy and social sciences, providing a general approach that could be applied indifferently in different domains (Giachetti, 2010).

Moreover, the European Commission, in its published roadmap for Enterprise Interoperability (EIR, 2006), has also considered the system theory as one of the most important ones to develop an EISB. The general perspective provided by a systemic approach is especially important when considering the different facets of interoperability: technical, organizational, and conceptual. Indeed, the same general approach and reasoning can be adopted whatever the considered system, be it technical (*e.g.* IT systems), organizational (e.g. business rules), conceptual (e.g. models) or any combination of these. A system can be real or abstract and can belong to any part of another system including but not limited to a software component, a hardware component, a person or a business rule (Naudet et al., 2010).

3.3. General system theory: relevant concepts and principles

This section aims at conducting investigations on the General System Theory and identifying the relevant concepts and principles related to the enterprise interoperability domain.

According to Bertalanffy (1968), "*a system is defined as a set of interconnected parts, having properties that are richer than the sum of the parts' properties. A system can be characterized by the elements composing it, which can themselves be organized in sub-systems potentially interconnected*".

A more complete definition, proposed in (Giachetti, 2010) defines a system as "*a set of discernible, interacting parts or subsystems that form an integrated whole that acts with a single goal or purpose. We can draw a boundary around the system, and everything inside the boundary is part of the system, while everything outside the boundary is part of the external environment. Discernible means we can distinguish between each part or subsystem (...). A system has one or more defining functions or properties that make it a system. If no function or property can be attributed to the system as a whole, then it is just an aggregation of parts*."

Thus, a system has boundaries locating it in the super-system it belongs to and a set of specific attributes characterizing what it is and differentiating it from other systems.

Holding a system's view helps to model the real world, bounded to the limited view of the observer. In particular, this limit fixes the point where things are considered no more decomposable. Such atomic elements are not regarded as systems in the systemic ontology view (Bunge, 1979), and so are composite things having no structure of interest. During a modeling process, it is often convenient however to postulate that everything under consideration is a system. In this case, non-systems are assimilated to systems having few or no interesting properties (Naudet et al., 2010).

3.3.1. The system's views: ontological and teleological

When studying the way in which the notion of system is used in the distinct scientific disciplines, it appears that there exist two quite different system notions, which will be referred to as the teleological and the ontological system notions (Dietz, 2006).

For the ontological perspective, the work of Bunge concerning the systemic ontology field (Bunge, 1977, 1979) provides another definition of system, which is characterized by its *composition*, *environment*, and *structure*.

The teleological perspective is concerned with the function and the (external) behavior of a system, all three being based on part-of and act-upon relations (Dietz, 2006). In particular, the reference work of Le Moigne is grounded in a teleological view. Le Moigne (1990) defines a canonical form of the general system: *a set of actions in a specific active environment, in which it functions and transforms, for a specific objective.*

3.3.2. Systems and complexity

Systems can be classified in two categories: complicated systems and complex systems (Morin and Le Moigne, 1999) (Clergue, 1997). Complicated systems are characterized by a behavior that can be predicted by analyzing the interactions between components. Complex systems are systems for which the behavior cannot be predicted by such an analysis.

At a very basic level, a system is defined as being complex because it is difficult to predict its behavior and a system is complicated because it is difficult to understand its behavior but it is understandable, especially by the *system-maker* (Giachetti, 2010).

A widely held viewpoint is that complexity is due to the large number of interacting parts (Rouse, 2003). However, complexity arises from not only the number of parts in the system, but also from the interrelationships of the system parts and the emergent behavior that cannot be predicted from the individual system parts alone (Sutherland and Van Den Heuvel, 2000).

Thus, as identified by Giachetti (2010), *two characteristics make systems complex: the number of parts and the network of relationships between the parts. A system with many parts is at least complicated to understand and may also be complex. To be complex, the relationships between the parts must be such that system behavior becomes difficult to understand and predict*.

Within this context an enterprise is considered as a complex system in the sense that it has both a large number of parts and the parts are related in ways that make it difficult to understand how the enterprise operates and to predict its behavior. According to Giachetti (2010), *an enterprise is a complex, socio technical system that comprises interdependent resources of people, information, and technology that must interact with each other and their environment in support of a common mission*.

The term *enterprise* is used because it encompasses all types of organizations: companies, government, not-for-profit, supply chains, virtual enterprises, as well as parts of a company such as a division or program (Giachetti, 2010). Figure 3.2 shows the classification of different types of enterprises.

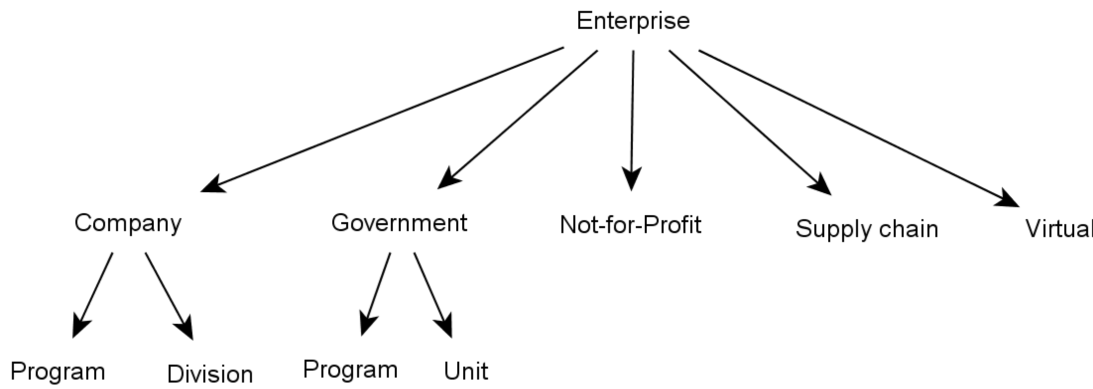

Figure 3.2. Enterprise as system classification (Giachetti, 2010)

3.3.3. Systemic approach vs reductionist approach

As we choose to have a systemic view of interoperability, it may be useful to contrast the systemic approach with the traditional reductionist one that dominates other fields such as engineering or management (Giachetti, 2010). The term reductionism refers to the practice of dividing the whole into its constituent parts, and then studying them separately (Flew, 1984). On the other hand, the term *holism* refers to the study of the whole with no division (Beed and Beed, 1996). Systemic thinking is basically a holistic conception. In the reductionist approach, a complex problem is broken up into smaller problems and each smaller problem is solved individually, and the solutions to these smaller problems are recombined to solve the original one. This approach is successful under the conditions that the interactions between the systems parts are minimal. It does not perform well when the system components have many and /or significant interactions between them.

According to Giachetti (2010), analysis has revealed the limitations of the reductionist approach. A real example for that is the one of the governments attempting to solve energy problems, transportation problems, or economic problems as if these were isolated problems. Yet in reality, changes to the availability of energy sources will have significant effects on economy and transportation.

In summary, an enterprise is a complex system that is difficult to model using a reductionist approach. Dealing with enterprise interoperability requires consideration of the enterprise from a general perspective, taking into account not only its different components and their interactions but also the environment in which it evolves. Interoperability problems must be solved globally to take into account the negative effects of solutions applied locally. Hence the GST appears more appropriate than a reductionist approach for EI.

3.4. Contribution of GST to Enterprise Interoperability

Systems theory is a way to view the world (Giachatti, 2009). It can be used as a paradigm to understand interoperability: interoperating systems, systems' interoperations and interoperability problems as well as solutions. This is particularly relevant since interoperability is about relations between systems. This section proposes that interoperability can also benefit from a systemic approach, which is moreover able to provide a framework independent from any particular domain.

Interoperability is a requirement inside a system. Its maturity depends on the kind of existing interactions or composition among its components. It is the same for the system itself, when it needs to be sufficiently flexible to interact with another system, or if it needs to be open to new components. When this ability is not achieved, interoperability becomes a problem that must be solved (Naudet et al., 2006). This assertion stays valid for whatever kind of system (Naudet et al., 2010). The general perspective provided by such a systemic approach is especially important when considering the different facets of interoperability, as defined in the European Interoperability Framework (EIF, 2004): technical, organizational, and conceptual.

3.4.1. Systemic core of interoperability

The most recognized definition of the system concept, originated from (Bertalanffy, 1968), called *general definition of system*, and often re-written by others using different words is the following: *a system is a set of interacting elements*.

As well as for the *system* concept, numerous definitions of interoperability also exist (see section 1.3). An analysis of most of them reveals that the concept of interoperability seems to be grounded in systemic. The most commonly admitted definition is provided by IEEE: *ability of two or more systems or components to exchange information and to use the information that has been exchanged* (IEEE, 1990). In this definition, the term *system* is explicitly cited, followed by *exchange* which is very close in meaning to *interact* as well as *to use* which means a functioning system. The US Department of Defense (DoD), which deals with interoperability in the military domain, considers: *the ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them* *to operate effectively together* (DoD, 2001). As for the IEEE definition, the term *system* is used and the text refers to interactions (exchange of services is a particular kind of interaction) and functioning (i.e. *to use*). In Europe, the definition issued from the Interop NoE considers: *interoperability as the ability or the aptitude of two systems that have to understand one another and to function together* (Chen et al., 2007). According to another point of view, the IDEAS project also proposes: *capacity of an enterprise software or application to interact with others* (...) (IDEAS, 2003). Both definitions confirm the smallest common factor of all the definitions, grounded in systemic: *Interoperability is about systems that interact* (Naudet et al., 2010) (see figure 3.3).

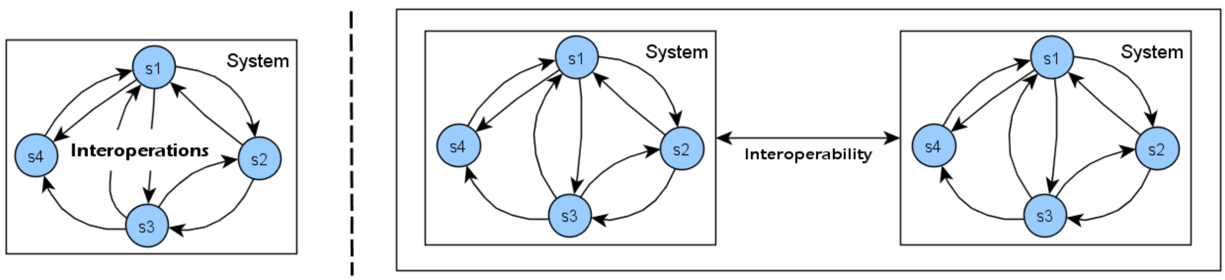

Figure 3.3. Systems interoperability

3.4.2. Systemic factors for interoperability

Several characteristics of a system can influence its ability to interoperate. Based on (Walliser, 1977), the main ones are the following:

- *The openness* of a system refers to the relationship between the system and its environment. Open systems affect and are affected by their environment (Giachetti, 2010). The opposite of an *open system* is a *closed system* that does not have any interaction with its environment. As a result of being closed, such a system cannot be interoperable.
- *Exotropic systems*, that can only send information to their environment, can be connected but have a bad interoperability since they force systems to which they connect to adapt.
- *Endotropic systems* (that only support inputs from the environment), or mixed systems have a better interoperability since they can react to their environment's inputs.
- *The stability* of a system should be considered. An unstable system will be prone to create interoperability problems due to its changing nature.

- *The adaptability* of a system is an important factor. A system that can react to changes and adapt its structure or behavior accordingly while keeping its original objective has a greater interoperability potential.
- *The reversibility* is one of the properties that interoperable system should have: even if the implementation of the interoperability between two systems leads to their adaptation or modification, these systems have to be able to come back to their initial state when interoperation ends (both from the point of view of structure and behavior).

3.4.3. Systemic solutions for interoperability

According to the work of Walliser (1977), the systems theory defines three classical ways that a system can use to adapt its organization or coordinate its sub-systems, to realize its objective: Exclusion, the rejection of a problematic sub-system; Domination, the limitation of the action field of a sub-system; Adjustment, the modification of the system's structure. These solutions can be applied in enterprise context to solve interoperability problems.

a) Exclusion

The Exclusion is a systemic solution which is defined by the rejection of a problematic subsystem. This solution is used for an interoperability problem due to a system failure or a non-adjustable system. A non-adjustable system is a system that cannot use the adjustment solution.

For example, if there is an interoperability problem, caused by a failure in an intermediary system in a production chain, that cannot be repaired, the solution is to reject this faulty system and to replace it by another one. This solution can also be used when an enterprise wants to remove a service and subcontract it to another company.

b) Adjustment

The Adjustment is a systemic solution defined by the modification of the system's structure while keeping its original objectives. It comprises the *bridging* solution (defined by OoI). The adjustment solution can be used for an interoperability problem caused by the system's structure, when the system is not adaptable. An adaptable system is an adjustable system that can react to changes and adapt its structure or behavior (Guédria et al., 2009).

For example, an interoperability problem could occur between two enterprises, because of the difference of their models; a solution to such a problem can be to insert a meta-model to facilitate the interoperation.

c) Domination

The Domination is a systemic solution which is defined by the limitation of the action field of a sub-system. This solution is applied when systems need to have a common reference or strategy for the enterprise and wish to avoid the adjustment costs. The difference between this solution and adjustment is that in the domination solution, the system does not keep its original objective instead it adopts the objective of the dominant system during the interoperation. If the same example is used with the adjustment solution, one of the systems would adopt the model of the other one.

3.5. Integration of the General System Theory to Ontology of Enterprise Interoperability

In this section we present the contribution of integrating the identified relevant concepts from the general system theory in the Ontology of Enterprise Interoperability (OoEI) proposed in chapter 2. The main enhancements of OoEI concern: 1) Validation of the existing system theory concepts of OoI, providing rigorous definitions, 2) Introduction and definition of systemic aspects not yet taken into consideration in the OoEI, 3) Integration of identified relevant system concepts in OoEI.

3.5.1. Origins of interoperability problems

From the beginning, the aim of the original work on OoI (Rosener et al., 2004), was to formally define interoperability and provide a framework to describe problems and related solutions pertaining to the interoperability domain. Hence, the point of view adopted for building the OoI (Rosener et al., 2004, 2005) considers interoperability from a problem-solving perspective, not restricted to communication matters.

Before attempting to solve any problem, the cause of the problem needs to be understood. *Interoperability* exists because there are at least two systems and a relation between them. The relation is of primary importance in the systemic view and it is the source of interoperability problems. *Problems of interoperability exist when there is a relation, of any kind, between incompatible systems in a super-system they belong to or they will form* (Rosener et al., 2005) (see figure 3.4). From this point of view, it is necessary to understand "system" and explore the nature of relations between systems.

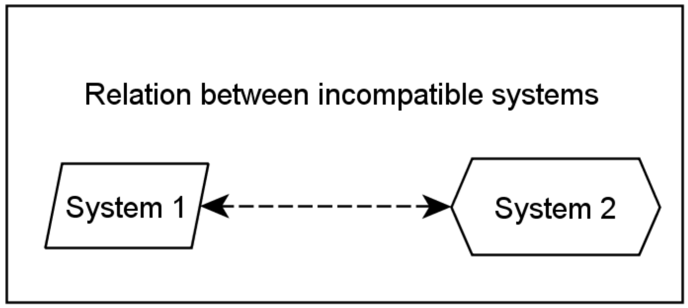

Figure 3.4. Source of interoperability problems

3.5.1.1. Understanding system

According to Walliser (1977) and Giachetti (2010), *a system is defined as a set of interconnected parts, having a structure, a function, an objective and a behavior*. These concepts are necessary to understand a system. Previous work on OoI does not explicitly use these concepts.

A *System* instance is composed of *SystemElement* instances, which are systems themselves, and *Relation* instances. In the following, previous and newly introduced system concepts to OoEI are defined.

Definition 3.1 *(SystemElement*). The specific term of *SystemElement* was introduced by Naudet et al. (2008), to highlight the *part-of* relation existing with the system. A system element is a component of a system. When assuming that all is system, system elements are systems that are parts of a super-system.

This simple view of a system also enables the representation of a system of systems, in whichever way the systems are related. The *Relation* class formalizes the relationships inside a system. They are particularly important since they are the only potential sources of interoperability problems. From a system's point of view, relations can be local or general (Walliser, 1977): between the system's elements or between the system and its environment. As a consequence, *Relation* is directly linked to *System*, through the *concernedSystem* property.

Definition 3.2 *(Relation)*. A relation is a link between two things, whatever the nature of this link.

The original definition of a system was centered on the concept of interacting elements (Bertalanffy, 1968). However the term relation is also used indifferently (Durand, 1979) (Naudet et al., 2006). Interaction is commonly defined as the mutual influence between two things. However, some differences exist between both terms: ‘interaction’ bears a dynamic aspect and implies behavior whilst the term ’relation’ can be structural. Things can be in relation while not interacting.

For modeling interoperability, the term relation is chosen (Rosener et al., 2005). However if interoperability is restricted to communication problems, the term interaction should be used instead. Finally, it is important to note that systems can be loosely or tightly coupled. The last case refers to system integration rather than interoperability.

The OoI formalizes the central concepts of *System* and *Model*. A model is considered with the same generality level as a system, according to the following definition, adapted from (Walliser, 1977) and (Le Moigne, 1994):

Definition 3.3 *(Model)*. A model is a simplified representation of a concrete or abstract reality, having a particular purpose (description, cognition, prediction, simulation, decision, etc.).

A model either describes an observed system, or defines a system to be built. A system can be defined or described by many different models, potentially overlapping, and realized for different purposes.

Systemically speaking, a model is also a system, with its own objective, composed of a mental representation which is its essence, and a set of structured symbols constituting its concrete formalization as an instantiation of a language: this will be referred to as the model’s representation. A model can also be a *MetaModel*, used to define a model. Meta-models are particularly useful for interoperability. In a unified approach, a meta-model is used for mappings, to solve some interoperability problems (see section 2.2.4).

Definition 3.4 *(Representation)*. Representation is the aggregation of symbols used to materialize a model. It includes the syntax and semantics of a concrete model, and carries the model’s pragmatic aspect that defines its possible uses.

The *Representation* of a model is, actually, a system constituting the perceivable formalization of this model. Models’ representations will be of particular importance when discussing syntactic issues in interoperability.

According to the definition of a system (see section 3.5.1.1), the *System* class is linked to *Function*, *Objective* and *Environment*. Hence *Function* class is added to OoEI and linked to *system* class by hasFunction property. Based on the canonical form of a general system given by Le Moigne (1990), the *function* of a system is defined as follows:

Definition 3.5 *(Function)***.** A system's function is the set of actions the system can execute in its environment, in order to realize its objective. The function is a property of the system representing what the system is meant for. *A system has one or more defining functions or properties that make it a system. If no function can be attributed to the system as a whole, then it is just an aggregation of parts* (Giachetti, 2010). The function of the system allows the detection of problems during inter-operation. An example for this is when a system is used for performing an action it is not able or supposed to do. In the context of interoperability, some situations require that a system has the ability to use the functionality of another system. Accessibility of a function by a third system is thus one important issue.

Definition 3.6 *(Objective)*. The objective or finality represents the system's goal at a given time. The objective of a system is often composed of sub-objectives and can change according to the situation. According to Aristotelian thinking, structure and function of a system are directly influenced by the objective (Le Moigne, 1994). An inter-operation conflicting with an objective is an interoperability problem, and an adaptation of a system's objective is often obtained by modifications of the structure or function. From an integration perspective, it is important to ensure consistency between the global objective of a system and local objectives of its components (or sub-systems). From an interoperability perspective, the consistency of objectives is not necessarily mandatory (notion of exchange of services).

Definition 3.*7* *(Environment)*. The environment represents anything that is outside a system's boundaries.

The environment is itself a system. As stated by Walliser (1977), we can consider two kinds of environments: the specific system's environment that acts on or is enacted by the system, and the global environment which is its complement in the universe (see figure 3.5). The global environment begins where the system is no longer influenced by others or influences others. The specific system's environment imposes constraints on a system, and also on the existence of a problem and application conditions of a solution.

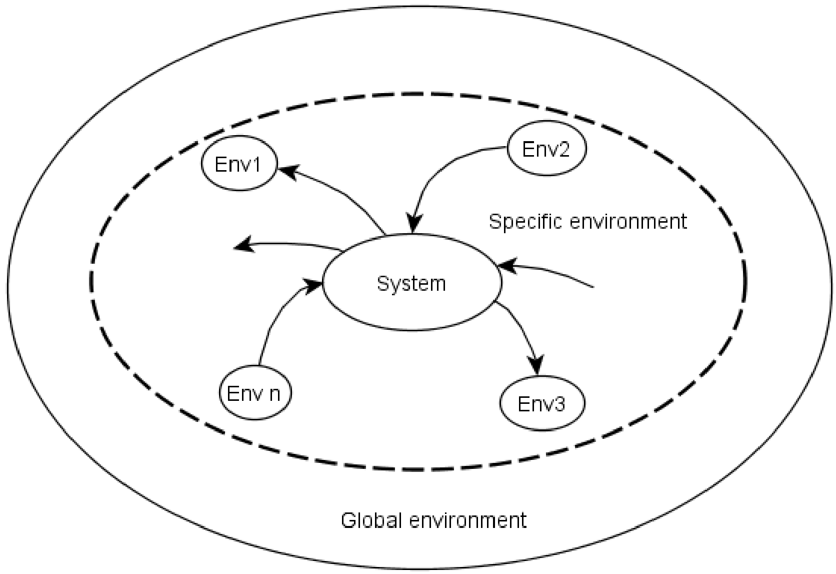

Figure 3.5. System environments, adopted from (Walliser, 1977)

Definition 3.8 *(Interface)*. The interface is a system's element through which a connection between the system and its environment can be established. It also represents the system's boundaries.

The interfaces are important for developing interoperability: open and configurable interfaces are preferred to closed and rigid ones. Design principles for high interoperability potential interfaces still need to be elaborated and considered as an a priori solution to build interoperable systems at the design phase.

Following the ontological and teleological views, it is useful to consider and define the notions of structure and behavior, which both characterize a system but at different granularity levels. These two concepts are added to OoEI and defined in the following.

Definition 3.9 *(Structure)*. The structure materializes the order in a system, or the organization of a system's elements and their relationships at a given time; it can be viewed as the system's form. A system's structure is not unique as soon as the system can evolve (Le Moigne, 1994). Viewed simply as the skeleton of the system, the structure is constituted by all the physical parts of the system: its elements, relations, and interface. This definition aggregates different assertions provided by Durand (1979), LeMoigne (1990) and Li (2005).

Definition 3.10 *(Behavior)*. Behavior can be defined as the manifestation of function in the course of time, i.e. the way the system acts and reacts (Dietz, 2006). It represents the running actions and transformations of the system, usually in relation to the environment. Behavior embraces the notions of function and objective.

The interoperability of systems that have predictable behaviors can be better quantified since their inputs and outputs can be matched more easily with other systems. This is true for causal and deterministic systems. However, it is much more difficult for complex systems, like enterprises, where interoperability is hardly predictable.

Structure and Behavior concepts are linked to the system class by the hasStructure and hasBehavior properties respectively. Figure 3.6 illustrates the system concepts (i.e. in green color) added into OoEI and their corresponding properties.

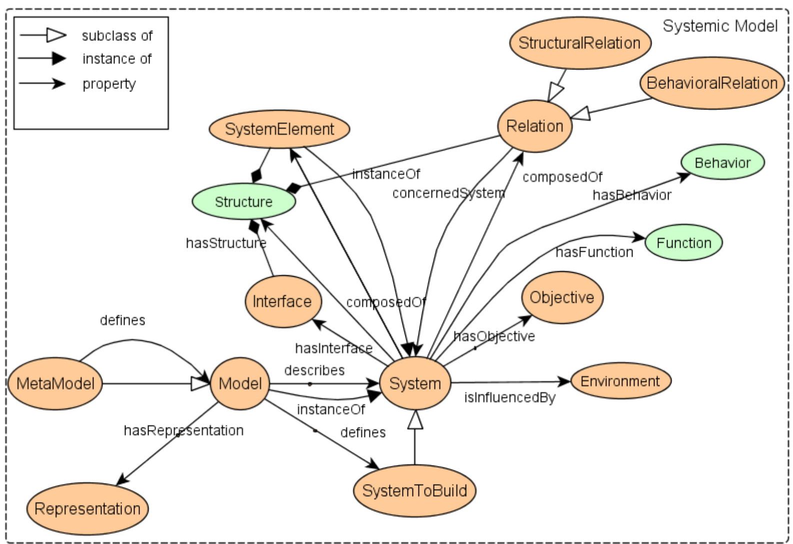

Figure 3.6. Enhanced OoEI with the three system concepts (structure, function and behavior)

3.5.1.2. Understanding systems relations

According to (Walliser, 1977), there are two types of relationships between systems: *local relations* and *general relations*. *Local relations refer to relations between each couple of sub systems of the system. This is related to the relations within the system's structure. General relations are non-local relations. They have direct influence on systems without being related to a particular subsystem*. This kind of relations do not concern the system's structure itself but any relation that influences the system's behavior without being related to an element of the system's structure. Naudet et al. (2008) presented two kinds of relations: structural and behavioral relations, but no definition was given. Thus, a coherent definition of these concepts, based on the definitions of system relationships, is needed.

Definition 3.11. A *structural relation* represents a *local relation* between systems. It relates to the *structure* of the related systems and concerns their *interfaces*, their *models* or the *representation* of their models.

Definition 3.12. A *behavioral relation* represents a *general relation*. It relates to the *behavior* of a system and concerns either its relation with the environment, its objective, its function inside a super system or the relation between its objective and the functionality of its component systems.

Incompatibility problems can then be divided into two sub-problems: incompatibility related to *structural relations*, called *structural incompatibility* and incompatibility related to *behavioral relations*, called *behavioral incompatibility*.

The *incompatibility* concept was introduced in (Ruokolainen et al., 2007) as follows: "*an interoperability problem occurs when some connected resources are heterogeneous. The heterogeneity can only occur between resources of a same nature, at a same holistic level in the system. (…). We consider the general concept of incompatibility, which is then partitioned into two kinds: Heterogeneity and Misalignment. Incompatibility concerns resources of any nature*."

According to the definition, *incompatibility* is introduced as a general concept covering both the notions of heterogeneity and misalignment. However, no precise definition was given to understand the concept itself which doesn't fit to the practical goal of an ontology in defining the core elements and their relationships in a most clear and extensive way (see section 2.4).

Incompatibility was studied in many domains and has different meanings depending on the area where it is defined (Brandom, 2010) (Kopac, 2006) (Das, 1973). Following a general point of view, the definition proposed by Perkmann (1998) has been adopted for the purpose of this research: *A systemic incompatibility can be defined as a dysfunctional interaction between parts of 'systems' or between 'systems'. Thus, incompatibilities are a 'failure' of a system to perform 'properly'.*

This definition is coherent in the OoI context. Incompatible systems induce a dysfunctional relation when put in contact, which by definition is an issue regarding interoperability. With reference to OoI, the incompatibility class is partitioned into *Heterogeneity* and *Misalignment*.

According to Ruokolainen et al. (2007), *"Heterogeneity relates to resources of the same nature"*. It concerns incompatibilities between models, interfaces, system elements, etc. This is related to the structural incompatibility or behavioral incompatibility. Hence *Heterogeneity* class is divided into *StructuralHeterogeneity* and *BehavioralHeterogeneity* that are related respectively to *StructuralIncompatibility* and *BehavioralIncompatibility* by *concerns* properties (Guédria et al., 2009a). *Misalignment can be observed when one resource constraints the way another one will be built, structured or will behave. The two resources are in this case of different nature"* (Ruokolainen et al., 2007). *Misalignment* can occur between a model and a system, a model and an interface, two models, two systems, etc. Generally speaking, it can occur between a system structure and its behavior, two systems structures or two systems behaviors. Hence *Misalignment* is related to the *Structuralincompatibility* and *Behavioralincompatibility* concepts by the *concerns* properties. Figure 3.7 summarizes the related changes and enhancements in the OoEI. The added concepts are presented in green color.

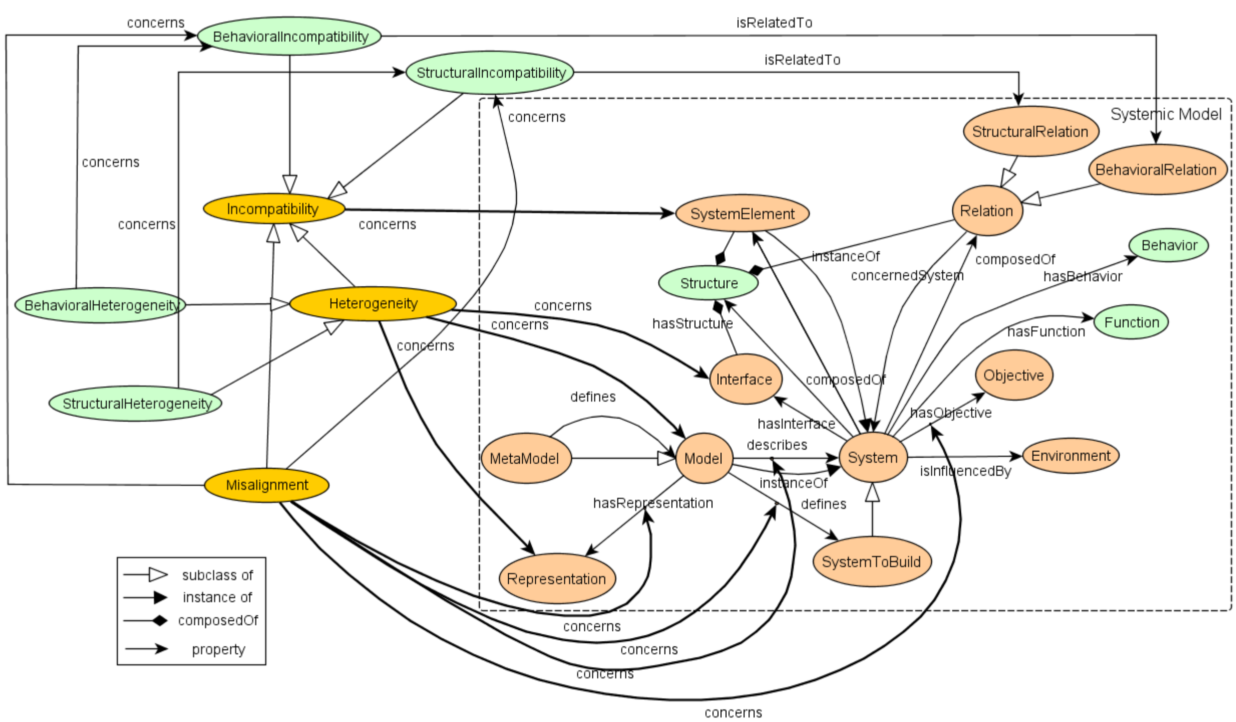

Figure 3.7. Integration of Structural and Behavioral incompatibility concepts into OoEI

Now that, sources of interoperability problems are defined and formalized from system theory point of view, the next sections present additional modifications and enhancements carried out with the adoption of system's solutions concepts.

3.5.2. Systemic solutions and additional OoEI enhancement

Two general types of solutions have been defined, classified into *a priori* or *a posteriori* solutions depending on their ability to solve the problem before or after its occurrence (see section 2.2.7). At a systemic level, such classical solutions are *bridging*, applied a posteriori by the insertion of a new sub-system connecting the problematic ones, and *homogenization* applied *a priori* on the problematic systems' models to insure their compatibility. Going back to the work of Walliser (1977), the systems theory provides more generic solutions, by defining three classical ways that a system can use to adapt its organization or coordinate its sub-systems (see section 3.4.3):

- *Exclusion*, the rejection of a problematic sub-system;
- *Domination*, the limitation of the action field of a sub-system;
- *Adjustment*, the modification of the system's structure, which comprises the bridging solution.

Consequently, these systemic solutions are integrated to the OoEI under the *Coordination* concept. Systemic solutions act on structure by rejecting a system element, adopting a method of work, homogenizing two models, etc. They also act on the system behavior through numerous ways such as limiting some functions of the system, dominating some function in favor of others, or rejecting some objectives. As a consequence, the *Coordination* concept is linked to *Structure* and *Behavior* concepts by the *ActsOn* property. This is illustrated by figure 3.8.

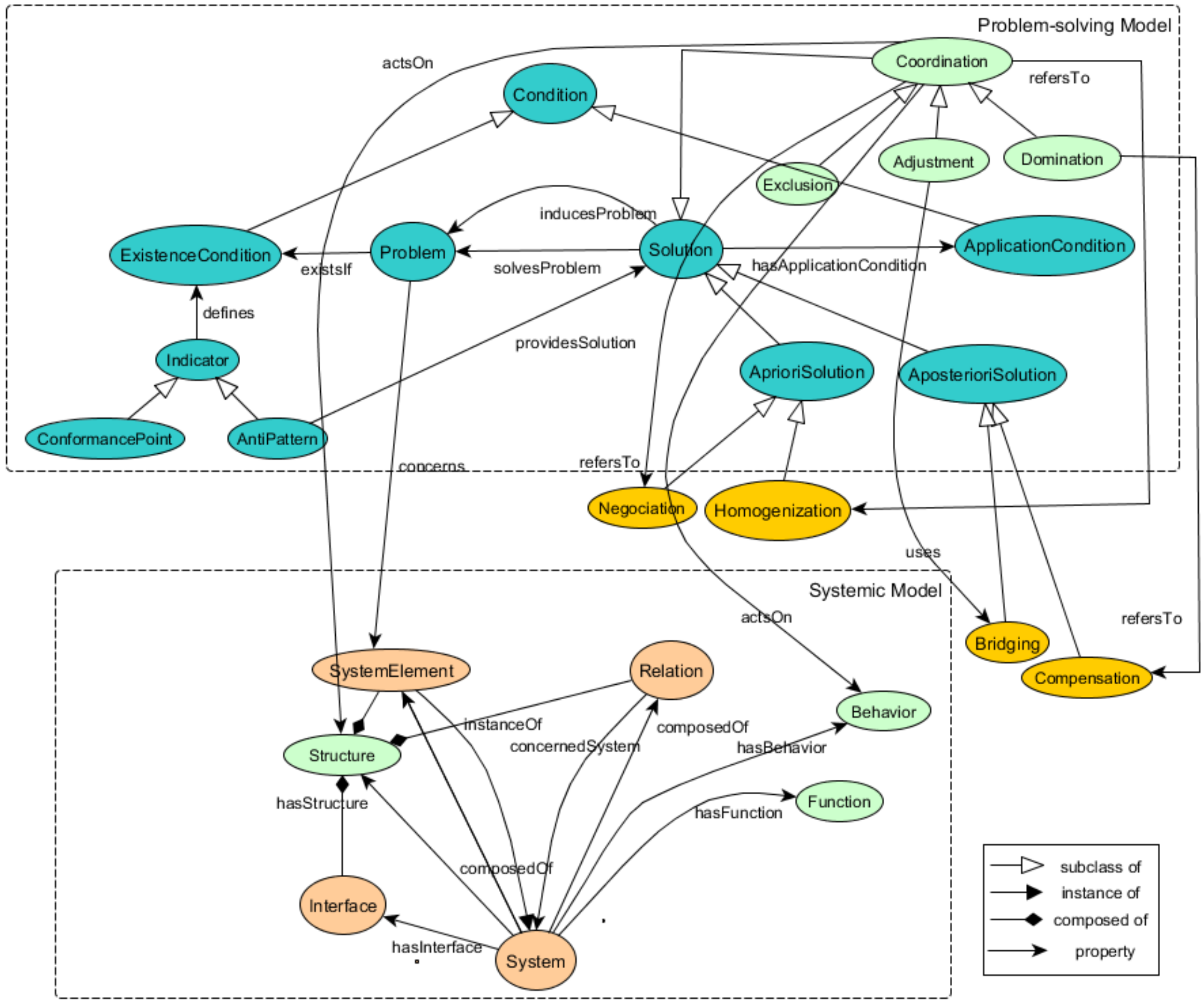

Figure 3.8. Integration of systemic solutions into the OoEI

With the systemic modeling provided by OoEI, conceptual interoperability barriers concern systems of the enterprise, linked by a structural relation, at the level of their models, which define the representation of the inputted or outputted information model. Solutions to such a problem can be, a) adjusting one or both of the systems; b) homogenizing the concerned models and rebuilding the systems; c) adjusting the enterprise system by inserting a bridge for information translation (software, hardware, or human translator).

Technological barriers relate to problems linked with the use of information technologies (architecture and platforms, infrastructure, etc.). From a systemic point of view, technical interoperability mainly concerns structural relations in the enterprise. This includes interfaces as well as models of IT elements: interfaces when some connections are prevented because incompatibles standards are used, models when connections can be made but lead to inconsistent use (for example: incompatibility between data and a database structure, unsuitable processing algorithm). Examples of technological barriers are legions at different systemic levels. Problems exist when systems use different communication protocols (behavioral incompatibility); have different models of data storage; or when one system requires functions other systems do not have. Solutions to such problems can be a) adjusting the enterprise system by inserting a bridge for system communication (software, hardware); b) adjusting one or both of the systems; or c) homogenizing their functions.

Organizational barriers relate to the definition of responsibility and authority so that interoperability can take place under good conditions. Such barriers appear when a system does not follow the enterprise's organization or when it is not aligned with business rules or processes; or when one of two interoperating enterprise-as-systems, S1 and S2, do not understand how the other is organized or managed. This can be a problem of structure, when e.g. S1 does not know to whom documents are addressed or signatures are requested; a problem of function when, e.g., S1 works with a specific business rule not known by or incompatible with S2; a problem of model when, e.g., business processes are not defined in the same way. Solutions to such problems can be a) adjusting one or both of the systems by, e.g., modifying problematic business rules and processes, b) homogenizing the concerned models, c) adjusting the enterprise system by defining all responsibilities and authorities to facilitate systems' communication.

When considering interoperability approaches to be applied in the building of an interoperation framework, models or systems of the whole enterprise are considered, comprising models of information to be exchanged by sub-systems that are interoperating.

The three interoperability approaches (i.e. integrated, unified and federated) can be used as *a priori* or *a posteriori* solutions. The integrated approach consists of using a common template for the representation of all the concerned models or for building systems. In the unified approach, a meta-model is used and serves as a common reference to map models' semantics and syntax, and thus their representation. At the level of systems, this meta-model could be used in a bridging system. In the federated approach, a dynamic adaptation of the models or sub-systems is performed (Bénaben et al., 2008) (Truptil et al., 2011). Contrary to the two other approaches, nothing is imposed and the interoperability problems are corrected when the whole system is running. At a systemic level this is a type of coordination.

3.5.3. Discussion

The establishment or diagnosis of enterprise interoperability leads to the identification of the different operational levels of concerned enterprises, as well as the interoperability aspects. In the FEI, enterprise interoperability concerns and interoperability barriers both define schemes to classify interoperability issues but do not allow precise identification of an enterprise element. Both would benefit from being further refined according to systemic elements. Indeed, enterprise interoperability concerns, defined by the FEI could be considered as sub-systems of the enterprise containing specific elements. Using a complete systemic model of the enterprise instead would help locate problems and solutions for interoperability with better granularity (Braesch and Haurat, 1995). With a systemic approach, an enterprise can be modeled as three main sub-systems (Le Moigne, 1994): an *operating or physical system* that transforms inputs flows into outputs, according to a defined goal; *a decisional or pilot system* that takes decisions; and *an information system* insuring information distribution and linking the two other systems. Today, this decomposition constitutes a basis for most systemic enterprise modeling techniques, and in particular for the GRAI model (Doumeingts et al., 1998), developed at the University of Bordeaux 1. Interoperability in the physical system is concerned with the interoperation of physical facilities through the product flow. For the decision system, taking into account interoperability implies making decisions so that the impact on the enterprise systems can be minimized. The information systems interoperability concerns the exchange of information between the two systems: it is thus directly related to conceptual interoperability.

The approaches proposed by the FEI to remove interoperability barriers, take a specific view to the enterprise that does not cover all systemic solutions but can be related to systemic concepts. Both *integrated* and *unified* approaches can be used as *a priori* or *a posteriori* solutions. The *integrated* approach consists of using a common template for the representation of all the concerned models or for building systems. Finally, in the unified approach, a meta-model is used and serves as a common reference to map models' semantics and syntax, and thus their representation. At the level of systems, this meta-model could be used in a bridging system. In the *federated approach*, a dynamic adaptation of the models or sub-systems is performed. Contrary to the two other approaches, nothing is imposed and the interoperability problems are corrected when the whole system is running. At a systemic level, this is a kind of *coordination*, which can be used as an *a priori* as well as an *a posteriori solution*. It contains the systemic solutions: exclusion, adjustment and domination.

3.6. Conclusion

In this chapter, the close link between Systems science (through the GST) and Enterprise Interoperability has been highlighted. Interoperability is a systemic concept by nature. Moreover, the enterprise is a complex system in the sense that it is not obvious to understand or predict its behavior. An enterprise should also be an open system since it interacts with its environment to meet its objectives.

The System theory has been investigated starting from its origins and the set of system concepts defined in relation to enterprise interoperability problems and solutions characterization. Aspects related to systems that are relevant to enterprise interoperability have been discussed.

Hence, the OoEI has been enhanced, by adding concepts from the system theory. In particular, the concept of *incompatibility* has been clarified and the general concepts of *structural incompatibility* and *behavioral incompatibility* added. The OoEI is extended with: (1) *structure, behav*ior and *function* concepts, to best follow a systemic approach, (2) *adjustment, exclusion* and *domination* concepts, to cover additional interoperability problems especially those related to the system structure and behavior.

The enhanced OoEI can be used as a basis for decision-aids in different domains. Each domain would add its own specific concepts and relations to allow the description of related problems and solutions. In order to avoid these problems and improve its ability to interoperate, it is very important for an enterprise to assess the current state and plan future actions to undertake. In particular, enterprises need to be prepared for interoperability in order to implement corrective actions before problems occur. To this end, an enterprise needs to assess its potential ability to interoperate. This is the purpose of the next chapter.

Chapter 4

MMEI: A Maturity Model for Enterprise Interoperability

4.1. Introduction

Among other needs, enterprises have to define their interoperability strategy and enhance their ability to interoperate. This can be achieved with the help of interoperability assessment. In a broader sense, assessing interoperability maturity allows a company to know its strengths and weaknesses in terms of interoperability with its current and potential partners, and to prioritize further actions for improvement. The objective of this chapter is to define a Maturity Model for Enterprise Interoperability that takes into account relevant existing maturity models while extending the coverage of the interoperability domain. The associated assessment methodology is also described to support the use of the proposed maturity model.

The chapter is structured as follows. In section 4.2 the different existing interoperability assessment approaches and the positioning of this research work within the research context are presented. Section 4.3 reviews the main known existing interoperability maturity models. Section 4.4 analyses these models and identifies the gaps in this research domain in order to define a new maturity model: the Maturity Model for Enterprise Interoperability (MMEI). Section 4.5 describes in detail the proposed MMEI. Section 4.6 then presents the associated assessment methodology. Best practices that an enterprise has to follow to improve its interoperability potential to reach higher maturity levels are outlined in section 4.7. Finally section 4.8 concludes this chapter.

4.2. Interoperability assessment: review and positioning

Many methods have been proposed in the literature to deal with interoperability assessment. Ford (2008) provides an overview of these methods. Each method can be classified as maturity model (i.e. leveling method) and non-maturity model-based (i.e. non leveling method). Generally, it is applicable to only one system and interoperability type (Ford, 2008). Figure 4.1 presents the chronology of the published interoperability measurement methods. Non-maturity model-based methods are shown in italics; maturity model-based methods are shown in boldface.

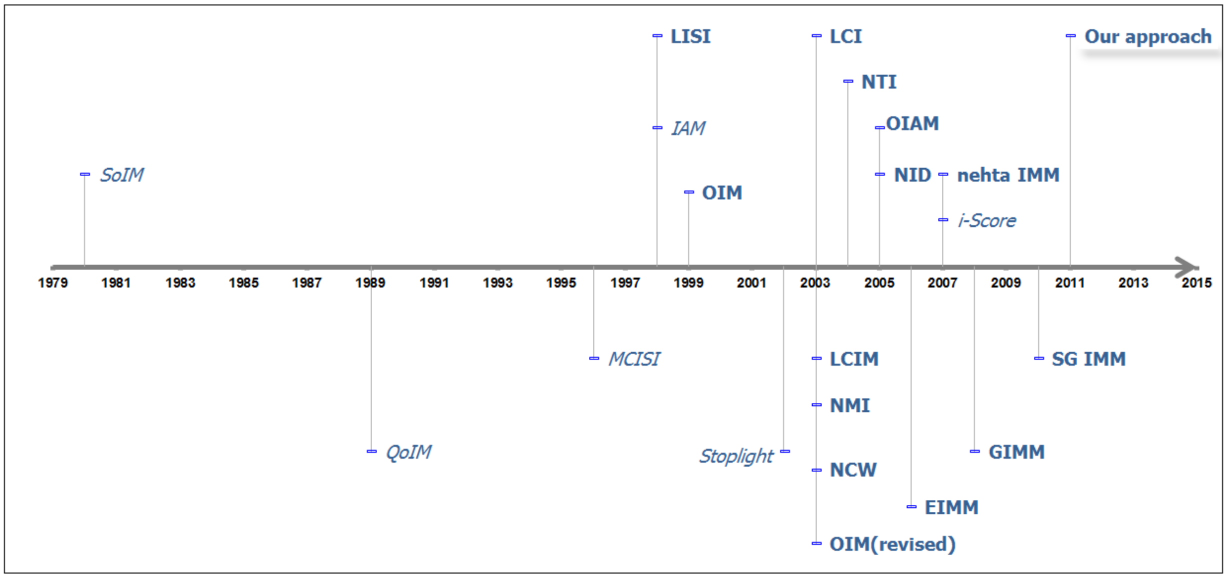

Figure 4.1. Chronology of published interoperability measurement methods (adopted from Ford, 2008)

The earliest known model is the Spectrum of Interoperability Model (SoIM). It was designed as a program management tool and defines seven levels of interoperability for technical systems (LaVean, 1980). Nearly a decade later (1989), the Quantification of Interoperability Methodology (QoIM) was published. It assigned a measure of effectiveness to each of its seven interoperability-related components (Mensh, et al., 1989).

In 1996, an interoperability measurement model, called Military Communications and Information Systems Interoperability (MCISI) was designed to model communications and information systems interoperability mathematically (Amanowicz and Gajewski, 1996). This model was not institutionalized after its publication (Ford, 2008).

Two years later, Levels of Information Systems Interoperability (LISI) (DoD, 1998) was published concurrently with the Interoperability Assessment Methodology (IAM) (Leite, 1998). The IAM provided an eclectic mix of interoperability attributes and assorted equations applied by a flowcharted interoperability assessment process (Leite, 1998). LISI was developed to define interoperability between information systems. It provides a mechanism to define the maturity of information systems and a way to proceed from one level to another. It focuses on technical interoperability, with a strong focus on information exchange and sharing, and does not consider organizational issues contributing to establishment, construction and maintenance of interoperability. This led to the definition of the Organization Interoperability Model (OIM)

(Clark and Jones, 1999). The focus of OIM Model is on the human activities and usage aspects of operations that are to be undertaken.

In 2002, Hamilton et al. published a *simple interoperability measurement model*, called Stoplight model in order to simplify the interoperability assessment process after criticizing LISI as being too complex to use (Hamilton et al, 2002).

Since 2002, many maturity models have been proposed in many fields, for example LCIM (Tolk and Muguira, 2003) and the NC3TA reference model for interoperability (NMI) (NATO, 2003) to deal respectively with conceptual aspects of interoperability and technical aspects of data exchange flows between enterprises.

In 2007, the interoperability Score (i-Score) was proposed by Ford et al. (2007, 2008). It considers that interoperability must be measured in the context of the operational mission which is implemented by systems of many types and that the number of interoperations is not as important as the quality of these interoperations. In the same year, within the health domain, the e-health interoperability maturity model was proposed by NEHTA (2007) to help e-health organizations improve their ability to use or deliver interoperable e-health systems.

The Government Interoperability Maturity Matrix (GIMM) was proposed in 2008 by Sarantis et al. (2008). Its main objective was to provide administrations with a simple, self-evaluation method that can be used to assess the current status of the administrations concerning eGovernment interoperability and the steps to be undertaken to improve their positioning towards system implementation and service provision to citizens and businesses.

Following the same approach, a new maturity model, called the smart Government Interoperability Maturity Matrix was elaborated in 2010 by Widergren et al. (2010).

The methods reviewed above deal with different interoperability issues in different domains with different approaches. According to Yahiya (2011), interoperability assessment methods can be classified as:

- Leveling and Non-leveling methods,
- Qualitative and quantitative methods,
- Black box and white box methods,
- A priori and a posteriori methods.

Table 4.1 summarizes these classifications.

Table 4.1. Interoperability assessment methods classifications

Properties	Classification	
Kinds	Leveling Methods	Non-leveling Methods
Measurement	Qualitative methods	Quantitative methods
Approach	Black Box methods	White Box methods
Application	A priori	A posteriori

4.2.1. Leveling and non-leveling methods

The non-leveling methods (non-maturity model-based interoperability measurement methods) are a much more diverse group and, as a whole, generally pre-date the maturity model-based methods. Like the maturity model methods, they are not generalized methods of measuring interoperability, but specialized to a particular type of system or interoperability (Ford, 2008). The interoperability maturity model measurement approach defines a basic set of interoperability maturity levels, listed as rows in the model, defined by a set of attributes (usually three or four, but sometimes only one) listed as columns in the model (Ford, 2008), as shown in table 4.2.

Table 4.2. General overview of maturity models

Interoperability Levels	Interoperability Attributes			
	A1	**A2**	**A3**	**A4**
Level 4				
Level 3				
Level 2				
Level 1				
Level 0				

4.2.2. Qualitative and quantitative methods

Interoperability assessment approaches define a variety of measures that can be qualitative or quantitative. Most of qualitative approaches are subjective and defined on the basis of general criteria of evaluation by associating a maturity level to a specific kind of interoperability (Yahia, 2011) (Panetto, 2007) (Chen and Daclin, 2007). Most of the existing maturity models use this kind of assessment approach.

Quantitative assessment approaches define numeric values to characterize the interoperations like the i-score (Ford et al., 2007) or the measures defined by Castano and De Antonellis (1998), Bianchini et al. (2006) and Daclin (2007).

4.2.3. Black boxes and white boxes methods

In the context of assessment, systems can be seen as black boxes or white boxes (Bertalanffy, 1968). The *black box* approach consists mainly in the study of the systems' inputs and outputs without worrying about their properties and interactions (see figure 4.2). On the other hand, the *white-box* or *transparent-box* approach represents a concept for which input-output mappings, the transformation structure as well as the state of the system (i.e. the whole of the system's characteristics at a given moment) are known. A schematic representation of black box and white box systems can be seen in Figure 4.2 (Heylighen, 2002).

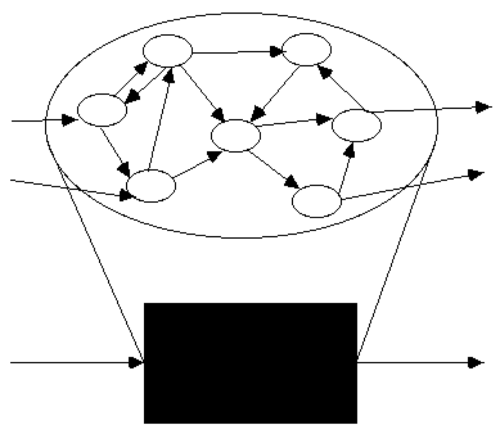

Figure 4.2. *White box* approach where a system is seen as a collection of interacting subsystems vs *black box* approach without observable components.

4.2.4. A priori and a posteriori methods

Enterprise interoperability maturity can be measured in two ways: *a priori* where the measure relates to the potential of a system to be interoperable with a possible future partner whose identity is not known at the moment of evaluation; *a posteriori* where the measure relates to a) the compatibility between two (or more) known systems willing to interoperate or b) to the performance of an existing interoperability relation between two known systems. More precisely, concerning *a posteriori* measure:

- Interoperability compatibility measure aims at evaluating the existence of possible interoperability problems between two or *n* existing known systems.
- Performance interoperability measure is, especially, related to the cost exchange, time (duration) of the exchange, quality and conformity of the exchange (Daclin et al., 2006).

Concerning the *a priori* assessment, interoperability potential measure consists of evaluating the potential of a system to be interoperable with an *a priori* unknown partner. It is, especially, related to the openness, flexibility and adaptability of a system to the external world. Table 4.3 summarizes the three types of interoperability measurements and their different characteristics.

Table 4.3. Interoperability assessment

	A priori	**A posteriori**	
	Potential measure	**Compatibility measure**	**Performance measure**
Scope (Where?)	Intra-Enterprise	Inter and intra-Enterprise	
Application (When?)	Before Interoperation Unknown Partner	Before and after Interoperation Known Partner	While interoperating
Purpose (Why?)	Improve ability to interoperate	Solve interoperability problems	Enhance operational performance
Outcomes (What?)	Potentiality assessment EI potential is enhanced	Compatibility assessment Find solutions to EI problems	Performance assessment Performance indicators

4.3. Research scope and positioning

Developing interoperability leads to identifying problems that have to be solved in order to achieve objectives targeted by enterprises. Solving interoperability problems is a long iterative process which can fail due to the lack of consensus between partners or the high cost of the solution. Predicting and solving the interoperability problems before they occur is simpler and usually less costly than developing corrective actions. For that, enterprises need to plan and be prepared for potential interoperations.

Hence, *a priori* assessment deserves particular attention, in order to properly plan future enterprise interoperations.

Despite its importance, most of the known interoperability maturity models mainly deal with the *a posteriori* measure of interoperability and do not sufficiently address the potential of interoperability. Moreover, they mostly focus on one single facet of interoperability (e.g. data, technology, conceptual, Enterprise modeling, etc.).

Based on the investigations and studies presented in previous sections and chapters, this chapter proposes to elaborate a maturity model for measuring enterprise interoperability potential. It covers, but is not limited to, the main aspects of existing maturity models. It combines *qualitative and white box* approaches to consider the different interactions and variables of the "system". Table 4.4 summarizes the positioning of this thesis' approach within the interoperability assessment domain.

Table 4.4. Positioning within interoperability assessment context

Properties	**Classification**	
Interoperability Assessment Methods	Leveling methods X	Non leveling methods
Used Measure	Qualitative methods X	Quantitative methods
Used Approach	Black Box methods	White Box methods X
Application	A priori X	A posteriori

The next section shows how existing approaches can be mapped and can contribute to the proposed MMEI model.

4.4. Interoperability maturity models: review, analysis and mapping

The maturity model concept was first developed by the US Air Force in 1987 (Humphrey and Sweet, 1987). At the beginning, the maturity model concept described the stages through which a process progresses (DoD, 1998), and was originally designed as a management tool to assess contractor software engineering ability. It was adopted in 1998 by the MITRE Corporation as the basis of the first maturity model-based interoperability measurement methods called Levels of Information System Interoperability (LISI) (DoD, 1998). Since 1998, other maturity models have been proposed. Despite their different assessment approaches, the principle behind them is the same: to enable an organization to identify its current capability status ('as is' interoperability position) and its desired capability maturity level ('to be' interoperability position) (Sarantis, 2008).

4.4.1. Review of main existing interoperability maturity models

The objective of this section is not to provide an exhaustive review of all existing maturity models but rather it is to present relevant models that are selected specifically for the purpose of this analysis. A more complete survey can be found in (Ford, 2008).

The selection of maturity models to review is based on the need to assess interoperability aspects (i.e. conceptual, technical and organizational). Based on (Tolk, 2003) the LISI and NMI have been successfully applied in the technical interoperability domain. Hence these two models are included in the analysis. Within the conceptual interoperability context, the study of Carnegie Mellon University on System of Systems mentions the LCIM as one of the candidates for successful evaluation approaches (Morris et al., 2004). Moreover LCIM was successfully applied in various domains and featured as a reference model in various journal contributions and book chapters (Tolk et al., 2006, 2007). It is also included in this research study.

Within an organizational interoperability context, the model that has been selected in this analysis is the OIM model (Clark and Jones, 1999). Another model elaborated by the European Project ATHENA (ATHENA, 2005) is also included; as its name is EIMM: Enterprise Interoperability Maturity model, it is necessary to see how it deals with enterprise interoperability, in particular to see which interoperability aspects are defined within it.

4.4.1.1. LISI (Levels of Information Systems Interoperability)

LISI (Levels of Information Systems Interoperability) Model (DoD, 1998) was adopted as a template for numerous maturity models (Ford, 2008). It focuses on Information Technology interoperability and the complexity of interoperations between information systems. It considers five levels, all describing both the level of interoperability and the environment in which it occurs, as shown in table 4.5.

Table 4.5. LISI maturity levels

Interoperability Level	Environment	Description
Enterprise	Universal	Data and applications are fully shared and distributed. Data has a common interpretation regardless of format.
Domain	Integrated	Information is exchanged between independent applications using shared domain-based data models.
Functional	Distributed	Logical data models are shared across systems
Connected	Peer-to-peer	Simple electronic exchange of data.
Isolated	Manual	Manual data integration from multiple systems.

At each level, LISI identifies additional factors that influence the ability of systems to interoperate. These factors comprise four attributes: Procedures, Applications, Infrastructure and Data (PAID). PAID provides a method for defining the set of characteristics required for exchanging information and services at each level.

LISI focuses on technical interoperability (IT) and the complexity of interoperations between systems. The model does not address the organizational issues that contribute to the development and maintenance of interoperable systems. In order to overcome this limitation, Clark and Jones (1999) proposed the Organizational Interoperability Model (OIM).

4.4.1.2. OIM (Organizational Interoperability Model)

The OIM (Clark and Jones, 1999) extends the LISI model to assess organization maturity issues. Five maturity levels were identified by the OIM model, as shown in table 4.6.

Table 4.6. OIM maturity levels

Level	Name	Description
4	Unified	The organization is interoperating on a continuing basis. Command structure and knowledge basis are shared.
3	Integrated	Shared value systems and goals, a common understanding to interoperate however there are still residual attachments to a home organization
2	Collaborative	Recognized interoperability frameworks are in place. Shared goals are recognized. Roles and responsibilities are allocated but the organizations are still distinct.
1	Ad hoc	Some guidelines to describe how interoperability will occur but essentially the specific arrangements are still unplanned. Organizations remain entirely distinct.

0	Independent	Organizations work without any interaction. Arrangements are unplanned and unanticipated. No formal frameworks in place. Organizations are able to communicate for example via telephone, fax and personal contact in meetings.

Beyond this organizational interoperability, the data exchange flows between enterprises is an issue that also requires a considerable attention. This is particularly addressed by the NATO C3 Technical Architecture (NC3TA), defining the NC3TA reference model for interoperability (NMI) (NATO, 2003).

4.4.1.3. NMI (NC3TA reference Model for Interoperability)

NATO C3 Technical Architecture (NC3TA) defined the NC3TA reference model for interoperability (NMI) (NATO, 2003). According to (Morris et al., 2004), NMI was updated in 2003 to "closely reflect the LISI model". NMI originally described four degrees of interoperability (not including degree 0) as depicted by table 4.7.

Table 4.7. NMI maturity levels

Level	Name	Description
4	Seamless sharing of information	Universal interpretation of information through cooperative data processing
3	Seamless sharing of data	Automated data sharing within systems based on a common exchange model
2	Structured data exchange	Exchange of human-interpretable structured data intended for manual and/or automated handling, but requires manual compilation, receipt, and/or message dispatch
1	Unstructured data exchange	Exchange of human-interpretable, unstructured data such as the free text found in operational estimates, analysis, and papers.

Unconnected systems, which would represent the interoperability level of degree zero are not mentioned in the NMI. The Seamless Sharing of Information (degree 3) equals the Universal Interoperability Level (level 4) of Enterprise Solutions as envisioned in LISI (NATO, 2003). Beyond the technical and organizational interoperability, at the conceptual level, the LCIM (Levels of Conceptual Interoperability Model) was proposed to address conceptual interoperability maturity.

4.4.1.4. LCIM (Levels of Conceptual Interoperability Model)

Tolk and Muguira (2003) proposed the Levels of LCIM to address levels of conceptual interoperability that go beyond technical models like LISI. The focus of LCIM lies on the data to be exchanged and the interface documentation. The model is intended to be a bridge between conceptual design and technical design (Tolk and Muguira, 2003). LCIM defines five maturity levels that are shown in table 4.8.

Table 4.8. LCIM maturity levels

Level	Name	Description
4	Harmonized data	Semantic connections are made apparent via a documented conceptual model underlying components.
3	Aligned dynamic data	Use of data is defined using software engineering methods like UML.
2	Aligned static data	Common reference model with the meaning of data unambiguously described.
1	Documented data	Shared protocols between systems with data accessible via interfaces.
0	System specific data	Black boxes components with no interoperability or shared data.

4.4.1.5. EIMM (Enterprise Interoperability Maturity Model))

Within the frame of the ATHENA (Advanced Technologies for interoperability Heterogeneous Enterprise Networks and Applications) project (Athena, 2005), the EIMM was defined. Contrary to what can be understood by the model's name, it is not defined with a general view of an enterprise but from an enterprise modeling perspective, as it is described in the table 4.9.

Table 4.9. EIMM maturity levels

Level	Name	Description
4	Optimizing	Enterprise systems are systematically traced to enterprise models and innovative technologies are continuously researched and applied to improve interoperability.
3	Interoperable	Enterprise models support dynamic interoperability and adaptation to changes and evolution of external entities.
2	Integrated	The enterprise modeling process has been formally documented, communicated and is consistently in use.
1	Modeled	Enterprise modeling and collaboration is done in a similar way each time, the technique has been found applicable. Defined meta-models and approaches are applied, responsibilities are defined.

0	Performed	Enterprise modeling and collaboration is done, but in an ad-hoc and chaotic manner.

4.4.2. Analysis and mapping

The maturity models reviewed above mainly focus on one single facet of interoperability (data or technology or conceptual or Enterprise modeling, etc.) and do not have a general view of the enterprise interoperability domain. So, when an enterprise needs to assess its whole interoperability, it has to use one maturity model for each interoperability field or concern (i.e. business interoperability, conceptual interoperability, technical interoperability, data interoperability, etc.). The use of more than one model to assess enterprise interoperability creates redundancies and incompatibilities and makes the aggregation process more difficult.

When assessing enterprise interoperability, it is obvious to consider the different operational entities where interoperability takes place within and between enterprises (i.e. Business, process, service and data, as defined by FEI). However, as the existing maturity models are not dedicated to enterprise interoperability, these issues are not properly addressed in a satisfactory way. Table 4.10 summarizes the coverage of interoperability aspects (i.e. conceptual, technical, and organizational) and interoperating entities (i.e. business, process, service and data) by the reviewed maturity models.

Table 4.10. Maturity models coverage within EI context

Maturity Models	Interoperability aspects addressed	Issues addressed in the model	Corresponding EI Concerns
LISI	Technical	Data/application	Data and Service
EIMM	Conceptual/ Enterprise modeling	Strategy/process	Business and process
OIM	Organizational	Responsibility, shared purpose, value, ethos	Business
NMI	Technical	Data exchange	Data
LCIM	Conceptual	Data	Data

Interoperability aspects are not covered by a single maturity model. Instead, each of the studied models covers mainly one aspect of interoperability and consequently deals with one interoperability barrier. Table 4.11, adopted from (Guédria et al., 2008), evaluates the coverage of these maturity models.

The '++++' means "addresses the issue best", '+++' denotes "addresses the issue", "++" stands for "partly addresses the issue" and '+' is for "relevant to the issue.

Table 4.11. Maturity models evaluation

	Interoperability barriers			Interoperability concerns				Interoperability approaches		
	Conceptual	Technological	Organizational	Business	Process	Service	Data	Integrated	Unified	Federated
LISI	+	++++				++	++++	++++	++	+
OIM	+		++++	++				+++	++	+
LCIM	++++	++					++++	+++	++++	+
EIMM	++++		+	+++	+++	++	++	+++		+
NMI	+	+++					++++	+++	+++	

LISI deals with the IT technological interoperability barriers between information systems. It was thereafter extended by OIM model to cover interoperability organizational issues. LCIM lies on the data to be interchanged and the interface documentation. The model is intended to be a bridge between conceptual design and technical design: while covering semantic barriers, it also deals with technological ones. EIMM deals specifically with enterprise modeling assessment, which mainly concerns conceptual barriers of interoperability. It focuses on the use of enterprise models and the maturity of their usage, which requires a correct syntactic and semantic representation (ATHENA, 2003). EIMM aims at measuring enterprise model maturity and covers main enterprise model views such as function, service, process, data, information, organization as well as other aspects such as business strategy, legal environment, security and trust.

Concerning the enterprise interoperability concerns, LISI enables information systems to work together and provides assessments for procedures, data, infrastructures and applications (PAID attributes) within each level. In that way, it covers the interoperability of data and services. LCIM deals with the interoperability of data: it focuses on data model alignment and 'meaningful' interoperability. LCIM proposes to use a unified approach: it explicitly proposes solutions for interoperability problems, like the development of a common ontology, common or shared reference models and standardized data elements. Other maturity models do not propose explicitly a solution; they provide a set of basic practices and guidelines to reach each of the maturity levels. The proposed guidelines require conformance and compliance to standards, which can be related to either integrated or unified approaches of interoperability. The use of a federated approach to improve interoperability is still missing in existing maturity models.

In addition to focusing on only one interoperability aspect, existing interoperability maturity models, except LISI, mainly address *a posteriori* interoperability, focusing on an efficient interoperation between known entities. LISI deals with the potential interoperability measurement of information systems and proposes a potential interoperability matrix to represent the potential for each system to interoperate with others and displays the level at which the interactions will potentially take place (DoD, 1998). EIMM is also said to cover potential aspects of interoperability; indeed, the optimizing level (i.e. EIMM level 4) requires dynamic interoperability and adaptation to changes and evolution of external entities (ATHENA, 2003). Other models do not explicitly address the potential aspect. Table 4.12 (Guédria et al., 2008) summarizes the relevance of the considered models with respect to the two types of measures.

Table 4.12. Interoperability potential vs. inter system interoperability

	NMI	LISI	OIM	LCIM	EIMM
Interop. Potential		+++			+
Interop. inter systems	++++	++++	++++	++++	++++

In summary, the comparison shows that the existing interoperability maturity models (LISI, NMI, OIM, LCIM, EIMM) are partial models only dealing with some aspects of the enterprise interoperability domain as defined in OoEI (i.e. interoperability dimensions). An interoperability maturity model covering all main areas of concerns and aspects of the enterprise interoperability still does not exist.

There is also a need to identify properties and metrics to allow better characterizing and measuring interoperability potential. Existing interoperability maturity models were not developed to a satisfactory level to measure explicitly potentiality. Although the LISI model proposes potential measurements of interoperability, it is still specific to information systems and misses other aspects involved in an enterprise interoperability context.

Based on this analysis, the reviewed maturity models are complementary rather than contradictory. It is therefore possible to structure them in one single maturity model in a harmonized way to look for completeness and avoid redundancy.

Consequently, the reviewed maturity models are extended in this thesis by proposing the MMEI (Maturity Model of Enterprise Interoperability) to assess interoperability *a priori* while covering the three interoperability aspects and the Enterprise operational entities (i.e. EI concerns).

Moreover, MMEI adopts a systemic point of view of the enterprise (Giachetti, 2010) (Braesch and Haurat, 1995). The defined MMEI levels refer to the state of the enterprise and consequently the state of its businesses, processes, services and data in terms of interoperability. In other words, MMEI targets one single system (i.e. the considered enterprise); *the purpose being to evaluate its ability to interoperate with any other unknown system*.

4.5. MMEI: specification and description

The Maturity Model for Enterprise Interoperability (MMEI) defines the metrics of enterprise interoperability and an improvement path from an ad-hoc, immature state where the enterprise has no ability to interoperate, to an organized and mature state, where the enterprise can interoperate with any unknown partner in its environment.

4.5.1. Identifying MMEI maturity levels

This section aims at defining the maturity levels of MMEI, based on analysis and mapping performed on the existing maturity models. Relevant elements from those models are identified and chosen for MMEI, as shown in tables 4.13, 4.14, 4.15, 4.16, 4.17.

Table 4.13. Elements of the maturity models level 0 and MMEI

Level 0	Level Name	Level Description	Relevant elements for MMEI	Concerned Interop Areas
LISI	Manual	Manual data integration from multiple systems	Manual Exchange of Data	DT0
OIM	Independent	Organizations work without any interaction. Arrangements are unplanned and unanticipated. No formal frameworks in place.	No formal frameworks in place.	BO0
NMI	Not defined			

LCIM	System Specific data	Black boxes components with no interoperability or shared data.	Closed data storage devices	DT0
EIMM	Performed	Enterprise modeling and collaboration is done, but in an ad-hoc and chaotic manner.	Enterprise modeling is done, but in an ad-hoc and chaotic manner.	BC0, PC0, SC0, DC0

Table 4.14. Elements of the maturity models level 1 and MMEI

Level 1	**Level Name**	**Level Description**	**Relevant elements for MMEI description**	**Concerned Interop Areas**
LISI	Connected	Simple electronic exchange of data.	Simple electronic exchange is possible	DT1
OIM	Ad hoc	Some guidelines to describe how interoperability will occur but essentially the specific arrangements are still unplanned. Organizations remain entirely distinct.	Some guidelines to describe how interoperability can occur	BO2, PO2, SO2, DO2
NMI	Unstructured data Exchange	Exchange of unstructured data such as the text found in operational estimates, analyses and papers	Exchange of unstructured data	DT1
LCIM	Documented data	Shared protocols between systems with data accessible via interfaces.	Shared protocols between systems with data accessible via interfaces.	DT1, DT2, DT3
EIMM	Modeled	Enterprise modeling and collaboration is done in a similar way each time, the technique has been found applicable. Defined meta-models and approaches are applied, responsibilities are defined.	Defined meta-models and approaches are applied. Responsibilities are defined.	BO1, PO1, SO1, DO1, DC1

Table 4.15. Elements of the maturity models level 2 and MMEI

Level 2	**Level Name**	**Level Description**	**Relevant elements for MMEI**	**Concerned Interop Areas**
LISI	Functional	Logical data models are shared across systems	Data models can be shared across systems.	DC2
OIM	Collaborative	Recognized interoperability frameworks are in place. Shared goals are recognized. Roles and responsibilities are allocated but the organizations are still distinct.	Roles and responsibilities are allocated	BO2

NMI	Seamless sharing of Data	Automated sharing of data amongst systems based on a common exchange model	Automated sharing of data amongst systems based on a common exchange model	DT2
LCIM	Aligned static data	Common reference model with the meaning of data unambiguously described.	Common reference model with the meaning of data unambiguously described.	BC2, PC2, SC2, DC2
EIMM	Integrated	The enterprise modeling process has been formally documented, communicated and is consistently in use.	Enterprise modeling process has been formally documented communicated and is consistently in use.	BC1, PC1, SC1, DC1

Table 4.16. Elements of the maturity models level 3 and MMEI

Level 3	**Level Name**	**Level Description**	**Relevant elements for MMEI**	**Concerned Interop Areas**
LISI	Domain	Information is exchanged between independent applications using shared domain-based data models.	Information can be exchanged between independent applications using shared domain-based data models.	DT3
OIM	Integrated	Shared value systems and goals, a common understanding to interoperate however there are still residual attachments to a home organization	Common understanding to interoperate	BO2
NMI	Not Defined			
LCIM	Aligned dynamic data	Use of data is defined using software engineering methods like UML.	Use of data is defined using meta models	DC3
EIMM	Interoperable	Enterprise models support dynamic interoperability and adaptation to changes and evolution of external entities.	Enterprise models support interoperability and adaptation to changes and evolution of external entities.	BC4, PC4, SC4, DC4

Table 4.17. Elements of the maturity models level 4 and MMEI

Level 4	**Level Name**	**Level Description**	**Relevant elements for MMEI**	**Concerned Interop Areas**
LISI	Enterprise	Data and applications are fully shared and distributed. Data has a common interpretation regardless of format.	Data has a common interpretation regardless of format.	DC3

OIM	Unified	Organizational goals, value systems and the knowledge bases are shared across the system.	Organizational goals, value systems and knowledge bases are shared across the system.	PO3, SO3
NMI	Seamless sharing of Information	Data processing based on cooperating applications	Data processing based on cooperating applications	DT4
LCIM	Harmonized data	Semantic connections are made apparent via a documented conceptual model underlying components.	Conceptual model is defined, underlying components that can be involved in future interoperations.	BC3, PC3, SC3, DC3
EIMM	Optimizing	Enterprise systems are systematically traced to enterprise models and innovative technologies are continuously researched and applied to improve interoperability.	Innovative technologies are continuously researched and applied to be open to any future interoperation.	BT4, PT4, ST4, DT4

Based on this analysis, relevant concepts defined in the reviewed maturity models are identified to serve as basis to define the MMEI levels' specifications.

The table 4.18 gives an overview summary of maturity levels defined in the considered maturity models. The MMEI maturity levels are proposed and mapped to the maturity levels of existing models.

Table 4.18. Mapping of MMEI maturity levels to existing ones

Level	LISI	OIM	LCIM	NMI	EIMM	MMEI
4	Enterprise (universal)	Unified	harmonized	Seamless information sharing	Optimizing	Adaptive (Federated)
3	Domain (integrated)	Integrated	Aligned dynamic	Seamless data sharing	Interoperable	Organized (Unified)
2	Functional (distributed)	Collaborative	Aligned static	Structured Exchange	Integrated	Aligned (Integrated)
1	Connected	Ad hoc	Documented	Unstructured Exchange	Modeled	Defifned (Connected)
0	Isolated	Independent	Specific		Performed	Unprepared (isolated)

4.5.2. MMEI levels specification

MMEI defines five levels of Enterprise interoperability. For each one of these maturity levels, previous maturity models and the way they define their levels have been considered and adapted to match an a priori assessment context. MMEI levels are first specified and a detailed description for each level is given. Table 4.19 gives an overview of the MMEI levels.

Table 4.19. Overview of MMEI levels

Maturity level	Description
Level 4 – Adaptive	Capability of negotiating and dynamically accommodating with any heterogeneous partner
Level 3 – Organized	Capability of performing needed mappings with multiple heterogeneous partners
Level 2 – Aligned	Capability of making necessary changes to align to common formats or standards
Level 1 – Defined	Capability of properly modelling and describing systems to prepare interoperability
Level 0 – Unprepared	Ad-hoc interoperability capabilities or no will to interoperate

Each MMEI maturity level is described by an m×n matrix $M = [P_{i,j}]_{m \times n}$, where m is the number of interoperability aspects (i.e. conceptual, technical, organizational) and n is the number of the enterprise concerns (i.e. business, process, service and data) (see Figure 4.3). These two dimensions constitute the problem space of enterprise interoperability. $P_{i,j}$, called *area of interoperability*, is the description of the criteria that an EI concern should meet to avoid interoperability barriers and acquire the target maturity level. The model presented here is an evolution of a preliminary version presented in (Guédria *et al*. 2009b, 2011).

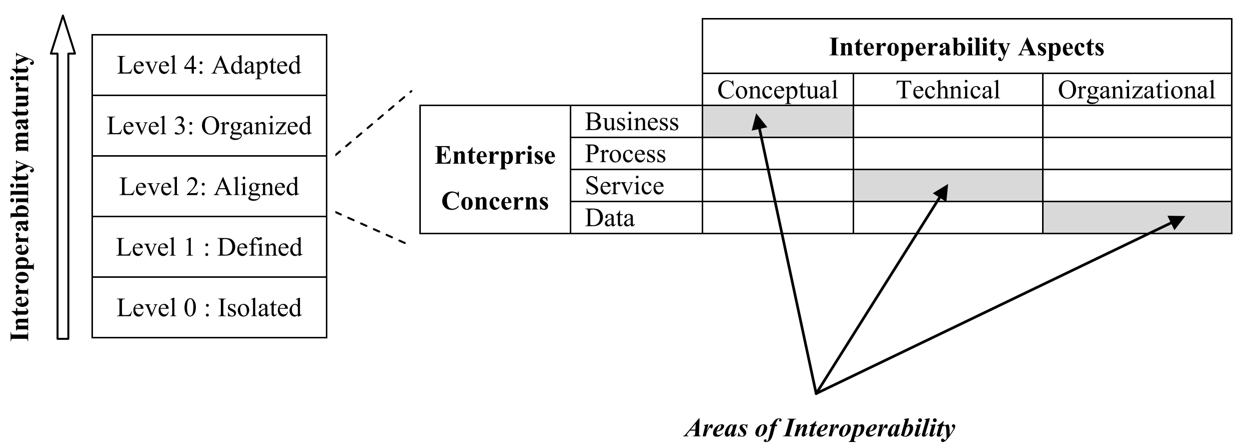

Figure 4.3. Structure of a MMEI level

As shown in figure 4.3, there are twelve areas of interoperability: Business-Conceptual (BC), Business-Technical (BT), Business-Organizational (BO), Process-Conceptual (PC), Process-Technical (PT), Process-Organizational (PO), Service-Conceptual (SC), Service-Technical (ST), Service-Organizational (SO), Data-Conceptual (DC), Data-Technical (DT), Data-Organizational (DO). Each of these areas describes the criteria that an enterprise entity (i.e. EI concern) should have for a considered interoperability aspect in order to reach a given maturity level. For the sake of clarity, each area is associated with its maturity. For example, BC1 contains the required criteria to prepare business interoperability at level 1, regarding conceptual interoperability aspect. In other words, the content of BC1 answers to the question "what should be put in place to avoid conceptual problems in a future business interoperability context at level 1?"

Table 4.20 provides a general view of the MMEI model with its contents. Each one of the five maturity levels is an instantiation of this general view with an evolution of the content regarding the evolution of the level.

Table 4.20. General view of MMEI model

	Conceptual	**Technical**	**Organizational**
Business	Business models, enterprise visions, strategies, objectives, policies	Infrastructure, technology	Work methods, business rules, and organizational structure.
Process	Processes models	Tools supporting processes modeling and execution	Responsibilities, Process management and rules
Service	Services models	Tools supporting services and applications	Responsibilities, service and application management and rules.
Data	Data models, (semantic, syntax).	Data storage and exchange devices	Responsibilities, data management and rules.

The general view of MMEI is based on OoEI concepts. Indeed, EI concerns (i.e. Business, process, service and data) and interoperability aspects (i.e. conceptual, technical and organizational) are concepts from OoEI. Additionally, the content of each cell of the table 4.20 can also be related to the OoEI. Figure 4.4 shows how these cells can be related to the OoEI.

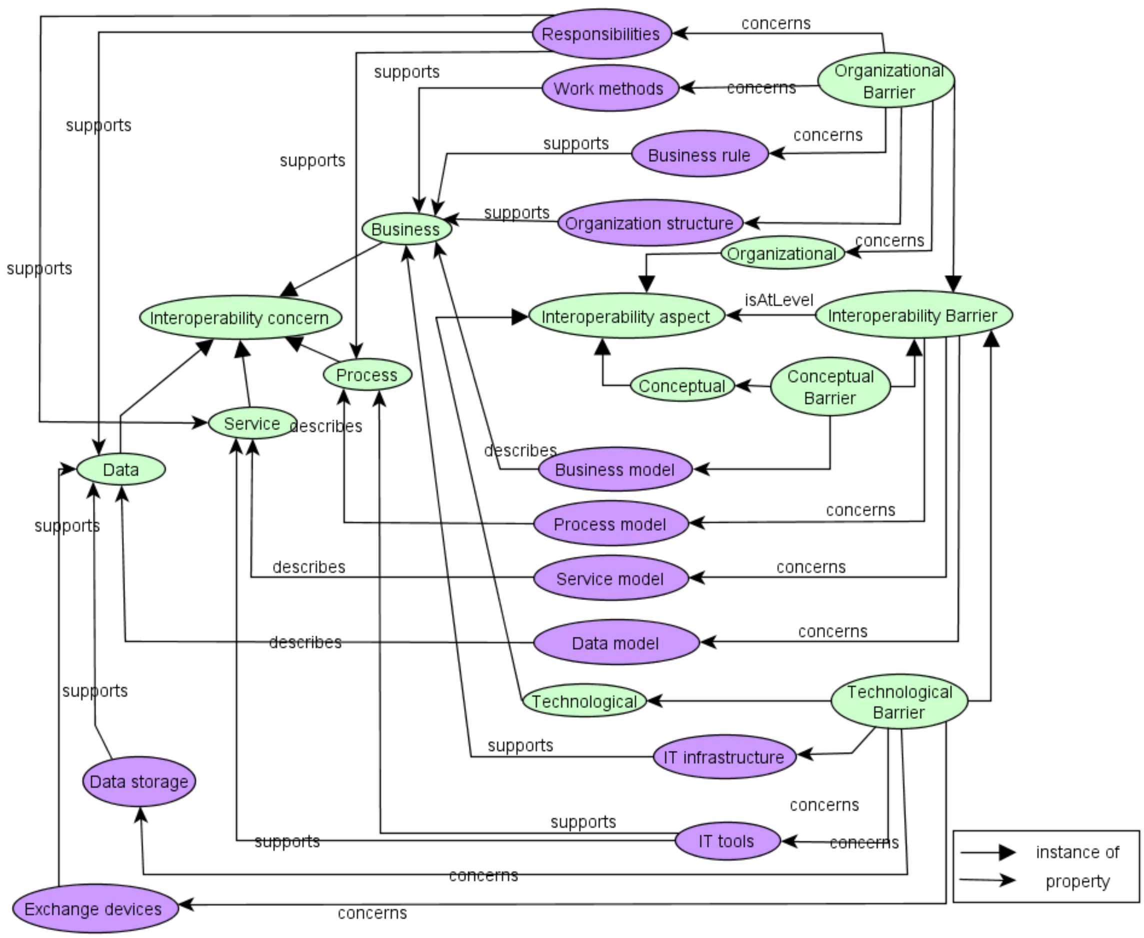

Figure 4.4. MMEI related to OoEI concepts

4.5.3. MMEI levels detailed description

In this section, the MMEI levels are presented in detail to define the "what to assess".

4.5.3.1. Level 0 - Unprepared

At the unprepared level, the enterprise generally does not have an appropriate environment for developing and maintaining interoperability; systems run stand-alone and are not prepared for interoperation. Enterprise modeling is not done, or done in an ad-hoc and inconsistent manner. Information exchange with external systems is mainly performed manually. No formal framework is in place and the existing infrastructure frequently fails or does not support efficient communication. There is no need or willingness to work in an open and collaborative environment. This level is characterized by proprietary or closed systems. Table 4.21 presents the states of the different interoperability areas, which represent the barriers that have to be removed in order to prepare for interoperability.

Table 4.21. Description of the MMEI Level.0

	Conceptual	Technical	Organizational
Business	Business model not explicitly modeled or documented.	No or unreliable IT infrastructure	No organization structure is defined
Process	Processes models not explicitly modeled or documented.	No IT support, manual processes	Processes responsibilities and authorities not explicitly defined
Service	Services models not explicitly modeled or documented.	Stand-alone services and applications	Services responsibilities and authorities not explicitly defined
Data	Data models not explicitly modeled or documented.	No or closed data storage devices, manual exchange	Data responsibilities and authorities not explicitly defined

4.5.3.2. Level 1 - Defined

Starting from this level, the system is considered *open* to interoperability. This means there is a willingness to prepare the system for future interoperations.

At level 1 system is capable of performing some ad-hoc interoperations with other systems. However, the interoperability remains very limited. It depends on the competence of the people in the organization and not on the use of some proven strategy and technology. Some basic IT devices are connectable, simple electronic data exchange becomes possible. The IT infrastructure (generally ad-hoc) is in place, providing support for some enterprise-wide information exchange. In this situation enterprise works with a limited number of partners, mainly some suppliers and customers.

Table 4.22. Description of MMEI level 1

	Conceptual	Technical	Organizational
Business	Modeled or documented	Basic IT infrastructure in place	Organization structure is defined and in place
Process		IT support for process. Ad hoc exchange of process information	Responsibilities/authorities defined and in place
Service		Applications/services connectable. Ad hoc information exchange possible	
Data		Data storage devices connectable, simple electronic exchange possible	

4.5.3.3. Level 2 - Aligned

A level 2 system is able to make changes in its components in order to adhere to common references. Processes, models, data and services are managed and mostly based on standards or common formats and practices. It is possible to adjust models, services or business policies, in order to adapt to environmental changes. In case of interoperation, the concerned sub-system provides adequate resources and assigns responsibility for performing this interoperation. Interoperability training has been performed for key personnel. Some guidelines exist to describe how interoperability can occur and how to adjust the business if needed. Reaching this level of interoperability maturity allows an enterprise to have a stable environment in which long term and stable partnerships can be established with its known suppliers, sub-contractors and customers.

Table 4.23. Description of the MMEI level 2

	Conceptual	Technical	Organizational
Business	Use of standards for alignment with other models	Standard and configurable IT infrastructures	Human resources trained for interoperability.
Process		Standard Process tools & platforms	Procedures for processes interoperability
Service		Standard and configurable architecture & interface	Procedures for services interoperability
Data		Automated access to data, based on standard protocols	Rules and methods for data management

4.5.3.4. Level 3 - Organized

At this level, the decision-making is generally decentralized to improve flexibility and reactivity. The use of ontologies, reference or meta-models is required in order to support interoperability with multiple partners and adaptations to change. Level 3 requires that people have been trained with collaborative approaches and interoperability methods and guidelines. The enterprise organization has achieved a certain degree of flexibility and is organized to deal with interoperability simultaneously with several heterogeneous partners. Services and applications can be shared with different partners. It is also possible to define different rules and methods regarding data management according to different requirements from partners, such as for example, security or public vs. private data. Level 3 interoperability maturity allows an enterprise to work simultaneously with different partners in an unstable partnership environment (partners can change) without the necessity to reengineer its systems each time.

Table 4.24. Description of the MMEI level 3

	Conceptual	Technical	Organizational
Business	Business models for multi partnership and collaborative enterprise	Open IT infrastructure	Flexible organization structure
Process	Meta-modeling for multiple model mappings	Platform & tool for collaborative execution of processes	Cross-enterprise collaborative processes management
Service		Automated services discovery and composition, shared applications	Collaborative services and application management
Data		Remote access to databases possible for applications, shared data	personalized data management for different partners

4.5.3.5. Level 4 - Adaptive

At this level, companies should be able to dynamically adjust and accommodate 'on the fly'. It is the highest level where interoperability itself becomes a subject of continuous improvement (evolution and adaptation). In general, shared domain ontologies may exist. There is a focus on continually improving the performance of the system fields through innovative methods and technological improvements that enhance the organization's ability to meet its quality and performance objectives. The performance, definition, and management of the interoperability process are continually improved. Level 4 interoperability allows an enterprise to work in a fully dynamic networked enterprise environment. Time and effort to prepare interoperability with a new heterogeneous partner who joins the network is considerably reduced in comparison with a level 3 case.

At this highest maturity level, the enterprise needs to have adaptive skills and has to be agile; which means that it should rapidly adapt to changing business challenges and opportunities (Cummins, 2009).

Table 4.25. Description of the MMEI level 4

	Conceptual	Technical	Organizational
Business	Adaptive business model	Adaptive IT infrastructure	Agile organization for on-demand business
Process	Modeling for dynamic process re-engineering	Dynamic and adaptive tools and engines for processes.	Real-time monitoring of processes, adaptive procedures
Service	Adaptive service modeling	Dynamically composable services, networked applications	Dynamic service and application management rules and methods
Data	Adaptive data models (both syntax and semantics)	Direct database exchanges capability and full data conversion tool	Adaptive data management rules and methods

According to the MMEI description, the different areas of interoperability can be characterized by a key property: expressing implicitly the focus and concerns at each maturity level and for each interoperability barrier category, as shown in table 4.26.

Table 4.26. Focus and concern of MMEI

Maturity Level	Conceptual	Technical	Organizational
Level 4 – Adaptive	Accommodated	Adaptable	Agile
Level 3 – Organized	Mapped	Open	Flexible
Level 2 – Aligned	Adhered	Alignable	Trained
Level 1 – Defined	Modeled	Connectable	Specified
Level 0 – Unprepared	Incomplete	Inaccessible	Inexplicit

4.6. MMEI assessment methodology

After having presented the different maturity levels and described the related interoperability areas, this section defines how to assess the maturity.

4.6.1. MMEI assessment overview

The assessment is an activity that can be performed either as part of a continuous improvement initiative, or as part of an interoperability analysis approach. In the following section, the different stages of the assessment process and the associated methodology to determine the enterprise interoperability maturity level are defined. The first stage when conducting an assessment process is to define the purpose of the assessment, its scope, under which constraints it is done (i.e., the context) and any additional information that needs to be gathered. Assessors may originate from the organization, be external to the organization or a combination of both. Figure 4.5 illustrates the proposed different stages of the assessment.

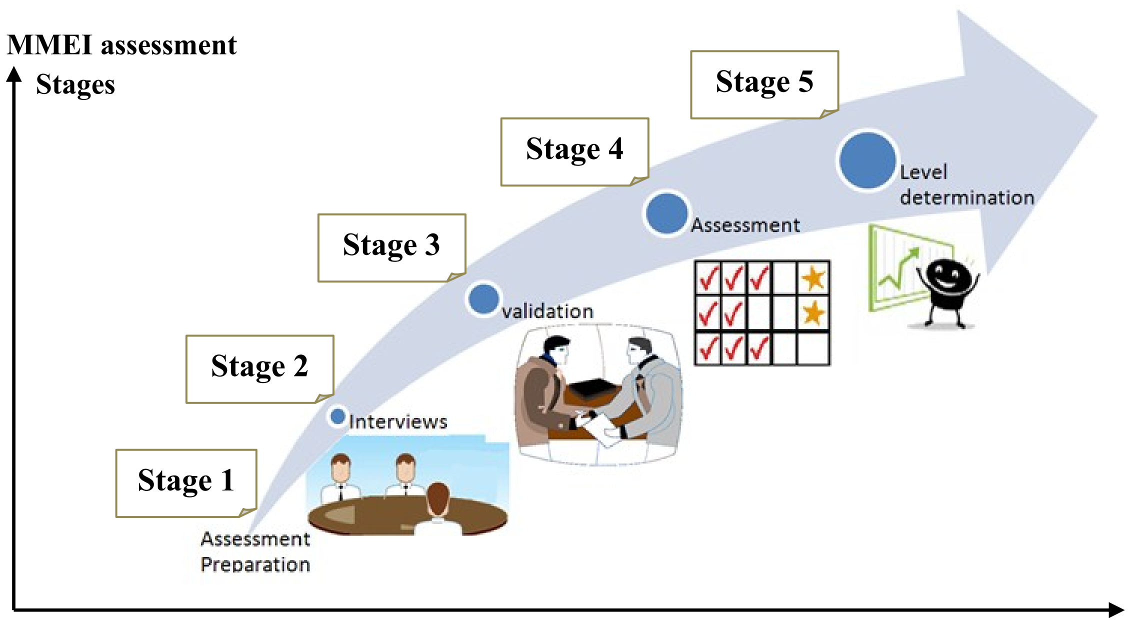

Figure 4.5. Assessment stages of MMEI

At stage 2, assessors need to collect information through a series of interviews. The co the assessment interview depends on the scope and the enterprise needs. From the interviews, a rating is assigned based on validated data.

Actions are taken to ensure that gathered data is accurate and sufficiently covers the assessment scope, including seeking information from independent sources; using past assessment results; and holding feedback sessions to validate the information collected (validation, stage 3). The assessing team then conduct a quick synthesis on the interview to derive a conclusion; a value is then associated to each area of interoperability. It is assigned based on the assessors' judgment about the degree of achievement of the required criteria defined in MMEI.

Such judgment is subjective and can be a source of incomplete information, interpersonal contradictions, etc. Moreover employees of the evaluated enterprise may reply to questions using their own words, which are not quantitative enough to measure a criterion achievement.

To facilitate the use of the collected information for the evaluation of the interoperability maturity, the use of linguistic values is proposed (like e.g. "achieved", "partially achieved", etc.) and the Fuzzy sets theory is exploited (Zadeh, 1994). Each assessor chooses a linguistic value to qualify the criteria achievements. From these values, scores are assigned, based on defined membership functions. A team rating is then calculated by aggregating the assessors' scores using the OWA operator (Yager, 1994). Finally, fuzzy rules (Zadeh, 1994) are used to find the reached maturity level of an enterprise.

4.6.2. Preparation, Interviews and Validation (stages 1, 2, 3)

As indicated previously, the first stage when conducting an assessment process is to define the purpose of the assessment, the context, the scope and any additional information that needs to be gathered. In particular, the assessor needs to understand the enterprise vision, objectives, problems, requirements, and constraints affecting the enterprise interoperability. He/she should prepare his/her interviews based on the information required by MMEI (i.e. based on the areas of interoperability) and identify the suitable person to interview. The interviewees should have a clear view of the enterprise business or a part of it. They can be directors, managers, employees or those in other positions of responsibility. Directors or those holding positions of responsibility can provide a strategic view of how they see problems and the future of the enterprise. Managers and employees are more involved in business services and processes and can provide a detailed view of how the business is done and identifying the problems they face. An interview requires commitment from the top management, interviewees, and the assessor needs to decide on an appropriate length of time for the interview. This depends on different factors including the availability of the person and purpose of the interview.

The assessor should prepare its questions to ensure that the interviewee interpret the questions in the same way that he/she intended (i.e. use of familiar words in short, simple sentences, avoid technical or special jargon, etc.). The purpose of the interview is then to gather the maximum information to analyze and evaluate the ability of the enterprise to interoperate with an unknown enterprise in a possible future collaboration and make changes in its way of doing business if needed. After preparing the assessment, the questionnaire and the interview, the assessor contacts the enterprise to meet the persons concerned by the interviews. When listening to the interviewees, the assessor needs to be an active listener, which means thinking about what they are saying.

During the data gathering process (i.e. interviews), the assessor should try to triangulate the facts by obtaining data from multiple sources to verify what is really happening (Yin, 1984).

After conducting a series of interviews, and collecting the needed information for the assessment, the assessor needs to validate the collected data to improve their understanding of facts. One way to do this is to summarize, rephrase, and describe implications of what they understand by the interviewee's responses. The interviewee can confirm and validate the assessor's understanding, correct it, or elaborate. The figure 4.6 summarizes the phases of preparation, collecting data and the validation of the collected data.

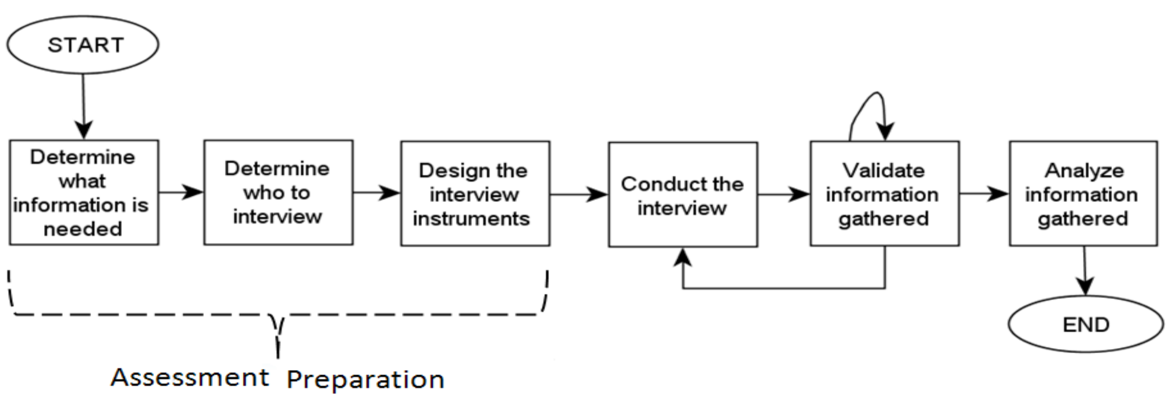

Figure 4.6. Interview flow chart (adapted from (Giachetti, 2010)

4.6.3. Assessment (stage 4)

After holding feedback sessions to validate the information collected, the assessors have to evaluate the collected information to determine the maturity level. To this end, most of the traditional measures are based on checklists where activities are evaluated with regards to characteristics that contribute to interoperability. This method is biased because the checklist limits the choice of the assessors' judgment to a yes/no response. However, the achievement of a task cannot be represented by a binary value (i.e. achieved or not achieved) as far as there is a degree of achievement for a considered task. Moreover, the gathered information through the series of interviews is collected from the employees who reply to the questions with their own words.

To deal with this bias and to ease the quantification using natural language, the idea is to use the Linguistic variables (Zadeh, 1994). The assessment is mainly based on two phases: in a first phase, each assessor gives his/her own evaluation (i.e. individual assessment), while in a second phase the assessing team needs to aggregate the individual assessments and reach a compromise about the assigned score for each practice (i.e. team assessment). The aggregation function used to obtain the collective value should reflect the opinions of the majority of assessors; to this end, the use of the Ordered Weighted Average (OWA) operator is proposed (Yager, 1994). These two phases are detailed in the following sections.

4.6.3.1. Phase 1: Individual assessment using linguistic variables

While variables in classical mathematics usually take numerical values, in fuzzy logic applications, non-numeric linguistic variables are often used to facilitate the expression of rules and facts. A linguistic variable is a variable whose associated values are linguistic rather than numerical. Each linguistic variable is characterized by a set $(x, T(x), U, G, M)$, such as:

x is the variable name, $T(x)$ is the set of linguistic values that may take x, U is the universe of discourse associated with the base value, G is the syntactic rule to generate linguistic values of x, M is the semantic rule for associating a meaning to each linguistic value.

The proposed assessment approach is inspired from SPICE (i.e. ISO-IEC15504) (SPICE2, 2003). The linguistic variable x which is a *state of a criterion* is defined with a set of terms:

$T(x) = (\text{Not Achieved, Partially Achieved, Largely Achieved, Fully Achieved})$, which forms the universe of discourse $\mathrm{U} = [0\%, 100\%]$. The base variable x is state. *Partially achieved* represents a linguistic value. Each maturity level and required system states at each level can be characterized by the following values: *NA (Not Achieved), PA (Partially Achieved), LA (Largely Achieved), FA (Fully Achieved)*. Each linguistic value is respectively represented by a membership function $\mu(T(x))$, plotted in figure 4.7.

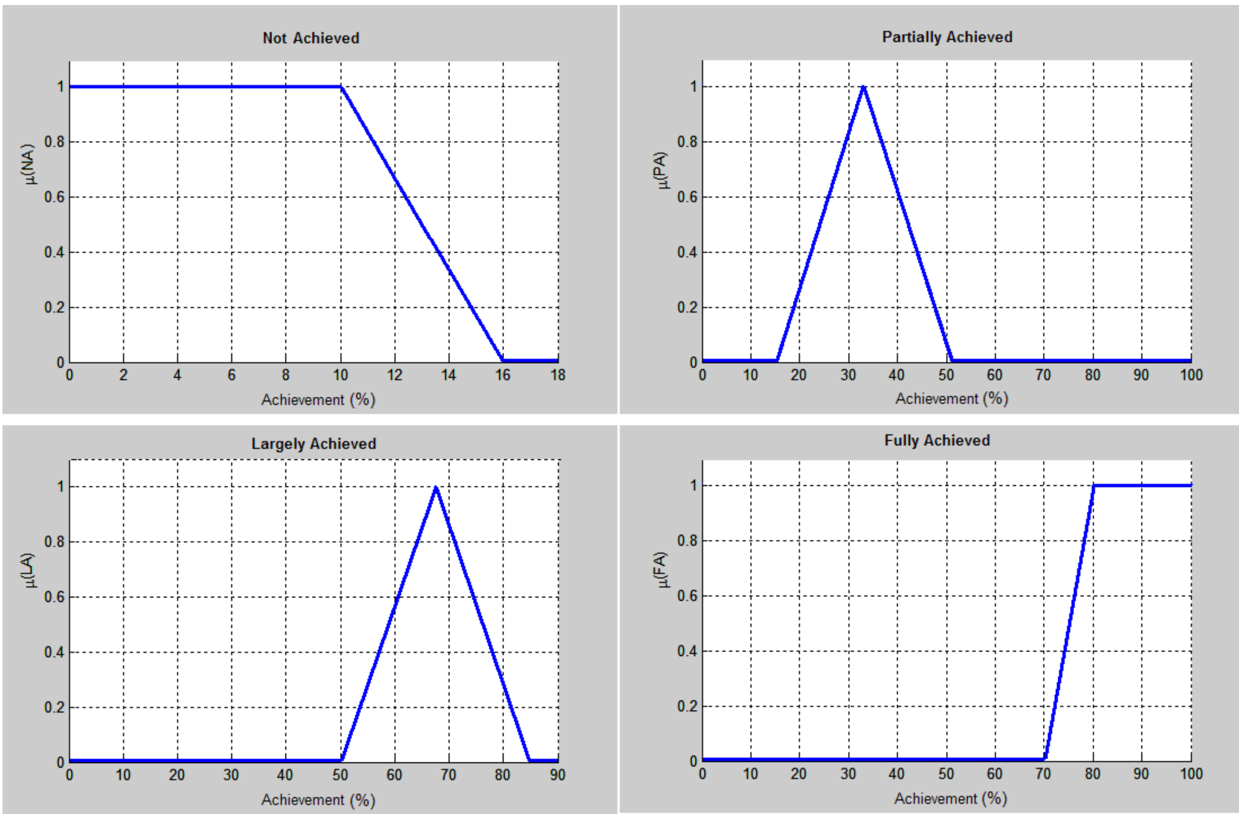

Figure 4.7. Membership diagrams of the linguistic variables

Boundaries between each linguistic value are determined using membership functions that are defined as follows:

1) A task or state is considered NA if its achievement is below 10%. At 14%, it is "only half" NA (half not achieved) and it is no longer "NA" above 16%. At this stage, we have:

$$\mu(NA) = \begin{cases} 1 \quad if \quad 0 \le x \le 10 \\ \dfrac{-x}{6} + \dfrac{8}{3} \quad if \quad 10 < x < 16 \end{cases}$$

2) If the set of states in an interoperability area is verified at 33.5%, it is called partially achieved (PA). Below 15%, it is not enough to be considered PA, Beyond 51%, it is no longer either.

$$\mu(PA)=\begin{Bmatrix} 1-\dfrac{2|x-33|}{36} & if \quad 15<x<51 \\ 0 \quad elsewhere & \end{Bmatrix}$$

3) The set of states in an interoperability area is considered largely achieved when realized at 65%. Below 50%, it is not enough to be considered as a performed task. Beyond 85%, it is no longer either.

$$\mu(LA)=\begin{Bmatrix} 1-\dfrac{2|x-67.5|}{35} & if \quad 50<x<85 \\ 0 \quad elsewhere & \end{Bmatrix}$$

4) The set of states in an interoperability area is considered to be fully achieved (FA) when it is realized with a percentage above 80%, with 75%, it is "only half" FA and it is not at all FA below 70%.

$$\mu(FA)=\begin{Bmatrix} 0 \quad if \quad x\leq 70 \\ \dfrac{x}{10}-7 \quad if \quad 70<x<80 \\ 1 \quad if \quad 80\leq x\leq 100 \end{Bmatrix}$$

Knowing these linguistic variables, assessors make their individual assessment and as an output of this phase, each one of them has to give an evaluation sheet. An overview of it is depicted by table 4.27.

Table 4.27. Individual assessment sheet

Criteria to evaluate	Observations	Individual Rating			
		NA	PA	LA	FA
Criterion1	Observation 1	☐	☐	☐	☒
Criterion 2	Observation 2	☐	☒	☐	☐

…	…	☐	☐	☒	☐
Criterion n	Observation n	☒	☐	☐	☐

Each linguistic value is associated with a score that is calculated based on the COG function (Centre of Gravity). Consequently the assessor doesn't intervene in the calculation of the ratings and the correspondence with the linguistic values. This is calculated automatically based on the formula defined bellow (Sladoje, 2007).

Definition 4.1. $COG(X) = \frac{\sum_{X\min}^{X\max} X.\mu(X)}{\sum_{X\min}^{X\max} \mu(X)}$

Where X = T(x), such as x is the variable name and T(x) is the set of linguistic values that may take x.

According to the definition and based on the membership functions defined in previous section, COG (FA) = 90.495, COG (LA) = 67.5, COG (PA) = 32.861, COG (NA) = 6.866.

Starting from the individual evaluations, the second phase is to aggregate them to have the team rating as explained in the next section.

4.6.3.2. Phase 2: Team rating using aggregation

In the enterprise context, multiple information sources having different knowledge levels can be exploited during an evaluation. Assessors need to aggregate linguistic values issued from these sources in order to determine the achieved degree of interoperability areas and thus the enterprise level (see figure 4.8). For that we use the OWA operators (Yager, 1994). The OWA operator was introduced by Yager (1988). It is a recent fuzzy aggregation technique based on the ordered weighted averaging operators. It allows a positive compensation between the assigned individual ratings in order to provide a team rating that takes into account the differences in ratings between assessors. From the obtained aggregation, we can determine if a level is fulfilled or not. A level is reached if it is at least "LA" and the lower levels are reached with "FA".

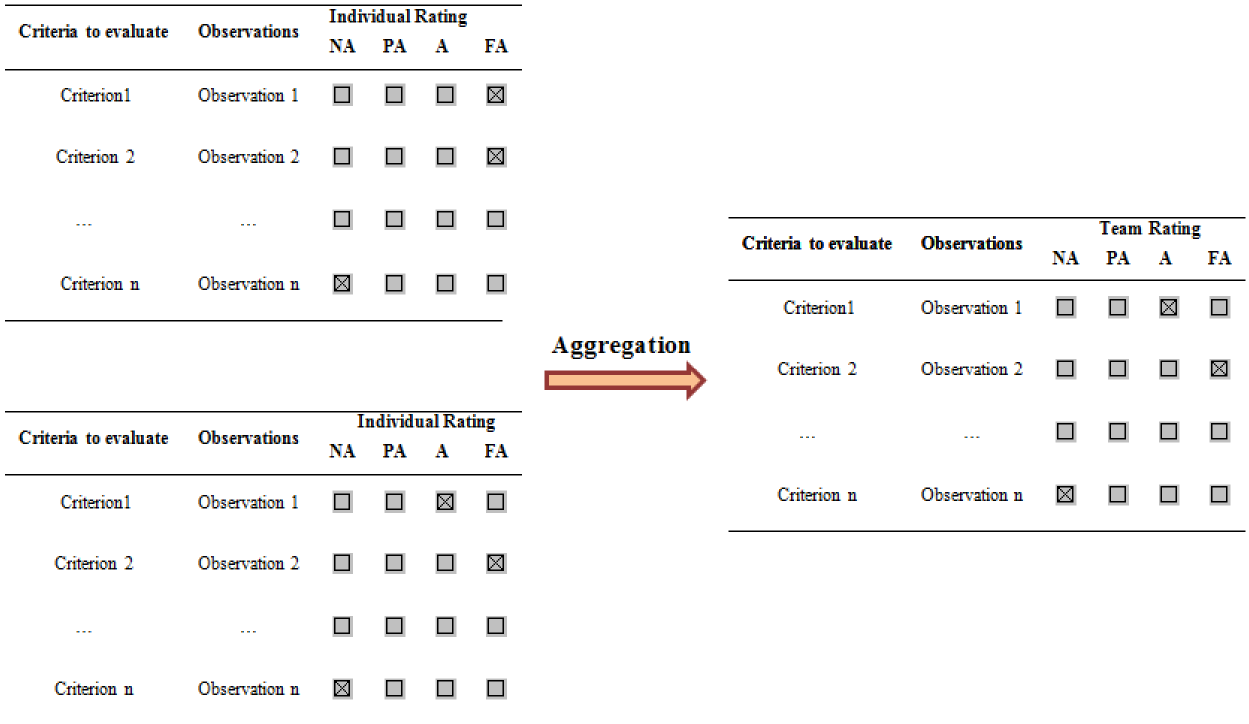

Figure 4.8. Team assessment based on the aggregation of the individual assessments

The OWA is calculated based on the following definitions:

Definition 4.2. An OWA operator of dimension n is a mapping OWA: $R^n \to R$ that has an associated vector $w = (w_1, w_2, \ldots w_n)$, such as $w_j \in [0,1]$, $1 \le j \le n$ and $\sum_{j=1}^{n} w_j = 1$, furthermore $OWA(a_1, a_2, \cdots, a_n) = \sum_{j=1}^{n} w_j b_j$ where b_j is the j-th largest element of the bag $(a_1, a_2, \ldots a_n)$.

Definition 4.3. Let $a_1, a_2, \ldots a_n$ be a collection of arguments, and let A be the average value of these arguments: $A = \frac{1}{n} \sum_{j=1}^{n} a_j$, then :

$s(b_j, A) = 1 - \dfrac{|b_j - A|}{\sum_{j=1}^{n} |a_j - A|}$; $j = 1, 2, \ldots n$ is called the similarity degree of the j-th largest argument b_j and the average value A.

Definition 4.4. Let $w = (w_1, w_2, \ldots w_n)$ be the weight vector of the OWA operator:

$$w_j = \frac{s(b_j, A)}{\sum_{j=1}^{n} s(b_j, A)} \quad ; j = 1,2,\ldots n$$

For example, assuming that $\mathrm{w} = (0.4, 0.3, 0.2, 0.1)$ then:

$$\mathrm{OWA}(0.7, 1, 0.2, 0.6) = 0.4 \times 1 + 0.3 \times 0.7 + 0.2 \times 0.6 + 0.1 \times 0.2 = 0.75$$

4.6.4. Maturity level determination (Stage 5)

The purpose of the stage 5 is to define the assessment rules determining the enterprise interoperability maturity level. To this end, fuzzy rules (Mamdani, 1977) (Zadeh, 1994) are defined, based on the assessment results (stage 4). The proposed fuzzy rules are heuristically defined using the four membership functions presented in Section 4.6.3.1, in combination with the widely used fuzzy IF– THEN rule structure (Mamdani, 1977), (Alonso and Magdalena, 2011). The determination of the enterprise interoperability maturity level using MMEI is based on the evaluation of its EI concerns and interoperability aspects. It is calculated as follows:

Let $R = \{r\}_i$ be the set of rules r allowing to calculate the interoperability maturity level L_E of an enterprise E and B_E, P_E, S_E and D_E the maturity levels of its business, process, service and data EI concerns respectively; and R_c the set of fuzzy rules allowing to determine the rating of an EI concern based on team ratings results (see section 4.6.3.2). Figure 4.9 gives a global view of level assessment rules.

$BCL, BTL, BOL, PCL, PTL, POL, SCL, STL, SOL, DCL, DTL$ *and* DOL represent the areas of interoperability (see section 4.5.2) at a level L, BL, PL, SL *and* DL denote respectively business, process, service and data EI concerns at level L.

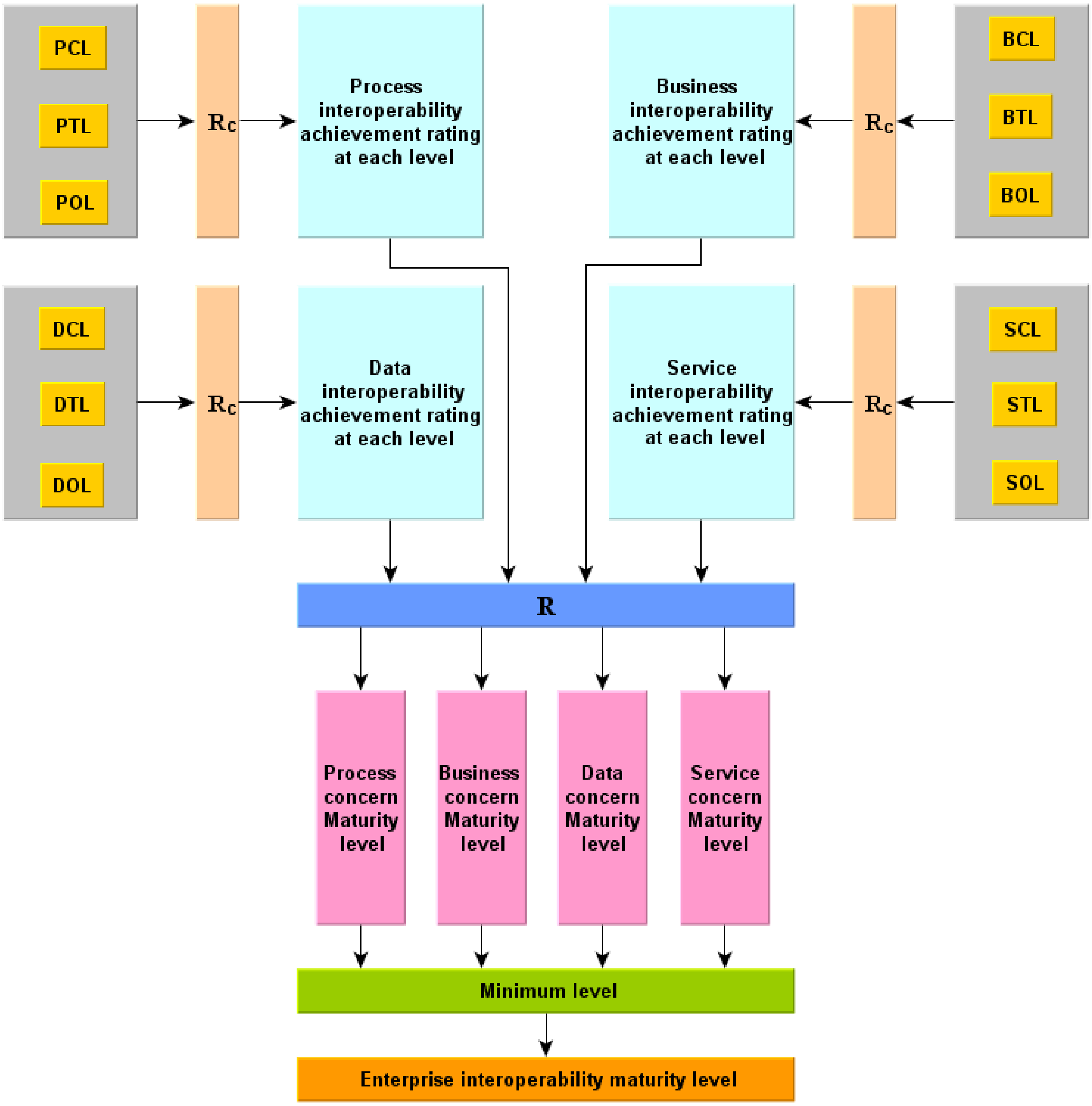

Figure 4.9. Global view of MMEI assessment rules

The Fuzzy R and Rc fuzzy rules are calculated as follows[3]*:*

$$
\begin{aligned}
&R_C = \{r_B, r_P, r_S, r_D\} \textit{ such as:}\\
&r_B = \{r_b\}: IF(BCL\ is\ \lambda_1)\ AND\ (BTL\ is\ \lambda_2)\ AND\ (BOL\ is\ \lambda_3)\ THEN\ (BL\ is\ \lambda_c)\\
&r_P = \{r_p\}: IF(PCL\ is\ \lambda_1)\ AND\ (PTL\ is\ \lambda_2)\ AND\ (POL\ is\ \lambda_3)\ THEN\ (PL\ is\ \lambda_c)\\
&r_S = \{r_s\}: IF(SCL\ is\ \lambda_1)\ AND\ (STL\ is\ \lambda_2)\ AND\ (SOL\ is\ \lambda_3)\ THEN\ (SL\ is\ \lambda_c)\\
&r_D = \{r_d\}: IF(DCL\ is\ \lambda_1)\ AND\ (DTL\ is\ \lambda_2)\ AND\ (DOL\ is\ \lambda_3)\ THEN\ (DL\ is\ \lambda_c)\\
&\textit{with}:\ \lambda_i, \lambda_c \in \{NA, PA, LA, FA\},\ L \in \{1,2,3,4\}
\end{aligned}
$$

$$
\begin{aligned}
&R = \{r'_B, r'_P, r'_S, r'_D\} \textit{ such as}:\\
&r'_B = \{r'_b\}: IF(B1\ is\ \lambda_{c1})\ AND\ (B2\ is\ \lambda_{c2})\ AND\ (B3\ is\ \lambda_{c3})\ AND\ (B_4 is\ \lambda_{c4})\ THEN(B_E = l)\\
&r'_P = \{r'_p\}: IF(P1\ is\ \lambda_{c1})\ AND\ (P2\ is\ \lambda_{c2})\ AND\ (P3\ is\ \lambda_{c3})\ AND\ (P_4 is\ \lambda_{c4})\ THEN(P_E = l)\\
&r'_S = \{r'_s\}: IF(S1\ is\ \lambda_{c1})\ AND\ (S2\ is\ \lambda_{c2})\ AND\ (S3\ is\ \lambda_{c3})\ AND\ (S4\ is\ \lambda_{c4})\ THEN(S_E = l)\\
&r'_D = \{r'_d\}: IF(D1\ is\ \lambda_{c1})\ AND(D2\ is\ \lambda_{c2})\ AND\ (D3\ is\ \lambda_{c3})\ AND\ (D4\ is\ \lambda_{c4})\ THEN(D_E = l)
\end{aligned}
$$

$L,\ l \in \{1,2,3,4\}\ \ \lambda_{ci} \in \{NA, PA, LA, FA\}$

Based on the obtained results, L_E is determined as follows:

$$L_E = \mathrm{Min}(B_E, P_E, S_E, D_E)$$

The set of fuzzy rules is defined based on two main steps:

- Step 1: applying R_C on EI concerns at all MMEI levels to calculate the rating of each concern regarding interoperability aspects. The result of this step is a rating by level for each EI concern.
- Step 2: Based on the results of step 1, step 2 consists of applying R on each concern to calculate its maturity level. The result of this step is the maturity level for each EI concern.

Based on the results of the two steps, the maturity level of the enterprise is determined by the minimum level among EI concerns maturity levels.

[3] The same notation is used in Annex 2

4.6.4.1. *Step 1: EI concerns assessment rules*

Based on the description of MMEI levels, three interoperability aspects need to be considered when evaluating enterprise interoperability concerns. The application of a specific set of rules (R_C) is needed to deal with the evaluation. Table 4.28 details some rules related to the assessment of enterprise business interoperability concerns at level 1. The complete list of the fuzzy rules is given in Annex 2. As output of this step, each EI concern at each level has an associated achievement rating.

Table 4.28. Extract from MMEI Fuzzy rules applied to business interoperability

Fuzzy rules – Extract from R_C –						
IF BC1 is NA	AND	BT1 is PA	AND	BO1 is NA	THEN	B1 is NA
IF BC1 is NA	AND	BT1 is PA	AND	BO1 is PA	THEN	B1 is PA
IF BC1 is PA	AND	BT1 is NA	AND	BO1 is NA	THEN	B1 is NA
IF BC1 is PA	AND	BT1 is NA	AND	BO1 is PA	THEN	B1 is PA
IF BC1 is PA	AND	BT1 is PA	AND	BO1 is NA	THEN	B1 is PA
IF BC1 is PA	AND	BT1 is PA	AND	BO1 is PA	THEN	B1 is PA
IF BC1 is NA	AND	BT1 is NA	AND	BO1 is LA	THEN	B1 is PA
IF BC1 is NA	AND	BT1 is LA	AND	BO1 is NA	THEN	B1 is PA
IF BC1 is NA	AND	BT1 is LA	AND	BO1 is LA	THEN	B1 is PA
IF BC1 is LA	AND	BT1 is NA	AND	BO1 is NA	THEN	B1 is PA
IF BC1 is LA	AND	BT1 is NA	AND	BO1 is LA	THEN	B1 is PA
IF BC1 is LA	AND	BT1 is LA	AND	BO1 is NA	THEN	B1 is PA

4.6.4.2. *Step 2: Level determination rules*

Based on the achievement ratings obtained from the EI concerns assessment (step 1), the maturity level of each interoperability concern is based on a list of fuzzy rules (R). It is important to note that an interoperability maturity level cannot be achieved if the preceding levels are not achieved with FA ratings. This point of view is adopted by most of the maturity models (Clark and Jones, 1999, Tolk, 2003). Assuming this, a set of fuzzy rules is associated to each MMEI level. Table 4.29 details some rules associated to the determination of the EI business concern level.

Table 4.29. Extract from Fuzzy rules for business level determination

Fuzzy rules – Extract from R –										
IF B1 is LA	AND	B2 is PA	AND	B3 is PA	AND	B4 is FA	THEN	B_E	=	1
IF B1 is LA	AND	B2 is LA	AND	B3 is NA	AND	B4 is PA	THEN	B_E	=	1
IF B1 is FA	AND	B2 is LA	AND	B3 is LA	AND	B4 is LA	THEN	B_E	=	2
IF B1 is FA	AND	B2 is LA	AND	B3 is NA	AND	B4 is NA	THEN	B_E	=	2
IF B1 is FA	AND	B2 is FA	AND	B3 is LA	AND	B4 is NA	THEN	B_E	=	3
IF B1 is FA	AND	B2 is FA	AND	B3 is LA	AND	B4 is PA	THEN	B_E	=	3
IF B_1 is FA	AND	B2 is FA	AND	B3 is FA	AND	B4 is LA	THEN	B_E	=	4
IF B_1 is FA	AND	B2 is FA	AND	B3 is FA	AND	B4 is NA	THEN	B_E	=	3
IF B_1 is FA	AND	B2 is FA	AND	B3 is FA	AND	B4 is FA	THEN	B_E	=	4
IF B_1 is FA	AND	B2 is FA	AND	B3 is FA	AND	B4 is PA	THEN	B_E	=	3

Based on the results given by the application of the R_C rules, the maturity level of each enterprise interoperability concern is determined using the set of fuzzy rules R. Figure 4.10 depicts the process of determination of the maturity level of the business interoperability concern.

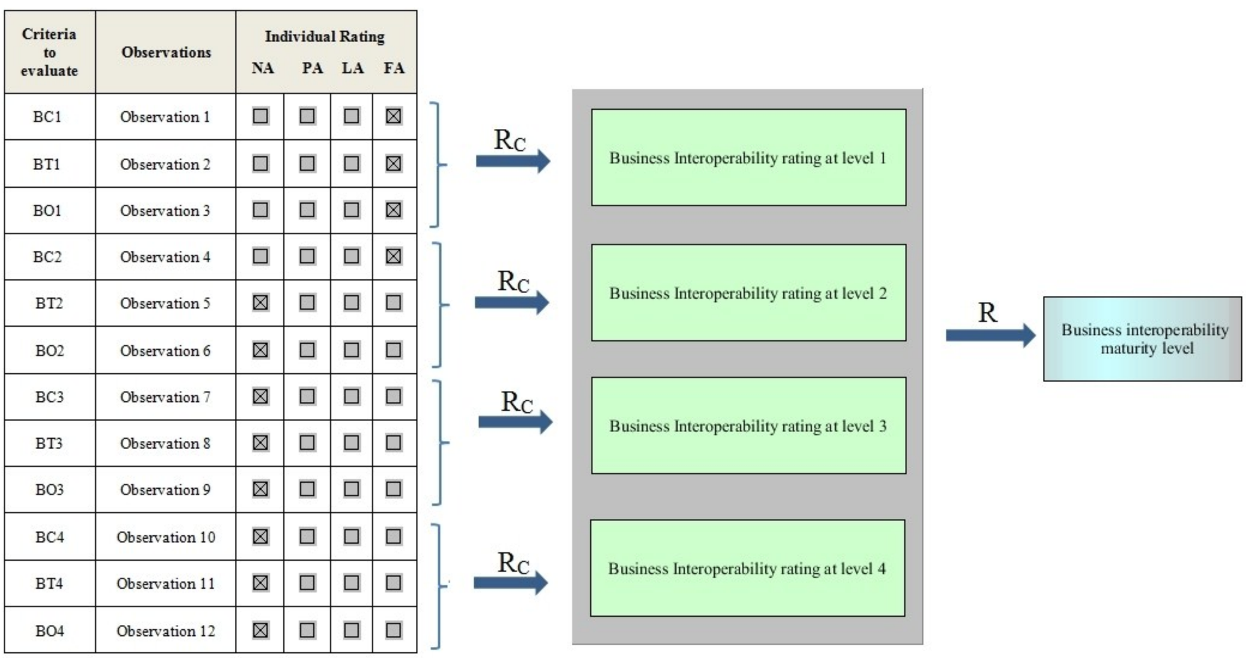

Figure 4.10. Determining maturity level of business interoperability concern

The enterprise interoperability maturity level is then determined by choosing the minimum level of its EI concerns maturity: $L_E = \text{Min}(B_E, P_E, S_E, D_E)$. For example, if $B_E = 3$, $P_E = 4$, $S_E = 2$, $D_E = 3$, the interoperability maturity level of the enterprise is 2.

4.6.4.3. *Discussion*

MMEI also allows the evaluation of the interoperability aspects. Based on the description of MMEI levels, four enterprise interoperability concerns need to be considered when evaluating these interoperability aspects. Table 4.30 details an example of rules related to the assessment of one interoperability aspect. BC1, PC1, SC1, DC1 and C1 stand, respectively, for Business-Conceptual area of interoperability at level 1, Process-Conceptual area of interoperability at level 1, Service-Conceptual at level 1, Data-Conceptual at level 1 and Enterprise Conceptual Interoperability at level 1, respectively.

Table 4.30. Example of MMEI Fuzzy rules applied to conceptual interoperability aspect

Fuzzy rules – Conceptual interoperability Aspect
IF BC1 is LA AND PC1 is LA AND SC1 is NA AND DC1 is NA THEN C1 is PA
IF BC1 is LA AND PC1 is LA AND SC1 is NA AND DC1 is FA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is NA AND DC1 is PA THEN C1 is PA
IF BC1 is LA AND PC1 is LA AND SC1 is FA AND DC1 is LA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is FA AND DC1 is NA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is FA AND DC1 is FA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is FA AND DC1 is PA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is PA AND DC1 is LA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is PA AND DC1 is NA THEN C1 is PA
IF BC1 is LA AND PC1 is LA AND SC1 is PA AND DC1 is FA THEN C1 is LA
IF BC1 is LA AND PC1 is LA AND SC1 is PA AND DC1 is PA THEN C1 is PA
IF BC1 is LA AND PC1 is NA AND SC1 is FA AND DC1 is LA THEN C1 is LA

The assessment process and level determination (stage 4 and 5) are summarized by the Algorithm 1: Firstly, a fuzzy set of input data is gathered (i.e. the linguistic terms expressed by assessors) and converted to a crisp set (i.e. numerical values) using membership functions and the COG method. Afterwards, the aggregation method is applied using the OWA operator in order to compute the team ratings. Lastly, the resulting crisp outputs are mapped to a fuzzy output (linguistic terms) using the membership functions and an inference is made based on a set of rules to determine whether the maturity level is achieved or not.

Algorithm 1 - Assessment process algorithm -

1. Define the linguistic variables and terms
2. Construct the membership functions
3. Convert collected fuzzy data to crisp values using the membership functions and COG method
4. Aggregate obtained crisp values using OWA method
5. Convert the computed crisp results into linguistic terms using membership functions
6. Calculate the rating of EI concerns at each level based on R1 fuzzy rules
7. Determine the MMEI level of each EI concern based on R
8. Determine enterprise maturity level by choosing the minimum level among EI levels

4.6.4.4. Graphical representation of MMEI assessment results

The interoperability assessment of an enterprise with MMEI can be represented in different ways. Figure 4.11[4] shows one possible representation of results as a Kiviat graph (radar plot) that allows one to represent the 5 maturity levels in relation to the 12 areas of interoperability based on the 4 interoperability concerns (i.e. Business, process, service and data) and the 3 interoperability barriers (conceptual, technological and organizational). Figure 4.11 also shows an illustrative example of an assessment of two enterprises' interoperability potential (green and blue lines). Depending on the enterprise goal to reach a particular maturity level, the existing and missing capabilities can be identified. In the example, for the green enterprise the organizational capabilities of the data and service concerns are at level 1 whereas the process concern does not even reach level 1. Technological capabilities of the business and data maturity levels are also at level 1 whereas the conceptual capabilities reaches the maturity level 3 for business, process and service, respectively. If level 2 was the desired level for the intended cooperation between the two enterprises, improvements would have to be made in technological capabilities on the business and data concerns and in organizational capabilities on the three concerns: process, service and data.

[4] Originally proposed by K. Kosanke and D. Shorter (CEN TC310/WG1)

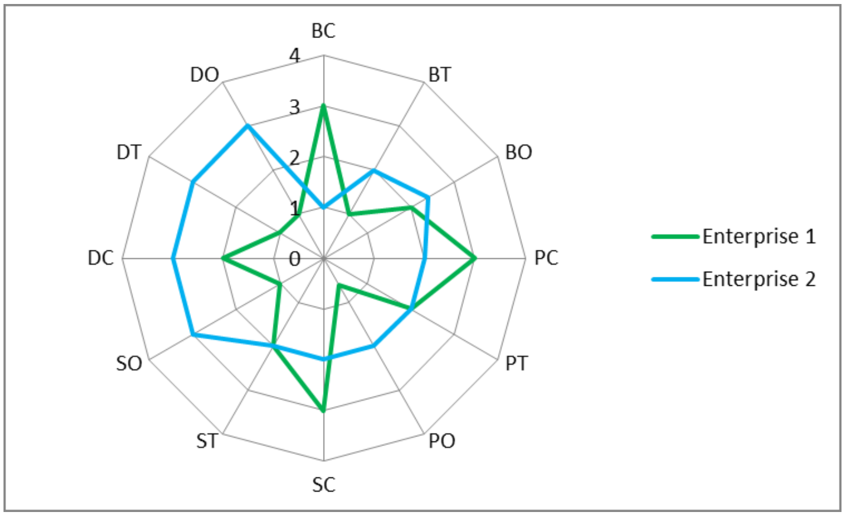

Figure 4.11. Example of a graphical representation of MMEI assessment

As a maturity level cannot be reached if the preceding levels are not achieved with *FA* ratings, detailed graphs can also be given in order to see if an enterprise has already made some progress in the higher levels and to localize potential interoperability problems. Figure 4.12 gives a detailed assessment of the process interoperability concern of the company presented in figure 4.11 with the green color (i.e. enterprise 1). The detailed version of the assessment results would allow the company to detect exactly where the problem is and what remains to be done in order to realize its target level. For example, the general graphical representation (figure 4.11) reports that the PO doesn't even reach level 1, but the company may need details to localize the problem. Indeed, as shown by figure 4.12, the company has defined procedures for process interoperability (i.e. PO2 is Achieved with *LA* rating) however the problem is that the PO1 is not achieved (i.e. *NA* rating) because there is no defined responsibility nor authorities for processes. So if the company needs to cooperate with the blue company at level 2 then it should reach PO1 with an *FA* rating, meaning that it has to define their processes' responsibilities and authorities and to apply definitions in everyday use.

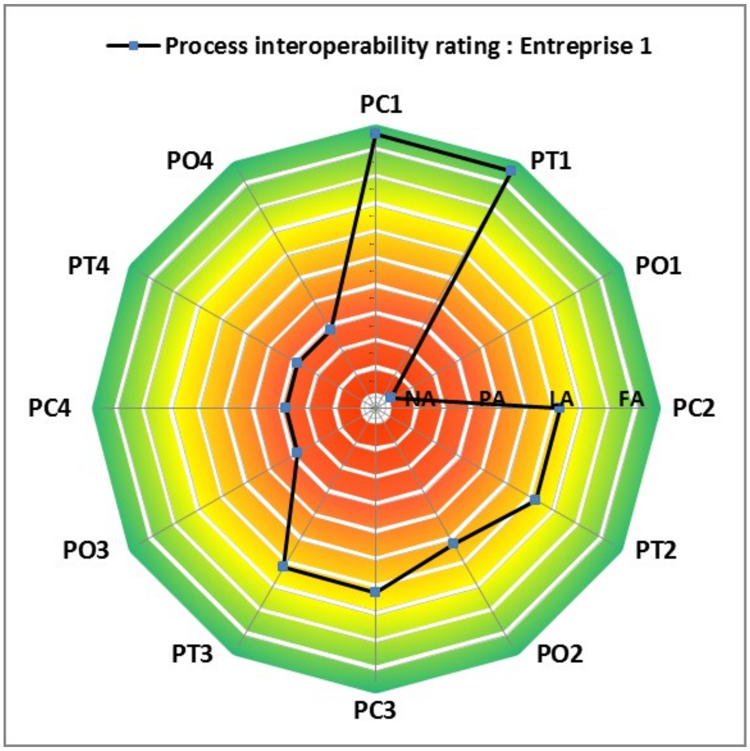

Figure 4.12. Example of process interoperability assessment details (enterprise 1)

4.7. MMEI best practices

In this section, the MMEI best practices that are given by the methodology to migrate from an interoperability maturity level to a higher one are defined. Best practices are suggested tasks and activities satisfying the criteria described in interoperability areas of MMEI (with the exception of the level 0).

The approach for defining best practices consists in describing the principles and leaving their implementation up to each enterprise, according to each objective, environment, and the experiences of its directors, managers and staff. They describe the "what" in broad terms so that organizations are left great leeway in creatively implementing the "how." For example, the MMEI might indicate that the IT infrastructure should be implemented but it does not prescribe how this infrastructure should be implemented, which kind of infrastructure to use, etc. An overview of the main best practices for an MMEI maturity level is presented in table 4.31. Each best practice consists of a single sentence, sometimes followed by a detailed description.

Table 4.31. Description of the MMEI level 1 best practices

Maturity Level	Conceptual	Technical	Organizational
Business	BC1.1. Define business models. BC1.2. Document Business models	BT1.1.Use of an IT infrastructure BT2. Make sure that the IT infrastructure is connectable	BO1.1. Define business responsibilities/authorities BO1.2. Make sure that defined responsibilities are known and in palace
Process	PC1.1.Define Process models PC1.2. Document process models	PT1.1. Put in place tools supporting processes PT1.2. Make tools supporting processes, accessible.	PO1.1 Define processes management responsibilities/authorities PO1.2. Make sure that defined responsibilities are known and in place
Service	SC1.1. Define service models SC1.2. Document service models	ST1.1. Put in place tools supporting services ST1.2. Make tools supporting services, accessible.	SO1.1. Define services management responsibilities/authorities SO1.2. Make sure that defined responsibilities are known and in place
Data	DC1.1. Define data models DC1.2. Document data models	DT1.1. Put in place tools supporting data storage DT1.2. Make data storage devices accessible	DO1.1. Define data management responsibilities/authorities DO1.2. Make sure that defined responsibilities are known and in place

Each one of these practices is detailed by a tabular description. Table 4.32 depicts the description of PC1 best practices. All other best practices of the different areas of interoperability are detailed in annex 1. It is to note that the used format of the table is the one adopted in ISO 15504 best practices documents (SPICE, 2001) (Cortina and Picard, 2011).

Table 4.32. Best practices of the PC 1 area of interoperability

EI maturity level	**Level 1**
EI Aspect	**Conceptual**
EI Concern	**Process**
ID	**PC1**
Purpose	**The purpose of the PC1 interoperability area is to verify to which extent Process models are defined and documented** *Note 1*: Some Process models can be defined and not documented. We can also find some activities or tasks of processes that are defined and documented whereas other elements are not properly defined. *Note 2*: The Process model defines the activities based on the business inputs (resources) and outputs (products).
Expected results	**Process models are defined and documented**
Assessment indicators	Assessors have to verify to which extent Process models are defined and documented. For that they have to see for each process if there are documents defining it. If yes, they have to look at (a) the formalism level of the models (depending on the used modeling language, if any); and (b) level of detail, access level (restricted or for everyone), and understandability of models description and explanations.
Best Practices	**PC1.1. Define Process models** Identify for each process its outcomes and related activities. Identify the involved resources: human, material and immaterial resources. Identify the sequence of execution of activities. Identify the rules of the process and restrictions (if any). Note 1: The Process model is mainly understandable by the person defining it and should be documented to have extra information explaining the description. **PC1.2. Document Process model** Add notes (metadata) to each process model in order to be support understanding by any person using the model.

4.8. Conclusion

The interoperability maturity assessment is an activity that can be performed either as part of an improvement initiative or as part of an interoperability analysis. In this chapter, a maturity model for enterprise interoperability (MMEI) was proposed based on the OoEI, defined in chapter 2 and enhanced in chapter 3. Five levels of maturity were defined. MMEI covers the four main enterprise interoperability concerns and the three main interoperability aspects which were usually dealt by separate distinct maturity models. The proposed MMEI focuses on interoperability potential assessment which is not well addressed by existing interoperability maturity models. It also proposes an innovative approach for interoperability assessment which is based on the fuzzy sets theory and uses the OWA aggregation operator. The latter allows a positive compensation between the assigned ratings, in order to provide aggregate summary of the findings of the enterprise assessors, which takes into account the differences in ratings between assessors.

From an assessor's point of view, the maturity model is considered as a basis for measurement: it defines 'what' an assessor should assess in order to determine the maturity of an enterprise. The assessment methodology, on the other hand, defines 'how' assessors should carry out the assessment to determine maturity (DoD, 1998).

Based on the result of the assessment, best practices are then provided to give a guideline (a set of actions to implement) answering to the question "what to do to improve" to reach higher levels of interoperability maturity.

Chapter 5

Case Application

5.1. Introduction

This chapter illustrates the application of the proposed MMEI within an industrial context through a case study. The case study concerns a multinational company: METS (Manufacture Electro-Technical of Sousse) a subsidiary of the German Draxelmaier group[5], specialized in automobile manufacturers including wiring harness systems, exclusive interiors and electrical components. To ensure its functions and reach its objectives, the company needs to interoperate with many partners, including its headquarters in Germany. This is relevant for the application of our approach.

In order to understand the way the enterprise functions, a series of interviews were conducted (see Annex 4), the OoEI was then instantiated and the MMEI model applied to determine the interoperability maturity level of the company.

5.2. Case presentation

Production of wiring harnesses is, despite automation of some elements of the process, labor-intensive. In the automotive industry car-makers do not produce wiring harnesses themselves: the cable purchaser is usually a specialist assembler of auto harnesses that supplies these items to the car-maker (see figure 5.1).

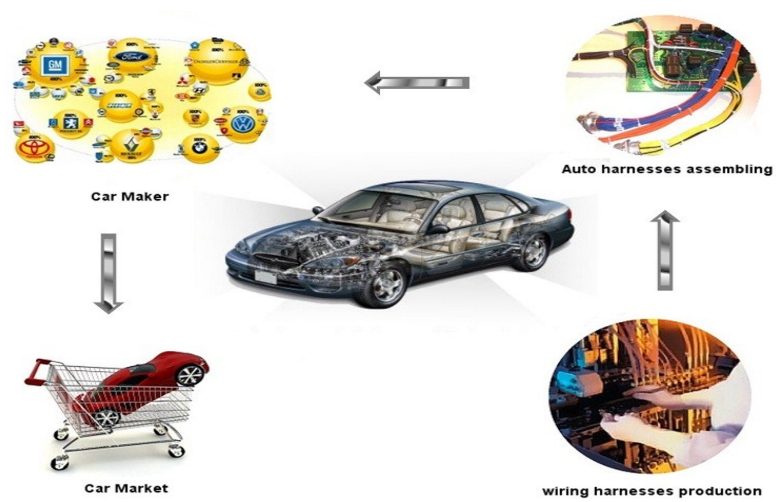

Figure 5.1. Car producing process

[5] http://www.draexlmaier.de

Dräxlmaier is a German group and one of the very few automotive suppliers possessing expertise in auto electric, wire harnesses, interiors, plastics, tool making and logistics. It is located at 56 sites throughout the world today. As an international partner to the automotive industry, the Dräxlmaier Group has a global presence on four continents, in over 21 countries, at over 50 locations.

In early 1974, METS Company (Manufacture Electro-Technical of Sousse) was created. It is 100% export oriented: all its production is directed to the headquarters in Germany. The headquarters are then responsible for the distribution to the clients or other production sites (see figure 5.2).

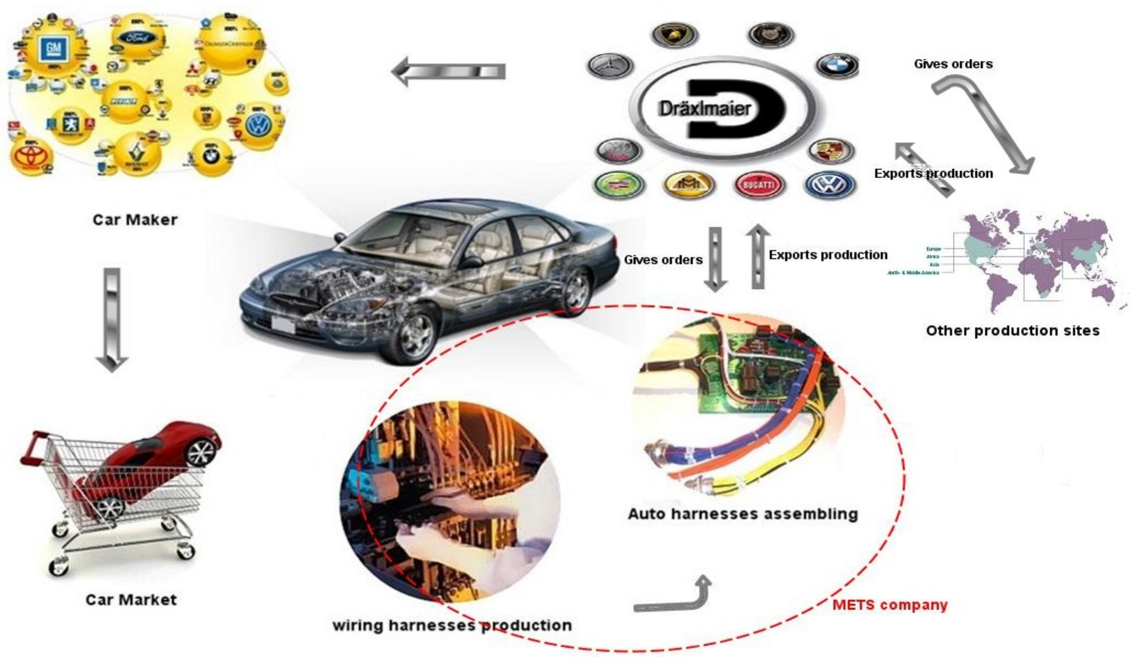

Figure 5.2. METS Company

The company includes 10 departments (see figure 5.3): General Direction (D.G), Production management (D.P), Maintenance Service (S.M), production service (S.P), stores department (S.M), Quality department (D.Q), Department of finance (D.F), research department (B.E), Logistics management (D.L), human resources department (D.RH).

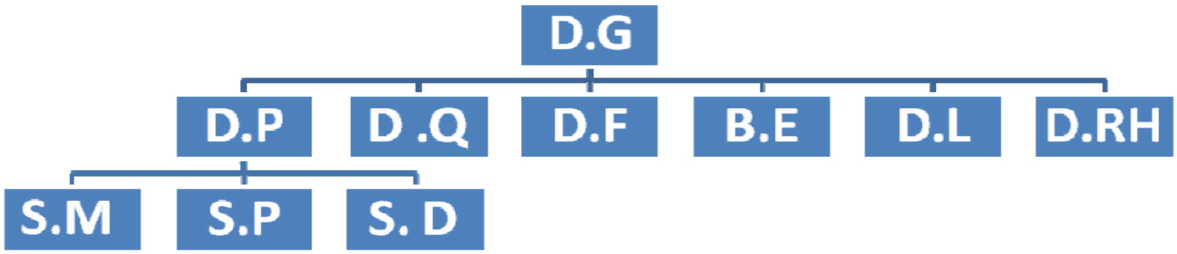

Figure 5.3. Organization chart of METS

Our study focuses on the assessment of the interoperability potential of METS. To do so, it is necessary to have a sufficient knowledge about its existent interoperations, problems and undertaken solutions. To this end, the OoEI was instantiated for this specific company. This was then followed by a demonstration of how the MMEI maturity model can be applied to determine the company's maturity level and potential corrective actions that can be taken to improve its interoperability maturity.

5.3. Case modeling using OoEI

In order to understand the interoperations of the company, its *normal* operational business process needed to be established. The "normal business process" starts when the company receives an order of production from the headquarters in Germany. If the order concerns a new product, then a prototyping is needed and a sample is produced. After a decision is reached, the production process can be launched, as described by figure 5.4.

There are five main stakeholders for the company. These are:

- The headquarters in Germany, from where the company receives orders.
- The production site in Poland to whom the company exports the semi-final products.
- The production sites, from where the company receives semi-final products to finalize.
- The suppliers of the raw materials and accessories.
- Customs for the export.

As analyzing relations are the first requirement for identifying interoperability problems, a formal representation of the METS Company and the main relations that may be source of incompatibility are provided, using OoEI.

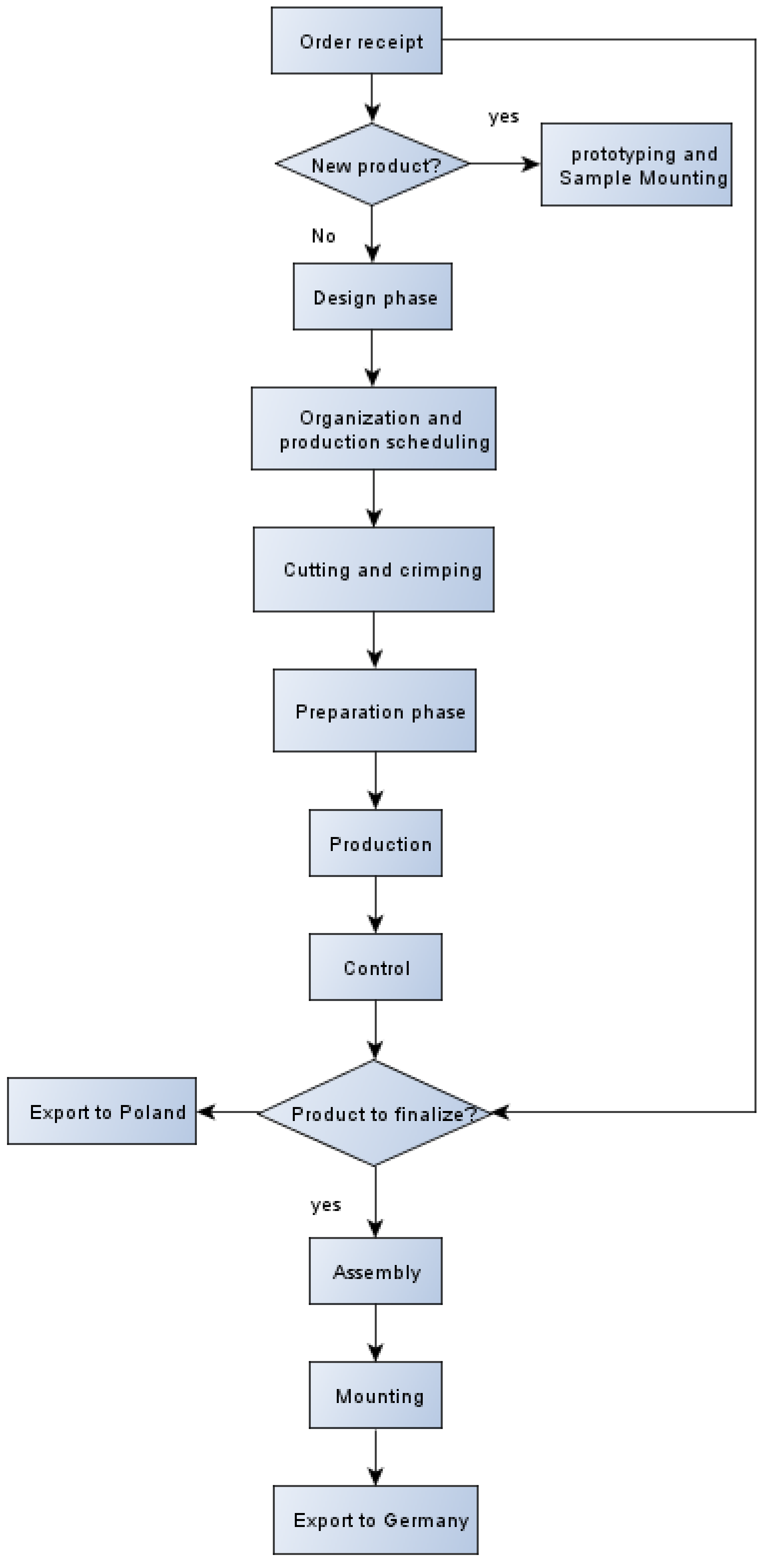

Figure 5.4. The normal business process of "METS" company

In order to differentiate between the instantiated concepts (i.e. specific to the company) and those of OoEI, the instantiated concepts are represented by blue rectangles as shown in figure 5.5.

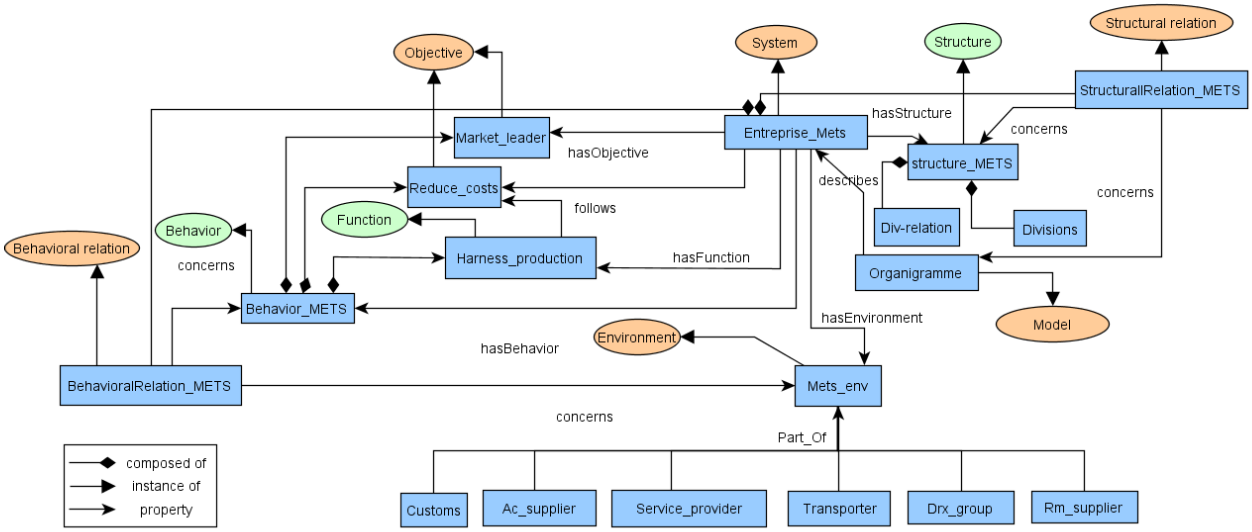

Figure 5.5. METS modeling using OoEI

The company is represented by the *Enterprise_Mets* concept. As an instance of *ooei:System*, it inherits all their properties and constituents. Hence it has its own structure and behavior, represented respectively by *Structure_METS* and *Behavior_METS*. The company produces wire harnesses for the cars and has two main objectives: continuous reduction of the costs of its production and to be the leader within its market. This is represented by the concept *Harness_production*, instance of *ooei:function* and two instances *ooei:objective*: *Market leader* and *Reduce costs*.

As any multinational enterprise, METS evolves in its environment and has many partners. This is represented by *Mets_env* concept, instance of *ooei:environment*. Within this environment, the customs, the supplier of the accessories, the transporter, the draxelmaier headquarters, the supplier of raw material and the provider of all other services are found. This is respectively represented by the concepts: *Customs*, *Ac supplier*, *Transporter*, *Drx group*, *Rm supplier*, *Service provider*.

The OoEI instantiation provides an overview of the enterprise structure and the main relations that exist. This gives an idea about the potential a priori interoperability problems. Based on this and the interviews that were conducted with the enterprise personnel, the next section details the application of the MMEI model.

5.4. MMEI application

In order to meet high standard, the company has established a management system which aims to continuously optimize their processes and therefore increase its competitiveness. This is known as the Dräxlmaier Process Management (DPM). The quality of this management system is regularly certified by TS 16949 (Hoyle, 2005).

The business processes of the company were determined and conceived under the consideration of the principle "as much uniformity as possible, as much individuality as necessary"[6]. This leads to synergy effects due to standardization, while also allowing enough flexibility for the integration of varying external requirements.

The process model serves as a communication platform. It contains the process structure and therefore supports the exchange of information within and between the process networks. Moreover, a process cockpit[7] exists in order to evaluate process performance using key performance indicators (KPI).

The working methods are called "work instructions". These instructions are formalized using standards, validated by the quality department and known by all employees, applied and categorized by department. Each employee has a function file where his/her role is defined with the detailed activities to be performed (role description) and the persons that are able to replace him in each activity in case of absence.

In order to ensure a regular monitoring of the site, the headquarters, in Germany, require that “Portfolio Management" is sent weekly. It is a document containing all ongoing tasks including but not limited to problems faced and tasks to do.

A questionnaire was defined and used in the METS Company to collect relevant information during the assessment process. Table 5.1 gives an extract of some of the main questions defined in the questionnaire for assessing the business interoperability area (the complete questionnaire can be found in Annex 3).

[6] www.draxelmaier.de

[7] Master process

Table 5.1. Extract from the MMEI questionnaire35

Extract from MMEI Questionnaire
Q1. *What are the main objectives of the enterprise?*
Q2. *What are the main activities of the enterprise?*
Q3. *What are the products of the enterprise?*
Q4. *Who are the enterprise clients?*
Q5. *Who are the enterprise partners?*
Q6. *Is there a defined business model?*
Q7. *Is business model using standards?*
Q8. *Who knows the business model and has access to?*
Q9. *Who is responsible to ensure that the defined business model is followed?*
Q10. *Is there a defined organization structure?*
Q11. *Is it easy to make changes in the organization structure? How?*
Q12. *Are there organized trainings for employees? If yes, is there one for interoperability?*
Q13. *How the enterprise reacts in case of a new partner? Is it easy to make changes, if needed?*
Q14. *In case of launching a new product, what are difficulties that can be faced?*
Q15. *How the communication and information exchange are ensured within the enterprise?*
Q16. *How the communication and information exchange are ensured with partners (suppliers, clients, etc)?*
Q17. *What are elements that the enterprise would like to improve? If exist, do you think this will impact considerably the enterprise business?*

The questionnaire was semi-structured and the questions listed above were used to initiate discussion on identified issues. Follow-through questions were then asked to check understanding of the question and reliability of the answer. It is to note that follow-through questions play an important role in the interviews to collect more detailed and complementary information. Table 5.2 provides extracts from answers to the questions related to the assessment of interoperability.

Table 5.2. Extract from the MMEI interview 36

Extract from Questionnaire and corresponding responses
Q1. Is there a defined business model? ***R1 :*** *Yes, there is a model that describes the enterprise business and all related elements.* ***Q2. In this business model, what are the main defined objectives of the enterprise?*** ***R2 :*** *Meet/Respect delivery deadlines, have a good quality to minimize customer complaints, reduce costs, maximize its profile and of course to be a leader in the market.* ***Q3. What are the products of the enterprise?*** ***R3 :*** *The company is specialized in the production of electrical auto wires for exportation to the headquarters for the assembly and redirection to the final clients (i.e. car manufacturers), it has a continuous production* ***Q4. What are the main activities of the enterprise?*** ***R4 :*** *Design of the technical sheets received from the headquarters using specific software. Purchasing raw materials: wires, accessories (connectors, accessories, etc., Cables cutting, Cable assembling: some accessories are connected by special machines and others are only connected manually (cannot be connected using machines), mounting, Etc.* ***Q5. What are the main resources that are used to realize these activities?*** ***R5 :*** *Cable coils, accessories, computers, machinery, iron, human resources, etc.* ***Q6. Who are the enterprise clients?*** ***R6 :*** *Car manufacturers: General Motors (Opel), Volkswagen, Audit, etc.* ***Q7. Who are the enterprise partners?*** ***R7 :*** *Raw material supplier (i.e. mainly “KBE” company); accessories’ supplier, Headquarters.* ***Q8. How is the enterprise achieving its objectives (strategy)?*** ***R8 :*** *There are three workstations: 24 hours a day and sometimes 7 days a week if needed. There are always some extra employees in case of necessity. For example, when the number of employees needed in the production chain is N, we usually find N+2 employees (variable number) allocated. In case of a production delay, it is compensated with extra hours on Saturdays and Sundays It is also to note that the company is investing heavily to reach its objectives: employees' training, acquisition of the latest versions of software, etc.*

Based on the collected information (through a series of interviews to different employees in the company) and the MMEI levels' criteria, the following evaluation sheets, presented by tables 5.3, 5.4, 5.5 and 5.5 detail the evaluation of the business, process, service and data interoperability respectively.

Table 5.3. Evaluation sheet for business interoperability potential

	Criteria to evaluate	Observations	Rating			
			NA	PA	LA	FA
BC1	Business model modeled or documented	Business model exists and is documented	☐	☐	☐	☒
BT1	Basic IT infrastructure in place	IT infrastructure is in place	☐	☐	☐	☒
BO1	Organization structure defined and in place	An organization chart is defined and in place	☐	☐	☐	☒
BC2	Use of standards for alignment with other business models	Business model is defined using standard format files. The alignment is done regularly with the headquarters.	☐	☐	☒	☐
BT2	Standard and configurable IT infrastructures	Use of satellite, e-mails, telephones.	☐	☐	☐	☒
BO2	Human resources trained for interoperability.	Personal know what to do in case of problems. The risk is managed. Regular training for employees.	☐	☐	☐	☒
BC3	Business models for multi partnership and collaborative enterprise	The different partners are mentioned in the business model. The enterprise business is based on collaboration.	☐	☐	☒	☐
BT3	Open IT infrastructure	Ability to introduce new IT applications and technical assets when needed.	☐	☐	☒	☐
BO3	Flexible organization structure	Change is possible for organization structure.	☐	☐	☒	☐
BC4	Adaptive business model	Enterprise business is adapted to catch new opportunities and use new technologies. A reuse strategy is used.	☐	☐	☒	☐
BT4	Adaptive IT infrastructure	Reusable components for processes and services and some home-made applications exist	☐	☒	☐	☐
BO4	Agile organization for on-demand business	Ability to launch new products, answer new partners' demand but need time. For that, a procedure defining actions to undertake is in place.	☐	☐	☒	☐

Table 5.4. Evaluation sheet for process interoperability potential

	Criteria to evaluate	Observations	Rating NA	PA	LA	FA
PC1	Process models modeled or documented	Processes are modeled and documented	☐	☐	☐	☒
PT1	IT support for processes. Ad hoc exchange for process information	IT tools are in place to execute processes. Processes information is exchanged with the headquarters.	☐	☐	☐	☒
PO1	Processes responsibilities/authorities defined and in place	Processes responsibilities and authorities are defined and in place.	☐	☐	☐	☒
PC2	Use of standards for alignment with other process models	Use of the DPM standard.	☐	☐	☒	☐
PT2	Standard Process tools & platforms	Process tools and platforms are using the standards (Tüv certification for processes execution).	☐	☐	☒	☐
PO2	Procedures for processes interoperability	Process model contains instructions to exchange information between the process networks.	☐	☐	☒	☐
PC3	Meta-modeling for multiple process model mappings	-------------	☒	☐	☐	☐
PT3	Platform & tool for collaborative execution of processes	Platforms were conceived under the collaboration principle.	☐	☐	☒	☐
PO3	Cross-enterprise collaborative processes management	Defined rules and responsibilities for collaborative processes management with headquarters.	☐	☐	☒	☐
PC4	Modeling for dynamic process re-engineering.	Some process models can be used and adapted to develop other processes but this is not done rapidly.	☐	☒	☐	☐
PT4	Dynamic and adaptive tools and engines for processes.	Processes activities are chosen dynamically on the computers assisting the production to answer a demand.	☐	☐	☒	☐
PO4	Real-time monitoring of processes, adaptive procedures.	Computers assisting the production allow a real time monitoring of processes. Procedures can be adapted but need time.	☐	☐	☒	☐

Table 5.5. Evaluation sheet for service interoperability potential

	Criteria to evaluate	Observations	Rating NA	PA	LA	FA
SC1	Service models modeled or documented	Service models are modeled and documented	☐	☐	☐	☒
ST1	Applications/services connectable. Ad hoc information exchange possible	IT tools supporting services and applications in place. Information exchange is done with headquarters.	☐	☐	☐	☒
SO1	Services responsibilities/authorities defined and in place	Services responsibilities and authorities are defined and in place	☐	☐	☐	☒
SC2	Use of standards for alignment with other service models	Standard services and applications (Tüv certification)	☐	☐	☒	☐
ST2	Standard and configurable architecture & interface	Standard and configurable interface for the enterprise production depending on the client 's demand	☐	☐	☒	☐
SO2	Procedures for services interoperability	Procedures are defined for the applications that are functioning in network.	☐	☐	☒	☐
SC3	Meta-modeling for multiple service model mappings	-----------------	☒	☐	☐	☐
ST3	Automated services discovery and composition, shared applications	Applications are shared within the enterprise. The discovery and composition of services are automatically done on computers assisting production.	☐	☐	☒	☐
SO3	Collaborative services and application management	Guidelines and responsibilities for services composition are defined	☐	☐	☒	☐
SC4	Adaptive service modeling	Service modelling is supporting service composition and can be adapted following the headquarters orders.	☐	☐	☒	☐
ST4	Dynamically composable services, networked applications	Applications are only shared with headquarters.	☐	☒	☐	☐
SO4	Dynamic management rules and methods of services and applications	-------------------	☒	☐	☐	☐

Table 5.6. Individual evaluation sheet for data interoperability potential

	Criteria to evaluate	Observations	Rating NA	PA	LA	FA
DC1	Data models modeled or documented	Data models are modeled and documented	☐	☐	☐	☒
DT1	Data storage devices connectable, simple electronic exchange possible	Data is exchanged by e-mails, on server, intranet, usb-devices, etc.	☐	☐	☐	☒
DO1	Data responsibilities/authorities defined and in place	Data responsibilities and authorities are defined and in place	☐	☐	☐	☒
DC2	Use of standards for alignment with other data models	Use of Merise and UML	☐	☐	☐	☒
DT2	Automated access to data, based on standard protocols	Data is available on server and accessed via intranet protocols.	☐	☐	☒	☐
DO2	Rules and methods for data management	DFM system in place and access to data based is access rights.	☐	☐	☒	☐
DC3	Meta-modeling for multiple data model mappings	--------------------------	☒	☐	☐	☐
DT3	Remote access to databases possible for applications, shared data	Shared applications and shared data.	☐	☐	☒	☐
DO3	personalized data management for different partners	No rules or methods for data personalization	☒	☐	☐	☐
DC4	Adaptive data models (both syntax and semantics)	----------------	☒	☐	☐	☐
BT4	Direct database exchanges capability and full data conversion tool	--------------	☒	☐	☐	☐
BO4	Adaptive data management rules and methods	--------------------	☒	☐	☐	☐

According to these assigned ratings and the fuzzy rules the maturity level of each EI concern is determined in the following (i.e. the fuzzy rules, detailed in annex 2, are mentioned with their rule number when used):

B_1=FA (see r_{b22}), B_2=FA (see r_{b37}), B_3= LA (see r_{b15}) and B_4=LA (see r_{b25}). Based on the R fuzzy rules, the business interoperability maturity is B_E=3 (see r'_{b97}). P_1=FA (see r_{p22}), P_2=LA, (see r_{p15}), P_3=PA (see r_{p11}), P_4=LA (see r_{p25}), the process interoperability maturity is P_E=2 (see r'_{p77}). S_1=FA (see r_{s22}), S_2=LA (see r_{s15}), S_3= PA (see r_{s11}), S_4=PA (see r_{s44}), the service interoperability maturity is S_E=2 (see r'_{s80}). D_1= FA (see r_{d22}), D_2=LA (r_{d38}), D_3=PA (see r_{d10}), D_4=NA (see r_{d1}), the data interoperability maturity is D_E=2 (see r'_{d78}). Taking the minimum value, the interoperability maturity level of METS Company is level 2. Figure 5.6 gives a graphical representation of the results of this assessment.

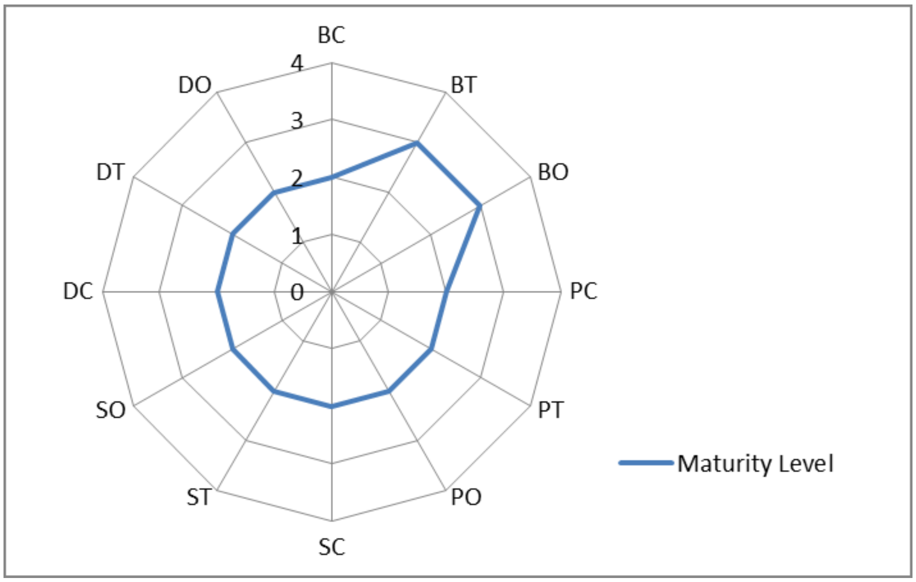

Figure 5.6. A graphical representation of the MMEI assessment of METS company

As shown by the figure 5.6, if METS wants to reach a higher interoperability potential, the enterprise should improve conceptual capabilities at all concerns (i.e. BC, PC, SC and DC), technological capabilities for process, service and data concerns (i.e. PT, ST and DT), and organizational capabilities for process, service and data concerns (i.e. PO, SO and DO).

The detailed assessment results allowing the company to detect deficiencies are presented by the figure 5.7. The figure shows that the enterprise has already achieved some progress on level 4 (i.e. BC4, BO4, PT4, PO4, SC4). However, the level 2 is not achieved with *FA* rating due to some deficiencies at BC2, PC2, DT2, DO2, SC2, ST2 and BC2 areas of interoperability.

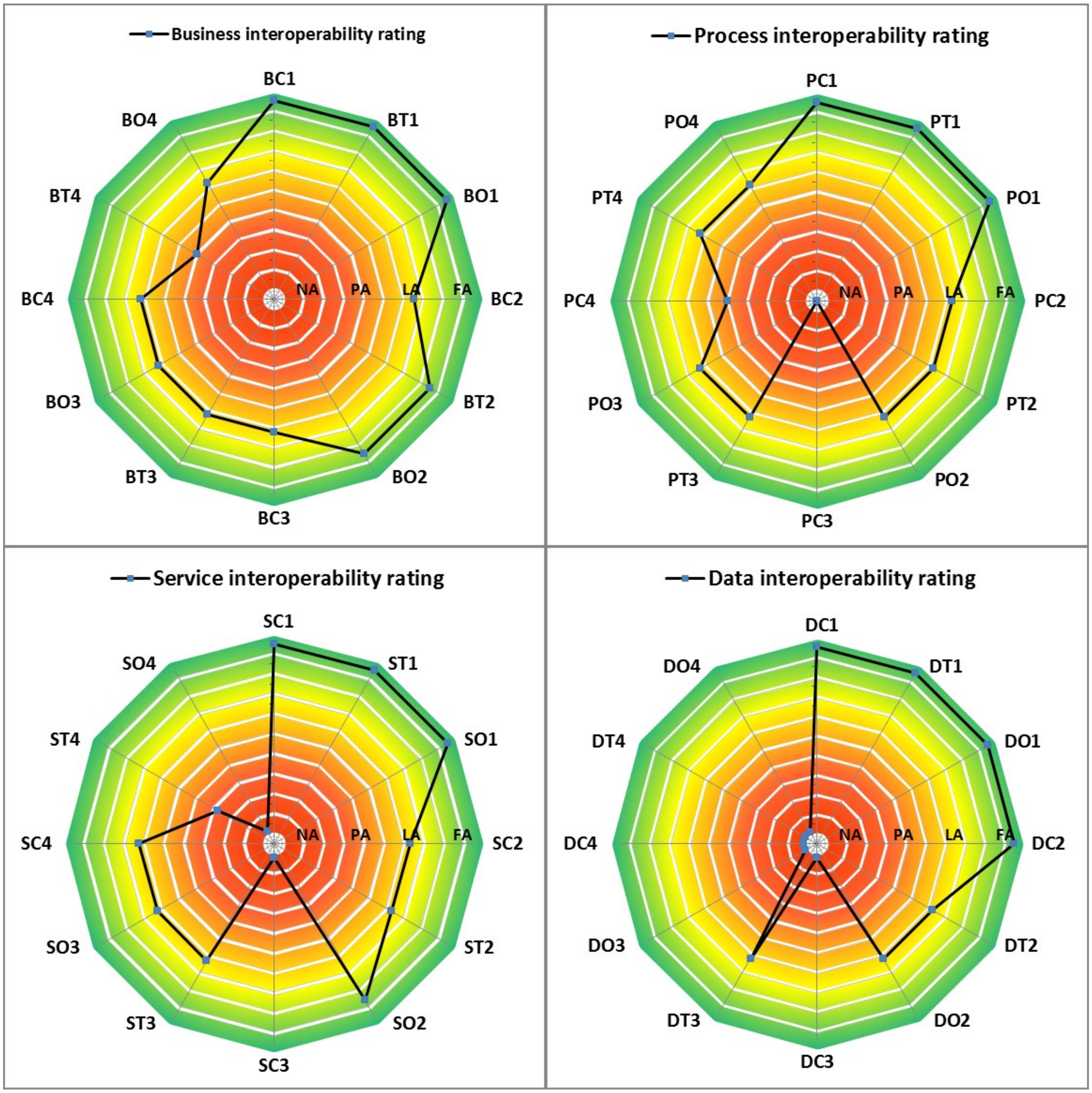

Figure 5.7. Detailed MMEI assessment results of METS company

Based on the assessment results, proposed best practices are those related to the improvement of level 2 (i.e. *fully achieve* BC2, PC2, PT2, PO2, DT2, DO2, SC2, ST2 and SO2) and achievement of level 3 (i.e. PC3, DC3, DO3 and SC3).

Table 5.7 presents some of the best practices that are proposed by the assessor (the complete list of the best practices can be found in annex 1).

Table 5.7. Extract of best practices to improve interoperability potential of METS company

Criteria for interoperability improvement	*Corresponding practices*
DC3. Meta-modeling for multiple data model mappings	**DC3.1. Identify concepts that are used by the main partners (past or future ones)** **DC3.2. Define meta-models for existing data models** **DC3.3. Use meta models for the data models definition** **DC3.4. Define possible mappings, semantic and syntactic correspondences for schema matching.**

5.5. Case application with assessing team

According to the defined methodology (see section 4.6), the assessment can also be done by 2 or more assessors at the same time. The results then need to be aggregated. In this section an example considering interoperability of processes with 3 assessors (E1, E2 and E3) is detailed. The target maturity level being 3, the results of the three assessments are presented in tables 5.8, 5.9 and 5.10.

Table 5.8. Individual evaluation sheet for process interoperability -E1-

	criteria to evaluate	**Observations**	**Individual Rating** NA	PA	LA	FA
PC2	Use of standards for alignment with other process models	Use of the DPM standard.	☐	☐	☐	☒
PT2	Standard Process tools & platforms	Process tools and platforms are using the standards (Tüv certification for processes execution).	☐	☐	☐	☒
PO2	Procedures for processes interoperability	Process model contains instructions to exchange information between the process networks.	☐	☐	☐	☒
PC3	Meta-modeling for multiple process model mappings	-------------	☒	☐	☐	☐
PT3	Platform & tool for collaborative execution of processes	Platforms were conceived under the collaboration principle.	☐	☐	☐	☒
PO3	Cross-enterprise collaborative processes management	Defined rules and responsibilities for collaborative processes management with headquarters.	☐	☐	☐	☒

PC4	Modeling for dynamic process re-engineering.	Process models can be used and adapted to develop other processes but this is not done rapidly.	☐	☐	☒	☐
PT4	Dynamic and adaptive tools and engines for processes.	Processes activities are chosen dynamically on the computers assisting the production to answer a demand.	☐	☐	☒	☐
PO4	Real-time monitoring of processes, adaptive procedures.	Computers assisting the production allow a real time monitoring of processes. Procedures can be adapted but need time.	☐	☒	☐	☐

Table 5.9. Individual evaluation sheet for process interoperability –E2-

	criteria to evaluate	**Observations**	**Individual Rating**			
			NA	**PA**	**LA**	**FA**
PC2	Use of standards for alignment with other process models	Use of the DPM standard.	☐	☐	☒	☐
PT2	Standard Process tools & platforms	Process tools and platforms are using the standards (Tüv certification for processes execution).	☐	☐	☒	☐
PO2	Procedures for processes interoperability	Process model contains instructions to exchange information between the process networks.	☐	☐	☐	☒
PC3	Meta-modeling for multiple process model mappings	--------------	☒	☐	☐	☐
PT3	Platform & tool for collaborative execution of processes	Platforms were conceived under the collaboration principle.	☐	☐	☒	☐
PO3	Cross-enterprise collaborative processes management	Defined rules and responsibilities for collaborative processes management with headquarters.	☐	☐	☒	☐
PC4	Modeling for dynamic process re-engineering.	Process models can be used and adapted to develop other processes but this is not done rapidly.	☐	☒	☐	☐
PT4	Dynamic and adaptive tools and engines for processes.	Processes activities can be chosen dynamically on the computers assisting the production to answer a demand but this necessitates human intervention.	☐	☒	☐	☐
PO4	Real-time monitoring of processes, adaptive procedures.	Computers assisting the production allow a real time monitoring of processes. Procedures can be adapted but need time.	☐	☒	☐	☐

Table 5.10. Individual evaluation sheet for process interoperability –E3-

	criteria to evaluate	Observations	Team Rating NA	PA	LA	FA
PC2	Use of standards for alignment with other process models	Use of the DPM standard.	☐	☐	☒	☐
PT2	Standard Process tools & platforms	Process tools and platforms are using the standards (Tüv certification for processes execution).	☐	☐	☒	☐
PO2	Procedures for processes interoperability	Process model contains instructions to exchange information between the process networks.	☐	☒	☐	☐
PC3	Meta-modeling for multiple process model mappings	-------------	☒	☐	☐	☐
PT3	Platform & tool for collaborative execution of processes	Platforms were conceived under the collaboration principle.	☐	☐	☒	☐
PO3	Cross-enterprise collaborative processes management	Defined rules and responsibilities for collaborative processes management with headquarters.	☐	☒	☐	☐
PC4	Modeling for dynamic process re-engineering.	Process models can be used and adapted to develop other processes but this needs time.	☐	☒	☐	☐
PT4	Dynamic and adaptive tools and engines for processes.	Activities are chosen on computers assisting production to form the process to be executed.	☐	☒	☐	☐
PO4	Real-time monitoring of processes, adaptive procedures.	Computers assisting the production allow a real time monitoring of processes.	☐	☒	☐	☐

Considering the three individual evaluations, the COG method (see section 4.6.3.1) is used to calculate the corresponding ratings; and the OWA operator (see section 4.6.3.2) to aggregate them, allowing the calculation of an aggregated score that takes into account the three evaluations. Table 5.11 summarizes the individual assessments and the associated team ratings.

Table 5.11. Assessment report of the process interoperability level 2

	E1	E2	E3	OWA	Team rating
PC2	FA	LA	LA	72	LA
PT2	FA	LA	LA	72	LA
PO2	FA	FA	PA	76	LA

Reminder:

$OWA\ (a_1, a_2, \cdots, a_n) = \sum_{j=1}^{n} w_j b_j$; b_j is the j-th largest element of the bag $(a_1, a_2, \ldots a_n)$

with:

$$w_j = \frac{s(b_j, A)}{\sum_{j=1}^{n} s(b_j, A)}, j = 1,2,\ldots n \ ; \ s(b_j, A) = 1 - \frac{|b_j - A|}{\sum_{j=1}^{n} |a_j - A|}, j = 1,2,\ldots n \ ; \ A = \frac{1}{n}\sum_{j=1}^{n} a_j$$

The team rating of PC2 is $\mathrm{OWA}(\mathrm{FA}, \mathrm{LA}, \mathrm{LA})$ that is calculated in the following:

Supposing that a_1, a_2 and a_3 are the associated values of these linguistic ratings, obtained through the application of the COG method (see section 4.6.3.1), $a_1 = COG(FA) = 90.495$, $a_2 = COG(LA) = 67.5$ and $a_3 = COG(LA) = 67.5$.

The re-ordered arguments $b_j, j = (1,2,3)$ in descending order are: $\mathrm{b}_1 = 90.495$, $\mathrm{b}_2 = 67.5$ and $b_3 = 67.5$.

Using the OWA formula, $\mathrm{w}_1 = 0.2$, $\mathrm{w}_2 = 0.4$, $\mathrm{w}_3 = 0.4$. The aggregated rating is computed as: $\mathrm{OWA}(\mathrm{a}_1, \mathrm{a}_2, \mathrm{a}_3) = 72$.

According to the defined membership functions (see 4.6.3.1), this value corresponds to the linguistic value *Largely Achieved*.

The team ratings of PT2 and PO2 correspond respectively to $\mathrm{OWA}(\mathrm{FA}, \mathrm{LA}, \mathrm{LA})$ and $\mathrm{OWA}(\mathrm{FA}, \mathrm{FA}, \mathrm{PA})$ are calculated in the same way.

Based on the MMEI assessment report (see Table 5.11) and the R_C fuzzy rules (see r_{p15} in Annex2), the MMEI level 2 is reached (i.e. P_2=LA).

As the MMEI level 2 is reached with *LA* rating, level 3 is not reached (i.e. a maturity level cannot be reached if the levels below are not achieved with *FA* rating). However, as the objective of the enterprise is to reach level 3, the assessment results of the level 3 are also given. Table 5.12 summarizes these results.

Table 5.12. Assessment report of the process interoperability level 3

	E1	E2	E3	OWA	Team rating
PC3	NA	NA	NA	6,866	NA
PT3	FA	LA	LA	72	LA
PO3	FA	LA	PA	58,7	LA

Based on the assessment report given by the table 5.12 and the R_C fuzzy rules (see r_{p11} in Annex 2), the level 3 of the EI process concern is reached with *PA* rating.

According to the assessment results of the EI process concern of the enterprise, improvements are needed to reach level 2 with *FA* rating and level 3 with at least *LA* rating.

Figure 5.8 depicts the rating results of the three assessors and the team ratings. As shown by the figure, the recommended improvements are the best practices related to PC2, PT2, PO2, PC3, PT3 and PO3, that can be found in annex 1.

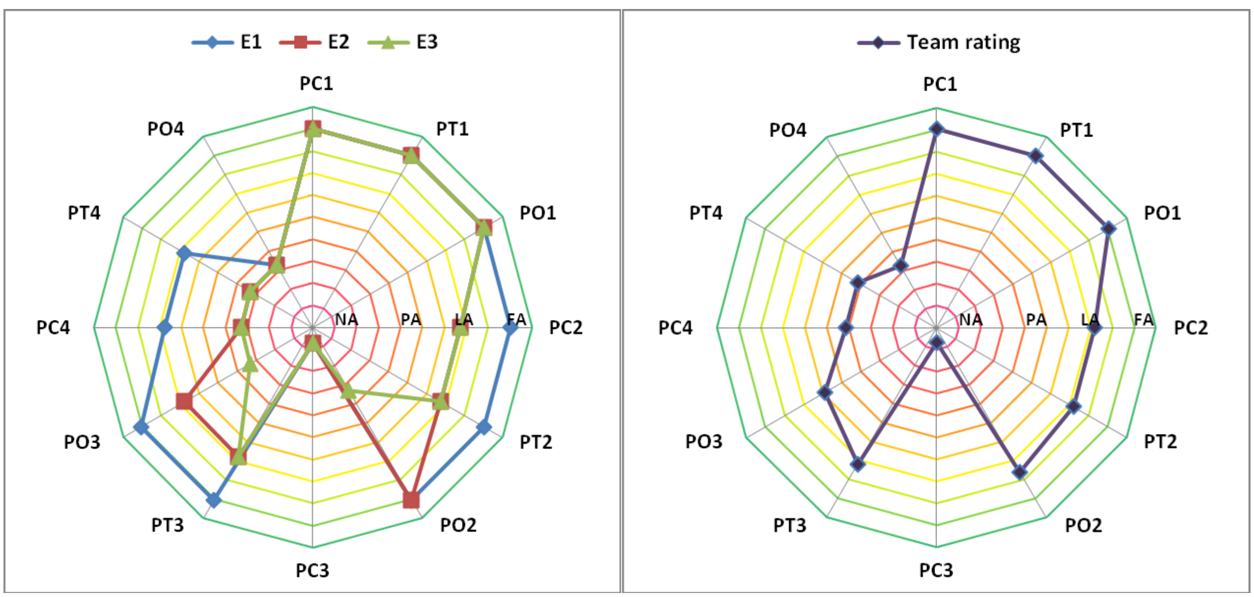

Figure 5.8. Three individual MMEI assessment results and their aggregation

5.6. Remarks and lessons learned

Although chapter 5 presents the application of the MMEI on one case study (METS), the model was also used to evaluate three other enterprises. Indeed, the company presented here is chosen because it is the most complex one having most interesting properties and characteristics for applying the model. The other three case studies were:

- A French-Tunisian company specialized in the textile production
- A Tunisian trading start-up company specialized in exporting olive wood products
- A Luxemburgish hospital (Guédria et al., 2012) (Bouzid et al., 2012).

Conducting assessments on these different case studies has allowed us to notice that the enterprise environment does influence considerably the use of MMEI. Indeed in a European context where the concurrence is more important than underdeveloped countries, the enterprises are more open to the use of improvement methods (i.e. maturity models) in order to be better than others. Moreover, the study was well supported by top management team and the companies were motivated to collaborate in assessment and eager to see the results. We have also noticed that the proposed approach is pertinent if the enterprise is interoperating in an evolving environment and needs to prevent interoperability problems and looks for collaboration opportunities. Indeed when an enterprise is well functioning and collaborating with fixed and stable partners, it does not always need to look for higher interoperability levels; It is used to do business in a certain way and do not easily accept changes. This was the case for the French-Tunisian company specialized in the textile production. The company has two sites the first one in France and the second one (production site) in Tunisia. The application of MMEI was difficult in this company because of rigid organization and working procedures. It has fixed partners with whom it collaborates. All works in an ad hoc way and improving interoperability is not a priority. The enterprise is able to reach its objectives in term of business. However, when it encounters problems (i.e. new partner, new product, etc.) it is not able to react in a reasonable time. In particular it is not ready to interoperate with new partners and to face any kind of change. With the trading start-up company, the case was different. The company was motivated to collaborate and to catch new market opportunities to sell its products clients but the application of the MMEI was not significant because of the small size of the company.

The proposed MMEI is shown as useful but some improvements are still needed in future research. This is especially for best practices. Each enterprise has its specific requirements and customerized best practices may need to be generated on the basis of general ones as defined in this thesis.

5.7. Conclusion

In this chapter, a case study was presented to show how to apply MMEI in a real industrial context. First, OoEI was used to formally describe the main elements and relationships of the enterprise-system. Second the assessment process and results were detailed. These were two-fold: i) a real individual assessment was carried out and ii) an example of assessment with three assessors was given, the purpose of which was to show the feasibility of the proposed methodology. The assessment was supported by a predefined semi-structured questionnaire with additional follow-through questions whenever needed. Best practices actions were then proposed to improve enterprise interoperability and migrate to a higher maturity level.

Although the case study was limited in time and the scope was restricted, it allows demonstrating the validity and usability of the MMEI in a real industrial context.

However, the success of industrial application of MMEI doesn't only depend on the scientific and technical qualities of the model but also on the willingness of the company to improve its interoperability.

General Conclusion

This thesis has contributed to build a scientific foundation for enterprise interoperability. A set of metrics for assessing enterprise interoperability was proposed in the form of a maturity model. This Maturity Model for Enterprise Interoperability (MMEI) is elaborated on the basis of a formalization of Enterprise interoperability, defined as an Ontology of Enterprise Interoperability (OoEI). OoEI describes essential concepts, entities and features related to enterprise interoperability. These concepts and their inter-relationships were identified by an analysis of the main existing works in the enterprise interoperability domain. This OoEI has been thereafter enhanced by the General System Theory which provides relevant concepts to allow laying down EI development in a more theoretical basis.

Chapter 1 identified and defined the scope and objectives of the research carried out in this thesis. It presented at first, the economic and research contexts of the enterprise interoperability, then definitions of Enterprise Interoperability and related concepts were studied. Interoperability problems that an enterprise can encounter were also presented and defined. Finally, research challenges and priorities were identified, research objectives and expected results refined.

Chapter 2 focused on defining and formalizing the Enterprise Interoperability domain where the Maturity Model for Enterprise Interoperability was thereafter built. This formalization was necessary due to the lack of the common understanding and explicit semantics of Enterprise Interoperability concepts. For that an analysis was conducted to identify key enterprise interoperability concepts that were needed to define enterprise interoperability problem and solution spaces. This is done through the study of existing frameworks and relevant interoperability models. Based on that, an Ontology of Enterprise Interoperability (OoEI) was elaborated.

Chapter 3 aimed at contributing to a scientific foundation for Enterprise Interoperability. It first reviewed existing neighboring scientific theories, in particular the General System Theory (GST) to identify relevant concepts and principles that can be used in Enterprise Interoperability domain. Then, selected relevant theoretical concepts were integrated in the OoEI. The enhanced OoEI served as basis to build the Maturity Model for Enterprise Interoperability (MMEI).

The main contribution of this thesis was presented in Chapter 4 which defined the Maturity Model for Enterprise Interoperability (MMEI) and its related methodology. The objective of MMEI is to evaluate the enterprise interoperability potential, enabling enterprise to prepare its interoperations with future partners. MMEI hasn’t been built from the sketch but takes into account the main existing maturity models. Moreover, the proposed metrics of MMEI are defined on the basis of OoEI, contributing to promote a rigorous formalized approach for interoperability development. The use of fuzzy sets theory in defining assessment methodology contributes to overcome part of subjectivity due to the participation of humans in the evaluation process.

Finally, chapter 6 provided a case application of a multinational German company to show how the defined MMEI can be used in an industrial context. The case study was first presented and modeled using OoEI. The assessment of the Enterprise interoperability maturity potential of the company using MMEI was then presented in detail. Based on the assessment, the strong points and weaknesses are highlighted; actions are thereafter proposed for interoperability potential improvement.

MMEI allows providing an answer to enterprise needs to understand its current interoperation ability. To this end, a global and aggregated assessment result is given. However this doesn’t allow enterprise to know precisely where their interoperability problems are. To remedy this, MMEI also provides a detailed analysis of the strengths and weaknesses of all interoperability areas within an enterprise.

MMEI assess the enterprise interoperability from the point of view of its potential to interoperate with a future unknown partner. Consequently, this cannot guarantee that two enterprises having the same MMEI maturity level can interoperate without problems. This depends on the specific context and incompatibility problems between two particular enterprise systems. However it is obvious that preparing enterprise interoperability and reaching higher maturity levels increase the chance to ease interoperations with future unknown partners.

MMEI allows determining the current interoperability maturity level of an enterprise and proposes a set of corrective actions to improve maturity and reach higher levels. However, it doesn’t prescript “how to implement actions” as this depends on the specific context of a given enterprise.

MMEI is based on OoEI. Although it is not our intention to elaborate a complete ontology of enterprise interoperability domain, the developed OoEI does provide a formalized set of relevant interoperability concepts to improve the understanding and facilitate the sharing of the concepts used in this research. Moreover, the integration of relevant concepts from GST into OoEI allows having a generic view of enterprise interoperability. This also, creates a link between existing neighboring scientific theories and existing pragmatic methodological interoperability research (i.e. frameworks, models, methodologies)

It is worth noting that the proposed MMEI is used as a main input to the standardization work currently carried out in CEN TC 310/WG1 and ISO TC 184 SC5/WG1 to develop a standard maturity model for enterprise interoperability (CEN 11345-2). It is fully compliant and consistent to the FEI now published as an international standard (ISO 11354 - 1).

The work presented in this thesis induces several other research tracks and questions that can be considered in the future:

- The OoEI was proposed as a conceptual model rather than a full ontology properly speaking. One of the future works consists in developing associated OoEI rules to allow automatic reasoning for developing tools for diagnosis of enterprise interoperability problems.
- MMEI was proposed for the assessment of enterprise interoperability potential. Another future work is to extend it to cover compatibility and performance measurements of enterprise interoperability. This would allow integrating both a priori and a posteriori assessments in a same assessment framework.
- An additional relevant research work is to investigate the possibility to elaborate an ontology of enterprise based on GST. This ontology could be integrated in the OoEI, so that MMEI concepts can be entirely instantiated from OoEI. This would allow developing tools for automatic enterprise interoperability assessment.
- Last but not least, the set of best practices should be considered as preliminary and needs to be further refined and developed when the state-of-the-art evolves in the future. They should also be considered as generic ones that each enterprise can adapt taking into account the requirements and specificities of the studied enterprise

Glossary

A

Application	Software that provides Functions that are required by an IT Service. Each Application may be part of more than one IT Service. An Application runs on one or more servers or clients[8].
Architecture	The structure of a System or IT Service, including the relationships of components to each other and to the environment they are in. Architecture also includes the standards and guidelines which guide the design and evolution of the System.
Assessment	Inspection and analysis to check whether a standard or set of guidelines is being followed (i.e. best practices), that records are accurate, or that efficiency and effectiveness targets are being met.
Assessment[9] indicator	Sources of objective evidence used to support the assessors' judgment in rating process attributes
Asset	Any resource or capability that could support the enterprise business. Assets can be one of the following types: Management, organization, process, knowledge, people, information, applications, infrastructure, and financial capital.
Authority	Permission. Right to exercise powers; to implement and enforce laws; to exact obedience; to command[10].

B

Best Practice	Proven Activities or processes that have been successfully used by multiple Organizations
Business model	The business model of a company is a simplified representation of its business logic. It describes what a company offers its customers, how it reaches them and relates to them, through which resources, activities and partners it achieves this and finally, how it earns money

[8] Most of these definitions are taken from ITIL Glossary v3.1.24, 2007

[9] International Standard ISO/IEC 15504-1 Information technology -Process assessment - Part 1: Concepts and vocabulary, 2004.

[10] From Barry, Sarrah. Responsibility vs. authority.

Business Process	A Process that is owned and carried out by the Business. A Business Process contributes to the delivery of a product or Service to a Business Customer. For example, a retailer may have a purchasing Process which helps to deliver Services to their Business Customers. Many Business Processes rely on IT Services.
Business Service	The term Business Service is also used to mean a Service that is delivered to Business Customers by Business Units. For example delivery of financial services to Customers of a bank, or goods to the Customers of a retail store. Successful delivery of Business Services often depends on one or more IT Services.

C

Capability	The ability of an organization, person, Process, Application, Configuration Item or IT Service to carry out an Activity. Capabilities are intangible Assets of an organization.
Capacity	The maximum Throughput that a Configuration Item or IT Service can deliver whilst meeting agreed Service Level Targets. For some types of CI, Capacity may be the size or volume, for example a disk drive.
Change	The addition, modification or removal of anything that could have an effect on IT Services. The Scope should include all IT Services, Configuration Items, Processes, Documentation etc.
Component	A general term that is used to mean one part of something more complex. For example, a computer System may be a component of an IT Service; an application may be a Component of a release Unit, etc.
Configuration	A generic term, used to describe a group of configuration items that work together to deliver an IT Service, or a recognizable part of an IT Service. Configuration is also used to describe the parameter settings for one or more IT component.

D

Data model	An (Enterprise) Data Model is an integrated view of the data produced and consumed across the entire organization. It incorporates an appropriate industry perspective and represents a single integrated definition of data, unbiased of any system or application. It is independent of "how" the data is physically sourced, stored, processed or accessed.
Design	An Activity or Process that identifies Requirements and then defines a solution that is able to meet these Requirements.

E

Evaluation	The Process responsible for assessing a new or Changed IT Service to ensure that Risks have been managed and to help determine whether to proceed with the Change. Evaluation is also used to mean comparing an actual Outcome with the intended Outcome, or comparing one alternative with another.

G

Guideline	A Document describing Best Practice that recommends what should be done.

I

Information Technology (IT)	The use of technology for the storage, communication or processing of information. The technology typically includes computers, telecommunications, Applications and other software. The information may include Business data, voice, images, video, etc.
Infrastructure	Generally, infrastructure is a relative term meaning “the structure beneath a structure”. This definition implies different layers of structure, which metaphorically provide support or services. In the physical word, the term infrastructure often refers to public utilities, such as water, electricity, gas, sewage, and telephone services. These utilities are just more layers of a total structure that includes IT infrastructure.
Infrastructure Service	An IT Service that is not directly used by the Business, but is required by the IT Service Provider so they can provide other IT Services. For example Directory Services, naming services, or communication services.
Interface	Method or piece of equipment, for interconnecting units or systems which may not otherwise be directly compatible.
IT Infrastructure	All of the hardware, software, networks, facilities etc. that are required to Develop, Test, deliver, Monitor, Control or support IT Services. The term IT Infrastructure includes all of the Information Technology but not the associated people, Processes and documentation.

M

Maturity model	A maturity model is a framework that describes, for a specific area of interest, a number of levels of sophistication at which activities in this area can be carried out[11].
Metric	Something that is measured and reported to help manage a Process, IT Service or Activity, etc.
Model	A model is an abstract representation of a real-world system that emphasizes some aspects of the system while excluding other aspects. What is excluded depends on the purpose of the model.
Monitoring	Repeated observation of a configuration item, IT service or process to detect events and to ensure that the current status is known.

O

Organization	A company, legal entity or other institution. Examples of organizations that are not companies include International Standards organization, etc. The term organization is sometimes used to refer to any entity which has people, resources and budgets. For example a project or business unit.

P

Partnership	A relationship between two organizations which involves working closely together for common goals or mutual benefit.
Policy	Formally documented management expectations and intentions. Policies are used to direct decisions, and to ensure consistent and appropriate development and implementation of processes, standards, roles, activities, IT infrastructure etc.
Procedure	A document containing steps that specify how to achieve an activity. Procedures are defined as part of processes.
Process	A structured set of Activities designed to accomplish a specific Objective. A Process takes one or more defined inputs and turns them into defined outputs. A Process may include any of the roles, responsibilities, tools and management.

[11] (Alonso et al. 2010)

Process model	The (Enterprise) Process Model is established as the medium for communicating how the enterprise operates its business. It is intended for multiple audiences each with differing views of the business operations. The Process Model serves as the foundation, framework and guidepost necessary to ensure the enterprise services execution. The model defines Enterprise Actors and Enterprise functions to establish consistent definitions to be used in the process model use cases.

R

Resource	A generic term that includes IT Infrastructure, people, money or anything else that might help to deliver an IT Service. Resources are considered to be Assets of an organization.
Responsibility	The state of being answerable for an obligation, and includes judgment, skill, ability and capacity.[12]
Role	A set of responsibilities, Activities and authorities granted to a person or team. One person or team may have multiple Roles.

S

Service	A service is an application of a business capability to provide business value by a community of service users. A service is requested to fill a need.
Service Catalog	A database or structured Document with information about all live IT services, including those available for deployment. The service catalog is the only part of the service portfolio published to customers, and is used to support the sale and delivery of services. The service catalog includes information about deliverables, prices, contact points, ordering and request processes.
Service model	The service model is in somehow the execution / implementation of the process model. Indeed, a service exists when someone delegates the responsibility for performing a process to a service provider. (see service provider)
Service provider	A service provider can be any person or system that can perform a task repetitively. In the outside world, service providers include people such as bank tellers and plumbers. In the IT world, a service provider might be a storage area network, a database, or an IT help-desk person

[12] From Barry, Sarrah. Responsibility vs authority.

Strategic	The highest of three levels of Planning and delivery (Strategic, Tactical, Operational). Strategic Activities include Objective setting and long term Planning to achieve the overall Vision.
Strategy	A Strategic Plan designed to achieve defined Objectives.

V

Vision	A description of what the organization intends to become in the future. A Vision is created by senior management and is used to help influence Culture and Strategic Planning.

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Annex 1: MMEI Best Practices

EI Maturity level	**Level 1**
EI Aspect	**Conceptual**
EI Concern	**Business**
ID	**BC1**
Purpose	**The purpose of the BC1 interoperability area is to verify to which extent business models are defined and documented** *<u>Note 1:</u>* The business model should give an overview of the function and objective of the enterprise. It contains all information about strategy, politic, rules, hierarchy, objective, functions, services, partners of the enterprise, etc. *<u>Note 2:</u>* Business model can be defined and not documented. Part of the business model can also be defined and documented whereas other elements of it are not properly defined.
Expected results	**Business models are defined and documented**
Assessment Indicators	Assessors have to verify to which extent business models are defined and documented. For that they have to check if there are documents related to business models. If yes, look at (a) the formalization level of the models (depending on the modeling language used, if any); and (b) level of detail, access level (restricted or for everyone), and understandability of models description and explanations. In case business models related documents are not observable or not existing, assessors need to look for the presence of a practice aiming at producing business models, and evaluate to which extent it is applied and provides intended results.
Best Practices	**BC1.1. Define business models** Describe the business of the enterprise: patterns of the business activities, including its functions, objectives, services, main processes, politic, main partners *<u>Note 1</u>*: The business model can be only understood by the person defining it **BC1.2. Document Business Model** Add notes and descriptions to business model in order to be understood by any person using the model.

EI Maturity level	**Level 1**
EI Aspect	**Technical**
EI Concern	**Business**
ID	**BT1**
Purpose	**The purpose of the BT1 interoperability area is to verify if an IT infrastructure is in place to support enterprise business** *Note 1*: The term IT infrastructure is defined in ITIL v3 (Veen and Bon, 2007) as a combined set of hardware, software, networks, facilities, etc. (including all of the information technology), in order to develop, test, deliver, monitor, control or support IT services. Associated people, processes and documentation are not part of IT Infrastructure.
Expected results	**Basic IT infrastructure in place**
Assessment Indicators	Assessors have to verify to which extent an IT infrastructure supporting the enterprise business is in place. For that they have to list existing hardware, software, networks, facilities, etc. supporting the enterprise business, and evaluate to which extent they support the enterprise business.
Best Practices	**BT1.1. Identify core IT elements supporting enterprise business** **BT1.2. Deploy identified elements** Implement technical assets that are needed within the enterprise *Note 1*: Technical assets includes tangible and intangible items (e.g. hardware, software, technical documentation)

EI Maturity level	**Level 1**
EI Aspect	**Organizational**
EI Concern	**Business**
ID	**BO1**
Purpose	**The purpose of the BO1 interoperability area is to verify if the Organization structure is defined and in place** *Note 1*: The organization structure defines the structure of the enterprise, its different entities, relations, etc.
Expected results	**Organization structure defined and in place**
Assessment Indicators	Assessors have to verify to which extent the organization structure is defined and in place. For that they have to check if there are documents related to the organization structure (i.e. organization chart). If yes, look if this is put in place within the enterprise (this should be observable and verifiable).
Best Practices	**BO1.1. Define organization structure** Define the different entities within the enterprise (i.e. services and departments) and relations between them. This includes Policies, contracts that bind two or more entities, roles played by each entity within the enterprise, etc. *Note 1*: The organization structure should be understood by everyone (internal or external to the enterprise). **BO1.2. Put in place the organization structure** The organization structure should be put in place: the defined departments exist, the relations between them are defined, the authorities that relies each one of them, etc.

EI Maturity level	**Level 1**
EI Aspect	**Conceptual**
EI Concern	**Data**
ID	**DC1**
Purpose	**The purpose of the DC1 interoperability area is to verify that Data models are defined and documented.** Note 1: The main aim of data model is to support the development of information systems by providing the definition and format of data[13]. It is used as a plan for developing applications, in particular, how data is stored and accessed. Note 2: A data model can be defined and not documented. Note 3: Some entities and attributes of the data model can be defined and documented whereas other elements of the data model are not properly defined.
Expected results	**Data models defined and documented**
Assessment Indicators	Assessors have to verify to which extent data models are defined and documented. For that they have to see the documents defining data models, information exchanged, etc. If yes, look at (a) the formalism level of the models (depending on the modeling language used, if any); and (b) level of detail and understandability of models description and explanations.
Best Practices	**DC1.1. Define Data models** Identify tools to be used to handle and manage data models (i.e. database, Excel sheet, UML model, tables on paper support, etc.) Define each entity and related attributes. Note 1: Data models are mainly understandable by the person defining them and should be documented to have extra information explaining the description. **DC1.2. Document Data model** Add notes/descriptions to data models to be understood by any person using the model.

[13] http://www.answers.com/topic/data-model

EI Maturity level	**Level 1**
EI Aspect	**Technical**
EI Concern	**Data**
ID	**DT1**
Purpose	**The purpose of the DT1 interoperability area is to verify if enterprise data storage devices are connectable and whether the simple electronic exchange of data is possible** *Note 1*: Data storage includes database, data files, etc. *Note 2*: A "data storage device" is connectable, means that: it is configured to receive a request for a piece of information from an electronic device (e.g. PC) or a remote storage server. *Note 3*: At this level, information exchange is generally restricted to simple homogeneous data formats. (e.g., text, Jpeg, etc.)
Expected results	**Data storage devices connectable, simple electronic exchange possible**
Assessment Indicators	Assessors have to verify to which extent the data storage devices are connectable. For that, they have to verify if the data storage devices of the enterprise are configured to be connected. If the enterprise uses paper files, then verify how the data is accessed. They have also to verify if simple electronic exchange is possible; for that they have to verify if a) an infrastructure that supports simple peer-to-peer connections exists, b) cables used to plug two intern systems together exist, c) low-level protocols exist for data exchange.
Best Practices	**DT1.1. Identify data that can be subject of future interoperation** **DT1.2. Configure data storage devices so that they are connectable** **DT1.3. Put in place technical assets supporting data exchange within the enterprise** **DT1.4. Define protocols that can be used for data exchange interoperability**

EI Maturity level	**Level 1**
EI Aspect	**Organizational**
EI Concern	**Data**
ID	**DO1**
Purpose	**The purpose of the DO1 interoperability area is to verify that responsibilities and authorities for data are defined and put in place.** Note 1: Authority is the permission and right to exercise power; to implement and enforce laws; to exact obedience; to command; to judge. Control over; jurisdiction[14]. Note 2: Responsibility is the state of being answerable for an obligation, and includes judgment, skill, ability and capacity. Note 3: Responsibilities and authorities related to data can be defined and not put in place and vice versa.
Expected results	**Responsibilities and authorities are defined and in place**
Assessment Indicators	Assessors have to verify to which extent data responsibilities and authorities are defined and put in place. For that they have to check if there are documents defining data responsibilities and authorities. If yes, look at (a) the formalism level of the documents and (b) level of detail, description and explanations. They have also to verify if this is really used.
Best Practices	**DO1.1. Define data responsibilities and authorities** Identify the involved resources: human, material and immaterial resources Define needed responsibilities/authorities for data Define data restrictions (if exist) **DO1.2. Put data responsibilities/authorities in place and in everyday use.** Identify and assign a person for each defined responsibility/authority Note 1: Data roles and responsibilities have to be clearly defined, and individuals assigned to specific roles for performing data management responsibilities, as a part of their regular job responsibilities.

[14] *Sara E. Barry* : Authority vs Responsibility

EI Maturity level	**Level 1**
EI Aspect	**Conceptual**
EI Concern	**Process**
ID	**PC1**
Purpose	**The purpose of the PC1 interoperability area is to verify to which extent Processes models are defined and documented** Note 1: Some Process models can be defined and not documented. We can also find some activities or tasks of the process that are defined and documented whereas other elements are not properly defined. *Note 2:* The Process model defines sequences of the activities execution based on the business inputs (resources) and outputs (products).
Expected results	**Process models are defined and documented**
Assessment indicators	Assessors have to verify to which extent Processes models are defined and documented. For that they have to see for each process if there are documents defining it. If yes, look at (a) the formalism level of the models (depending on the modeling language used, if any); and (b) level of detail, access level (restricted or for everyone), and understandability of models description and explanations.
Best Practices	**PC1.1. Define Process models** Identify for each process its outcomes and related activities. Identify the involved resources: human, material and immaterial resources Identify the sequence of execution of activities Identify the rules of the process and restrictions (if any) *Note 1:* The Process model is mainly understandable by the person defining it and should be documented to have extra information explaining the description. **PC1.2. Document Process model** Add notes and descriptions to each process model in order to support understanding by any person using the model.

EI Maturity level	**Level 1**
EI Aspect	**Technical**
EI Concern	**Process**
ID	**PT1**
Purpose	**The purpose of the PT1 area of interoperability is to verify that there are IT tools supporting the enterprise processes and that the ad hoc exchange of processes' information is possible** *Note 1*: IT tools include software to elaborate and execute enterprise processes. *Note 2*: Process information exchange includes: 1) exchange of processes models 2) relate two different process models together to form a collaborative process
Expected results	**IT support for processes and Ad hoc exchange of process information**
Assessment Indicators	Assessors have to verify to which extent IT tools are supporting processes and whether the exchange of the process information is possible. For that they have to look at 1) existing IT tools that are supporting processes, 2) if the exchange of processes models is possible, 3) if relating two different processes models together to form a collaborative process is possible.
Best Practices	**PT1.1. Put in place technical assets supporting enterprise Processes** Identify and implement the processes technical assets that are needed **PT1.2. Verify that exchange of process information is possible** *Note 1*: This verification can be done based on past and current experiences.

EI Maturity level	**Level 1**
EI Aspect	**Organizational**
EI Concern	**Process**
ID	**PO1**
Purpose	**The purpose of the PO1 interoperability area is to verify to which extent Processes responsibilities/ authorities are defined and in place** *Note 1:* Authority is the permission and right to exercise power; to implement and enforce laws; to exact obedience; to command; to judge. Control over; jurisdiction. *Note 2*: Responsibility is the state of being answerable for an obligation, and includes judgment, skill, ability and capacity. *Note 3:* Processes responsibilities and authorities can be defined and not put in place and vice versa.
Expected results	**Processes responsibilities and authorities defined and put in place**
Assessment indicators	Assessors have to verify to which extent Processes responsibilities/authorities are defined and put in place. For that they have to check for each process if there are defined responsibilities, authorities, management rules, etc. If yes, look at (a) the formalism level of the documents and (b) level of detail, description and explanations. They have also to verify if this is really used.
Best Practices	**PO1.1. Define process responsibilities and authorities** - Identify the involved resources: human, material and immaterial resources- Define for each process the needed responsibilities/authorities (related to each activity within it). - Define the processes restrictions (if any) **PO1.2. Put in place processes responsibilities/authorities** Responsibilities/authorities that are defined should be put in place. Each responsibility/authority should be assigned to a role /employee. - Assign a person for each responsibility/authority defined.

EI Maturity level	**Level 1**
EI Aspect	**Conceptual**
EI Concern	**Service**
ID	**SC1**
Purpose	**The purpose of the SC1 interoperability area is to verify to which extent services models are defined and documented** *Note 1*: The Service model defines the business functions and outcomes based on the business inputs. *Note 2*: Some entities and attributes of the service model can be defined and documented whereas other elements of the service model are not properly defined.
Expected results	**Service models defined and documented**
Assessment Indicators	Assessors have to verify to which extent services models are defined and documented. For that they have to see for each service if there are documents defining it. If yes, look at (a) the formalism level of the models (depending on the modeling language used, if any); and (b) level of detail, access level (restricted or for everyone), and understandability of models description and explanations.
Best Practices	**SC.1.1. Define Service models** Define for each service the business outcomes and for whom it is addressed, *what* are the customers value, *who* depends on the services, *how* do they use the services, *why* are they valuable to them, etc. *Note 1*: The Service model is mainly understood by the person defining it and should be documented to have extra information explaining the description. **SC.1.2. Document Service model** Add notes and descriptions to each service model for it to be understandable by any person using the model.

EI Maturity level	**Level 1**
EI Aspect	**Technical**
EI Concern	**Service**
ID	**ST1**
Purpose	**The purpose of the ST1 area of interoperability is to verify that existing applications and services are connectable and that information exchange is possible.** *Note 1*: A service can be supported by an IT application *Note 2*: Services are connectable means that the enterprise is able to connect its applications/services to another enterprise to exchange services.
Expected results	**Applications/services are connectable and Ad hoc information exchange is possible**
Assessment Indicators	Assessors have to verify to which extent services and applications of the enterprise are connectable and whether an exchange of their information is possible. For that they need to verify if the information export from software applications is possible and whether the exported format can be used by other applications. They have also to check if there exist communication networks connectable to other ones.
Best Practices	**ST1.1. Identify possibilities of information extraction from services/applications and their reusability by other applications.** **ST1.2. Identify technical assets supporting interconnection between services** **ST1.3. Make sure that an information exchange of applications/services is possible**

EI Maturity level	**Level 1**
EI Aspect	**Organizational**
EI Concern	**Service**
ID	**SO1**
Purpose	**The purpose of the SO1 interoperability area is to verify to which extent services responsibilities and authorities are defined and put in place** *Note 1:* Authority is the permission and right to exercise powers; to implement and enforce laws; to exact obedience; to command; to judge. Control over; jurisdiction. *Note 2*: Responsibility is the state of being answerable for an obligation, and includes judgment, skill, ability and capacity. *Note 3:* Service responsibilities and authorities can be defined and not put in place and vice versa.
Expected results	**Service responsibilities and authorities defined and put in place**
Assessment Indicators	Assessors have to verify to which extent services responsibilities are defined and put in place. For that they have to see for each service if there are defined responsibilities authorities, management rules, etc. (documentation). If yes, look at (a) the formalism level of the documents and (b) level of detail, description and explanations. They have also to verify if the defined responsibilities and authorities are effectively used.
Best Practices	**SO1.1. Define Service responsibilities and authorities** Identify the involved resources: human, material and immaterial resources Define rules on services resources (e.g. money, people and products) and on the activities that can be done (e.g. manage, organize, develop, etc.). Define for every service the needed roles and associated responsibilities and authorities. Define the restrictions of each service role (if any) **SO1.2. Put in place service responsibilities/authorities** Assign a person for each role and responsibility/authority defined.

EI Maturity level	**Level 2**
EI Aspect	**Conceptual**
EI Concern	**Business**
ID	**BC2**
Purpose	**The purpose of the BC2 interoperability area is to verify to which extent business models are using standards to facilitate alignment with other business models** *Note 1: A* business model of a company is a simplified representation of its business logic. It describes what a company offers its customers, how it reaches them and relates to them, through which resources, activities and partners it achieves this and finally, how it earns money (Osterwalder, 2007)[15]. *Note 2*: At this level, the use of standards is recommended in order to facilitate the alignment with other models in case of interoperations. *Note 3*: "Standard" includes standards and *de facto standards*.
Expected results	**Use of standards for alignment with other business models**
Assessment Indicators	Assessors have to verify if the enterprise use standards (from both semantic and format points of view) to define its business model. For that they have to see in the documents related to business models if they follow standards. If yes, they have to verify if the used standards are relevant for the enterprise environment. *Note 1*: The enterprise has to use relevant standards that are used in its environment (taking into account its partners, clients, providers, etc.).
Best Practices	**BC2.1. Identify relevant standards for interoperability** Identify the frequently used standards and de facto standards in the enterprise environment (including partners, providers, clients, etc.). **BC2.2. Use relevant standards for interoperability** Relevant standards are used to facilitate alignment with other business models

[15] Osterwalder, A., How to describe and Improve your Business Model to Compete Better, 2007. Available at: http://www.privatebankinginnovation.com/en/wp-content/uploads/tools/Draft-Business-Model-Manual.pdf

EI Maturity level	**Level 2**
EI Aspect	**Technical**
EI Concern	**Business**
ID	**BT2**
Purpose	**The purpose of the BT2 interoperability area is to verify if the enterprise IT infrastructure is using standards and whether it is configurable** *Note 1*: "standard" includes standards and de facto standards. *Note 2*: The IT infrastructure has to be configurable, means that it can be modified, according to finite set of parameters, to align to partner's one.
Expected results	**Standard and configurable IT infrastructures are used**
Assessment Indicators	Assessors have to verify to which extent the enterprise IT infrastructure is configurable and standard-based. For that they have to verify a) if IT infrastructure elements are using standards b) if its elements and structure can be modified.
Best Practices	**BT2.1. Put in place a standard-based IT infrastructure** Identify technical assets that are needed for the business enterprise Identify the frequently used standards within the enterprise environment. *Note 1*: Technical assets includes tangible and intangible items (e.g. hardware, software, technical documentation) **BT2.2. Identify IT elements and parameters that are expected to be configurable** Identify IT elements that can be configured Identify parameters of the identified elements that are expected to be configurable **BT2.3. Configure identified IT elements**

EI Maturity level	**Level 2**
EI Aspect	**Organizational**
EI Concern	**Business**
ID	**BO2**
Purpose	**The purpose of the BO2 interoperability area is to verify if the enterprise human resources are trained for interoperability**
Expected results	**Human resources trained for interoperability**
Assessment Indicators	Assessors have to verify to which extent the enterprise employees are trained for interoperability. For that they have to check if some training sessions for interoperability have been organized. Assessors need also to ask some employees what to do in case of some interoperability problems.
Best Practices	**BO2.1. Organize training sessions for interoperability** **BO2.2. Anticipate problematic situations and inform employees what to do in case of problems.** *Note1*: This includes policies, standards, contracts that bind two or more entities, roles played by persons or groups (e.g. users, service providers, support groups), events that occur at specific times (e.g. service failures/ interruptions, scheduled maintenance)

EI Maturity level	**Level 2**
EI Aspect	**Conceptual**
EI Concern	**Process**
ID	**PC2**
Purpose	**The purpose of the PC2 interoperability area is to verify to which extent process models are using standards** *Note 1*: At this level, the use of standards is recommended in order to facilitate the alignment with other models in case of interoperations. *Note 2*: "Standard" includes standards and de facto standards.
Expected results	**Use of standards for alignment with other process models**
Assessment Indicators	Assessors have to identify standards that are used to defined process models. If yes, they have to verify if the used standards are also used in the enterprise environment. *Note 1*: The enterprise has to use relevant standards that are recognized in its environment (taking into account its partners, clients, providers, etc.).
Best Practices	**PC2.1. Identify relevant standards for interoperability** Identify the frequently used standards in the enterprise environment (including partners, providers, clients, etc.). **PC2.1. Use relevant standards for interoperability** Relevant standards or de facto (example BPMN) are used to facilitate alignment with other process models

EI Maturity level	**Level 2**
EI Aspect	**Technical**
EI Concern	**Process**
ID	**PT2**
Purpose	**The purpose of the PT2 interoperability area is to verify if the process-related tools and platforms are standard-based.** *Note 1:* Process tools are software that supports processes modeling and execution.
Expected results	**Standard Process tools & platforms**
Assessment Indicators	Assessors have to verify whether process-related tools and platforms are using standards. For that they have to check a) what are the used standards, b) if they are frequently used in the enterprise environment.
Best Practices	**PT2.1. Identify processes tools and platforms that are needed** **PT2.2. Use standard process tools and platforms**

EI Maturity level	**Level 2**
EI Aspect	**Organizational**
EI Concern	**Process**
ID	**PO2**
Purpose	**The purpose of the PO2 interoperability area is to verify to which extent procedures for process interoperability are put in place.**
Expected results	**Procedures for processes interoperability are in place**
Assessment indicators	Assessors have to verify to which extent defined procedures are set to ensure process interoperability. For that they have to check if there exist documents to define procedures for processes interoperability. If yes, look at their applicability and if they are set for everyday use.
Best Practices	**PO2.1. Specify requirements for process interoperability** **PO2.2. Specify conditions and restrictions for process interoperability** **PO2.3. Define procedures for process interoperability** **PO2.4. Set policy, guidance and oversight to ensure that relevant processes are interoperable with other systems, internal and external to the enterprise.**

EI Maturity level	**Level 2**
EI Aspect	**Conceptual**
EI Concern	**Service**
ID	**SC2**
Purpose	**The purpose of the SC2 interoperability area is to verify to which extent service models are using standards** *Note 1*: At this level, the use of standards is required in order to facilitate the alignment with other models in case of interoperations. *Note 2*: "Standard" includes standards and de facto standards
Expected results	**Use of standards for alignment with other service models**
Assessment Indicators	Assessors have to identify standards that are used to defined service models. If yes, they have to verify if the used standards are used in the enterprise environment. *Note 1*: The enterprise has to use relevant standards that are recognized in its environment (taking into account its partners, clients, providers, et.).
Best Practices	**SC2.1. Identify relevant standards for interoperability** Identify the frequently used standards in the enterprise environment (including partners, providers, clients, etc.). **SC2.1. Use relevant standards for interoperability** Relevant standards are used to facilitate alignment with other service models

EI Maturity level	**Level 2**
EI Aspect	**Technical**
EI Concern	**Service**
ID	**ST2**
Purpose	**The purpose of the ST2 interoperability area is to ensure that services architectures and interfaces are configurable and using standards** *Note 1:* Service architecture considered here is IT architecture for service such as SOA or other enterprise application architectures. *Note 2:* Service interface is needed to relate services and applications together for information exchange
Expected results	**Standards and configurable service architecture and interface**
Assessment Indicators	Assessors have to verify if the enterprise services architectures and interfaces are configurable and standard-based. For that they have to verify if a) there exist defined parameters to configure in the architectures and interfaces of the enterprise services, b) services architectures and interfaces can be supportable by other systems internal or external to the enterprise, b) services architectures and interfaces are using standards c) a peer to peer connection is possible.
Best Practices	**ST2.1. Put in place standard technical assets supporting services** Identify standards that are used within the enterprise environment to define and implement service and applications. **ST2.2. Define parameters to configure for enterprise services** Define parameters to configure for services architectures and interfaces allowing them to be supported by other systems (inside or outside the enterprise) **ST2.2. Make sure that tools supporting services are configurable** Verify that existing services and applications can be modified in order to align to other services and applications for interoperability.

EI Maturity level	**Level 2**
EI Aspect	**Organizational**
EI Concern	**Service**
ID	**SO2**
Purpose	**The purpose of the SO2 interoperability area is to verify to which extent procedures for services interoperability are in place** *Note 1*: The procedure defines the steps to follow and tasks to be done for; (1) to establish service interoperability, (2) to deal with exception management in case of unplanned events, (3) to maintain process interoperability / interoperations
Expected results	**Procedures for services interoperability are in place**
Assessment Indicators	Assessors have to verify to which extent procedures for services interoperability are in place. For that they have to see if there are defined procedures for services interoperability and if there are put in place for everyday use.
Best Practices	**SO2.1. Specify services interoperability requirements** Define for each service its requirements (resources, etc.). **SO2.2. Define Services interoperability procedures** Identify interoperability guidelines for each service

EI Maturity level	**Level 2**
EI Aspect	**Conceptual**
EI Concern	**Data**
ID	**DC2**
Purpose	**The purpose of the DC2 interoperability area is to verify to which extent data models are using standards** *Note 1*: At this level, the use of standards is required in order to facilitate the alignment with other data models in case of interoperation. *Note 2*: "Standard" includes standards and *de facto standards*.
Expected results	**Use of standards for alignment with other data models**
Assessment Indicators	Assessors have to verify to which extent data models are using standards. For that they have to identify if the defined data models are using standards. If yes, they have to verify if the used standards are used in the environment of the enterprise (frequently). *Note 1*: The enterprise has to use relevant standards that are used in its environment (i.e. partners, clients, providers, etc.).
Best Practices	**DC2.1. Identify relevant standards for interoperability** Identify the frequently used standards in the enterprise environment (including partners, providers, clients, etc.). **DC2.1. Use relevant standards for interoperability** Relevant standards are used to facilitate alignment with other data models

EI Maturity level	**Level 2**
EI Aspect	**Technical**
EI Concern	**Data**
ID	**DT2**
Purpose	**The purpose of the DT2 interoperability area is to ensure that the access to data is automated and based on standard protocols** *Note 1*: automated access to data means that a data storage device is accessible by other software applications *Note 2*: standard protocols or de facto ones are used for data exchange between a data storage device and a third application
Expected results	**Automated access to data based on standard protocols**
Assessment Indicators	Assessors have to verify to which extent the access to data is automated and whether the protocols are following standards. For that assessors have to verify if data storage devices support automated access to data and standard protocols are used for that.
Best Practices	**DT2.1. Parameter data storage devices in order to ensure automated access to data** **DT2.2. Use standard data transmission protocol**

EI Maturity level	**Level 2**
EI Aspect	**Organizational**
EI Concern	**Data**
ID	**DO2**
Purpose	**The purpose of the DO2 interoperability area is to verify if rules and methods for data managements are in place.** *Note 1:* Data management includes the management of data for future interoperability purposes.
Expected results	**Rules and methods for data management are in place**
Assessment Indicators	Assessors have to verify to which extent rules and methods for data management are defined and put in place. For that they have to see if there are documents defining data management rules and methods. If yes, look at the level of detail, description and explanations. They have also to verify if this is really put in place in everyday use.
Best Practices	**DO2.1. Define data management rules** Define data guidelines, standards, policies and procedures **DO2.2. Identify private data** Identify data that are private to the enterprise and can't be accessed by external people and requirements for a secure access **DO2.3. Set data management rules in place**

EI Maturity level	**Level 3**
EI Aspect	**Conceptual**
EI Concern	**Business**
ID	**BC3**
Purpose	**The purpose of the BC3 interoperability area is to verify to which extent business models are designed for multi partnership and can be used within a collaborative context** _Note 1_: A Business model that is designed for multi partnership identifies the different partners of the enterprise and describes the business that should be jointly developed in collaboration with other partners, business rules and benefits for the enterprise and their partners
Expected results	**Business models designed for multi partnership and collaborative enterprise**
Assessment Indicators	Assessors have to identify to which extent the designed business models can be used for multi partnership and within a collaborative context. For that they have to verify a) if there is a strategy to develop business based on collaboration and multi partnerships), b) if a collaboration with several partners have been developed, c) if rules for multi partnership exist in the business model.
Best Practices	**BC3.1. Identify core business of the enterprise and the business that can be subject of collaboration** **BC3.2. Identify preferred possible partners that enterprise can collaborate with, based on its requirement, the market and its past experiences**

EI Maturity level	**Level 3**
EI Aspect	**Technical**
EI Concern	**Business**
ID	**BT3**
Purpose	**The purpose of the BT3 interoperability area is to verify if the enterprise has an open IT infrastructure** Note 1: The enterprise architecture is open in the sense that it formulates the following principles (cooper, 2004): ***Open to users***. It does not force users into closed groups or deny access to any sectors of society, but permits universal connectivity, as does the telephone network. ***Open to providers***. It provides an open and accessible environment for competing commercial and intellectual interests. It does not preclude competitive access for information providers. ***Open to network providers***. It makes it possible for any network provider to meet the necessary requirements to attach and become a part of the aggregate of interconnected networks. ***Open to change***. It permits the introduction of new applications and services over time.
Expected results	**Open IT infrastructure**
Assessment Indicators	Assessors have to verify to which extent the enterprise IT infrastructure is open. They need to verify a) if new components can be added to the existing IT infrastructure of the enterprise, b) if the IT infrastructure of the enterprise could support additional IT components and allows the introduction of new application and services over time, c) if it is possible to change its components and modify its structure (relationships between components), d) if it is possible to modify its properties and rules of access, etc.
Best Practices	**BT3.1. Put in place standard technical assets supporting enterprise business** Define the technical assets that are needed within the enterprise and those that are frequently used within the enterprise environment. **BT3.2. Identify the technical elements that are configurable** **BT3.3. Put in place configurable technical elements if they don't exist**

EI Maturity level	**Level 3**
EI Aspect	**Organizational**
EI Concern	**Business**
ID	**BO3**
Purpose	**The purpose of the BO3 interoperability area is to verify if the organization structure of the enterprise is flexible** Note 1: Flexible **o**rganization structure means that for a given defined organization structures, several behaviors are possible. This means that the enterprise can react to the market demands different ways while keeping its structure unchanged, i.e. the structure of the organization doesn't change but the behavior changes.
Expected results	**Flexible organization structure**
Assessment Indicators	Assessors have to verify to which extent the enterprise organization structure is flexible. For that, they have to verify whether: a) delegation of responsibilities is defined and in place, b) main responsibilities are shared, c) multiple roles are defined, d) cooperate knowledge management performed.
Best Practices	**BO3.1. Define delegation for main responsibilities.** Identify more than one manager for one responsibility (in case of absence) Trainings for polyvalence (of competence). **BO3.2. Manage employees competence** Identify who replaces each employee in case of departure In case of a departure of an employee the enterprise should manage this and the absence of this employee shouldn't influence the enterprise business.

EI Maturity level	**Level 3**
EI Aspect	**Conceptual**
EI Concern	**Process**
ID	**PC3**
Purpose	**The purpose of the PC3 interoperability area is to verify if there exist meta-models, to facilitate multiple model mappings.**
Expected results	**Meta-modeling for multiple Process model mappings**
Assessment Indicators	Assessors have to identify whether process meta models exist in the enterprise. This process meta model can be various forms: standard, glossary, taxonomy, ontology, etc. They can be specific to the enterprise or defined by other parties (i.e. existing ontologies on internet, etc.). If exist, they have to verify if the used meta models can be exploited to facilitate multiple model mappings.
Best Practices	**PC3.1. Define meta models for existing process models** Select concepts that are involved in processes interoperability and can be sources of interoperability problems. **PC3.2. Identify concepts that are used by the main partners (past or future ones)** The aim is to define possible mapping between terms and formats used by the company and those used by partners. **PC3.3. Use meta models for the process models definition** Relevant standards are used to facilitate alignment with other process models

EI Maturity level	**Level 3**
EI Aspect	**Technical**
EI Concern	**Process**
ID	**PT3**
Purpose	**The purpose of the PT3 interoperability area is to verify if the existing platform and IT tools can support the execution of collaborative processes.**
Expected results	**Platform & tool for collaborative execution of processes**
Assessment Indicators	Assessors have to verify whether existing platform and IT tools support the execution of collaborative processes. For that they have to verify if: a) process modeling and execution tools can be shared by different partners, b) it is possible to link various company's processes to form a collaborative process, c) a collaborative process is accessible and followed by various partners.
Best Practices	**PT3.1. Identify collaborative processes** **PT3.2. Identify technical assets to support collaborative processes** **PT3.3. Define the execution steps of the identified collaborating processes** **PT3.4. Make sure that execution of the collaborative processes is ensured**

EI Maturity level	**Level 3**
EI Aspect	**Organizational**
EI Concern	**Process**
ID	**PO3**
Purpose	**The purpose of the PO3 interoperability area is to verify to which extent cross-enterprise collaborative process management is in place** *Note 1*: The process responsibilities' definition is very important, to know who does what, and "who replaces who" in case of necessity (competence management).
Expected results	**Cross-enterprise collaborative processes management**
Assessment indicators	Assessors have to verify for collaborative process (past or present) if rules and responsibilities are (or were) defined and put in place. For that they have to verify whether a cross enterprise collaborative process exists and if it is respected by concerned partners. If it the case, look at a) if a collaborative process management document exists, b) if collaborative process rules defined, c) collaborative process management responsibilities effectively assigned,
Best Practices	**PO3.1. Identify requirements for networked collaborative process management** **PO3.2. Define rules and responsibilities to manage networked collaborative processes for present and future collaboration** **PO3.3. Identify relevant tools for collaborative process management** **PO3.4. implement defined rules, responsibilities and tools in the company for collaborative process management**

EI Maturity level	**Level 3**
EI Aspect	**Conceptual**
EI Concern	**Service**
ID	**SC3**
Purpose	**The purpose of the SC3 interoperability area is to verify to which extent service models are using meta models to facilitate mappings with other models** *Note 1*: At this level, the use of meta models is required in order to facilitate the mappings with other service models in case of networked multi-partners interoperations.
Expected results	**Meta-modeling for multiple service model mappings**
Assessment Indicators	Assessors have to identify whether services meta models exist in the enterprise. A service meta model can be various forms: standard, glossary, taxonomy, ontology, etc. they can be specific to the enterprise or defined by other parties (i.e. existing ontologies on internet, etc.). Assessors have to verify if the used meta models could facilitate multiple model mappings.
Best Practices	**SC3.1. Define meta models for existing services models** Identify concepts that are involved in services interoperability in the context of networked enterprise and that can be sources of interoperability problems. **SC3.2. Identify concepts that are used by the main partners (past or future ones)** The aim is to define possible mapping between concepts and formats used by the company and those used by partners. **SC3.3. Use meta models for the services models definition** Relevant standards are used to facilitate alignment with other services models

EI Maturity level	**Level 3**
EI Aspect	**Technical Interoperability**
EI Concern	**Service concern**
ID	**ST3**
Purpose	**The purpose of the ST3 interoperability area is to ensure that services discovery and composition is automated and that applications can be shared** *Note 1*: Enterprise services discovery and composition means that basic services and applications can be composed automatically to build high level service or application. For that the set of basic services / applications must be visible, i.e. can be recognized by service composition software.
Expected results	**Automated services discovery and composition, shared applications**
Assessment Indicators	Assessors have to verify if the enterprise services discovery and composition is automated and if applications are shared. For that they need to verify: a) if there exist a set of basic services/applications with their defined functionalities and semantics, b) if they are interoperable to form complex service / application, c) can be shared and used by networked partners.
Best Practices	**ST3.1. Put in place technical assets supporting enterprise services discovery and composition** **ST3.2. Decompose service/application in basic ones** **ST3.3. Ensure interoperability between basic services and applications.** **ST3.4. Clearly define its functions and semantics** **ST3.5. Make sure that services and applications can be shared by partners**

EI Maturity level	**Level 3**
EI Aspect	**Organizational**
EI Concern	**Service**
ID	**SO3**
Purpose	**The purpose of the SO3 interoperability area is to verify to which extent collaborative services and applications are managed**
Expected results	**Collaborative services and application management**
Assessment Indicators	Assessors have to verify to which extent collaborative services and applications are managed. For that they have to verify if there are a) defined procedures, rules or guidelines allowing managing collaborative services, b)defined responsibilities for the collaborative services, c) exception handling in place
Best Practices	**SO3.1. Identify collaborative services and applications** **SO3.2. Define procedures, rules and guidelines for collaborative services**

EI Maturity level	**Level 3**
EI Aspect	**Conceptual**
EI Concern	**Data**
ID	**DC3**
Purpose	**The purpose of the DC3 interoperability area is to verify to which extent data models are using meta models for multiple model mappings** _Note 1:_ The use of meta models facilitates the multiple data models mappings.
Expected results	**Meta-modeling for multiple data model mappings**
Assessment Indicators	Assessors have to identify whether meta-models for data exist in the enterprise. This data meta model can be various forms: standard, glossary, taxonomy, ontology, etc. They can be proper to the enterprise or defined by other parties (i.e. existing ontologies on internet, etc.). If exist, they have to verify if the used meta models can be used to facilitate multiple data model mappings.
Best Practices	**DC3.1. Identify concepts that are used by the main partners (past or future ones)** The aim is to define mapping between concepts and formats used by the company and those used by partners. **DC3.2. Define meta models for existing data models** Identify concepts that are involved in data interoperability and that can be sources of interoperability problems. This problems mainly concern semantic (meanings of terms) and syntactic (format). **DC3.3. Use meta models for the data models definition** Relevant standards are used to facilitate alignment with other data models **DC3.4. Define possible mappings, semantic and syntactic correspondences for schema matching.**

EI Maturity level	**Level 3**
EI Aspect	**Technical**
EI Concern	**Data**
ID	**DT3**
Purpose	**The purpose of the DT3 interoperability area is to ensure that the remote access to databases is possible for applications and that data can be shared**
Expected results	**Remote access to databases possible for applications, shared data**
Assessment Indicators	Assessors have to verify to which extent the remote access to databases for applications and data sharing are possible. For that assessors have to verify if there exist a) applications have access to databases b) Infrastructure is supporting remote access.
Best Practices	**DT3.1. Identify applications that need a remote access to databases** **DT3.2. Secure the remote access to databases** **DT3.3. Make sure that data can be shared among applications**

EI Maturity level	**Level 3**
EI Aspect	**Organizational**
EI Concern	**Data**
ID	**DO3**
Purpose	**The purpose of the DO3 interoperability area is to verify that the data management is personalized for different partners.** *Note 1*: When interoperating, an enterprise may exchange with a partner information that should not be exchanged with another one. The enterprise should be able to personalize its data management depending on the partner with whom it is interoperating.
Expected results	**Personalized data management for different partners**
Assessment Indicators	Assessors have to verify to which extent rules and methods for personalized data management are defined and put in place. This requires that assessors verify if such personalization has been already done in the past. If yes, look if there exist used documents and tools for personalization. If none exist, verify that the enterprise has means to personalize its data according to the partner needs.
Best Practices	**DO3.1. Define personalization data management rules** Identify and define needed restrictions for mapping data personalization Define procedure to personalize data (work methods, associated responsibilities, etc) **DO3.2. Identify parts of data that can be personalized (privacy issue, security issue, etc).** This concerns data that cannot be exchanged indifferently with different partners. Privacy and security issues can change according to the partner: the enterprise can exchange data with partner X that cannot or doesn't want to exchange with a partner Y.

EI Maturity level	**Level 4**
EI Aspect	**Conceptual**
EI Concern	**Business**
ID	**BC4**
Purpose	**The purpose of the BC4 interoperability area is to verify to which extent the enterprise business model is adaptive**
Expected results	**Adaptive business model**
Assessment Indicators	Assessors have to verify to which extend business model is adaptive, according to the change of the market demand, new opportunities, new partners, services, technologies and new way of doing business. For that they have to verify whether in the past the enterprise had successfully adapted its business model to answer to its environment changes. They have also to verify if there exists a procedure to revise its business model periodically or upon event.
Best Practices	**BC4.1. Define and implement periodic review procedure to adapt the business model to changing external environment.** **BC4.2. Adopt a reuse-centric strategy and make the concerned actors aware of its importance** Note: this includes design for reusability, design for changeability, re-configurability, etc. **BC4.3. Identify the reusable components in the company** NB: A component can be a procedure, a model, a process, a service, etc.

EI Maturity level	**Level 4**
EI Aspect	**Technical**
EI Concern	**Business**
ID	**BT4**
Purpose	**The purpose of the BT4 interoperability area is to verify to which extent the IT infrastructure is adaptive** *Note 1:* According to (Robertson and Sribar, 2004)[16], an adaptive infrastructure should exhibit several key properties: a) Efficiency. The ability to provide reusable components that are reasonably priced and can be turned around quickly for new application development projects. b) Effectiveness. The easy integration of all components in a way that supports their robust operation. c) Agility. Effective planning and design processes that allow companies to develop new applications quickly and re-purpose or upgrade their existing infrastructure to support new requirements for existing or new applications. *Note 2*: A key reason for building an adaptive infrastructure is that many design standards and actual physical components of the infrastructure can be reused.
Expected results	**Adaptive IT infrastructure**
Assessment Indicators	Assessors have to verify to which extent the enterprise IT infrastructure is adaptive. For that they have to verify: a) if existing physical components of the infrastructure can be reused, b) if the IT infrastructure architecture can be rearranged and c) if new components can be added.
Best Practices	**BT4.1. Identify reusable components that can be turned around quickly for any new application development.** **BT4.2. Perform necessary re-engineering of existing IT infrastructure to make it rearrangeable and reconfigurable**

[16] Robertson, B. and Sribar, V. The Adaptive Enterprise: It Infrastructure Strategies to Manage Change and Enable Growth. Intel Press; Édition : illustrated edition, ISBN-13: 978-0971288720, 2004.

EI Maturity level	**Level 4**
EI Aspect	**Organizational**
EI Concern	**Business**
ID	**BO4**
Purpose	**The purpose of the BO4 interoperability area is to verify to which extent the enterprise organization is agile for on-demand business** *Note 1:* Enterprise organization is agile means that it rapidly adapts to changing business challenges and opportunities (Cummins, 2009)
Expected results	**Agile organization for on-demand business**
Assessment Indicators	Assessors have to verify to which extent the enterprise organization is agile. For that they have to verify: a) the delay of the reaction to a new event is short. This can be based on past experiences, b) the enterprise has clear and simple procedures to follow, c) the existence of defined methods that describe what to do in case of problems, introduction of a new product, new partner, etc.
Best Practices	**BO4.1. Define methods facilitating enterprise business agility** Describe what to do in case of business interoperability problems, how to react in case of introduction of a new partner, a new service, a new product, etc. This includes also internal new events (i.e. employee departure, unavailability, etc.) where the management of the human resources competences has to be ensured. **BO4.2. Shorten the delay of reaction to a new event (quickly decision making procedure, delegation of responsibility in case of absence,** **BO4.3. Make enterprise business procedures clearer and simpler**

EI Maturity level	**Level 4**
EI Aspect	**Conceptual**
EI Concern	**Process**
ID	**PC4**
Purpose	**The purpose of the PC4 interoperability area is to verify to which extent process modeling supports dynamic re-engineering.** *Note 1*: Dynamic process re-engineering implies that process modeling is dynamically performed to face new market challenges and opportunities in terms of product, services and partnerships. *Note 2*: To be truly efficient and reusable, processes must be decoupled and become independent activities from the person or system that interacts with them (ref)
Expected results	**Process modeling for dynamic re-engineering**
Assessment Indicators	Assessors have to verify to which extent enterprise process modeling supports dynamic re-engineering. For that, they have to verify that a) existing process models are reusable, adaptable and easily modifiable, b) process modeling methods used in the company are suitable to support dynamic re-engineering of processes
Best Practices	**PC4.1. Identify reusable processes components** *Note1*: The advantage of having reusable process components is to save time in designing new processes by using existing reusable components. **PC4.2. Adopt a model driven engineering approach** It allows transforming automatically business oriented process models into executable processes models and thus support dynamic rapid process re-engineering.

EI Maturity level	**Level 4**
EI Aspect	**Technical**
EI Concern	**Process**
ID	**PT4**
Purpose	**The purpose of the PT4 interoperability area is to verify to which extent processes tools and engines are dynamic and adaptive.** *Note 1*: Tools support dynamic and adaptive process re-engineering means that process tools support the process model change and this change can be done "on the fly".
Expected results	**Dynamic and adaptive tools and engines for processes.**
Assessment Indicators	Assessors have to verify to which extent tools could support rapid change of existing process models. For that they have to verify a) if easy modification of processes models using IT tools is possible, b) if enterprise has process model transformation tools to transform conceptual process models (e.g. BPMN) into executable process models (e.g. BPEL).
Best Practices	**PT.4.1. Make sure that existing IT tools support rapid process model changes. If this is not the case: Acquire new suitable tools.** **PT.4.2. Acquire necessary tools to support model driven engineering approaches.**

EI Maturity level	**Level 4**
EI Aspect	**Organizational**
EI Concern	**Process**
ID	**PO4**
Purpose	**The purpose of the PO4 interoperability area is to verify to which extent enterprise processes are real time monitored and that procedures are adaptive.** *Note 1:* Adaptive procedure means that the enterprise is able to make necessary changes to its process management procedures when needed without significant impact on processes.
Expected results	**Real-time monitoring of processes, adaptive procedures**
Assessment Indicators	Assessors have to verify to which extent real-time monitoring of processes is ensured and whether procedures are adaptive. For that, they have to verify if managers know for their processes a) what has been executed, b) what is being executed and c) what remains to be done. For adaptive procedures, assessors have to verify in the past if procedures have been successfully changed without delay and whether this can be repeated in the future.
Best Practices	**PO4.1. Identify key processes to be monitored** **PO4.2. Define explicitly responsibility for process monitoring and assign appropriate persons.** **PO4.3. Separate parts of procedures that cannot be modified from those that can be changed.** **PO4.4. Define conditions or rules under which a part of procedure change is possible**

EI Maturity level	**Level 4**
EI Aspect	**Conceptual**
EI Concern	**Service**
ID	**SC4**
Purpose	**The purpose of the SC4 interoperability area is to verify to which extent on-demand and adaptive service modeling is possible.** *Note 1*: In order to support adaptive business model, services need to be frequently re-engineered according to the changing demands. To this end, services must be decoupled and reusable.
Expected results	**Adaptive service modeling**
Assessment Indicators	Assessors have to verify to which extent the service modeling is adaptive. For that they have to verify if modeling methods for enterprise services support the description of services composition and decomposition.
Best Practices	**SC4.1. Identify modeling methods that supports services decomposition and composition** **SC4.2. Model basic reusable enterprise services components** **SC4.3. Adopt a model driven engineering approach** *Note 1:* It allows transforming automatically business oriented service model to executable service models and thus supporting dynamic rapid service re-engineering.

EI Maturity level	**Level 4**
EI Aspect	**Technical**
EI Concern	**Service**
ID	**ST4**
Purpose	**The purpose of the ST4 interoperability area is to verify to which extent the services can be dynamically composed and applications are networked** *Note 1*: To be truly efficient and reusable, services must be decoupled and become separate processes from the person or system that interacts with them (Robertson and Sribar, 2004)[17].
Expected results	**Dynamically composable services, networked applications**
Assessment Indicators	Assessors have to verify to which extent the enterprise services can be dynamically composed and if applications are networked. For that they have to verify if a) existing services can be re-engineered 'on the fly', b) services can be exchanged with other partners 'on the fly', c) there exist tools to support the above activities.
Best Practices	**ST4.1. Identify tools and platforms that support dynamic services engineering** *Note 1:* Dynamic service engineering means service composition and service interoperability performed 'on the fly'. **ST4.2. Decompose services into manageable and composable elements** Break down services into independent elements that can be managed by different teams or suppliers.

[17] Robertson, B. and Sribar, V. The Adaptive Enterprise: It Infrastructure Strategies to Manage Change and Enable Growth. Intel Press; Édition : illustrated edition, ISBN-13: 978-0971288720, 2004.

EI Maturity level	**Level 4**
EI Aspect	**Organizational**
EI Concern	**Service**
ID	**SO4**
Purpose	**The purpose of the SO4 interoperability area is to verify to which extent dynamic service and application management rules and methods are applied**.
Expected results	**Dynamic service and application management rules and methods**
Assessment Indicators	Assessors have to verify to which extent the enterprise services are dynamically managed. For that they have to verify if: a) rules and methods for dynamic service and application management are documented, b) procedures for dynamic negotiation, adaptation and accommodation are defined.
Best Practices	**SO4.1. Identify key services and applications that are directly involved in inter-enterprise interoperability.** **SO4.2. Define rules, methods and procedures that are needed for dynamic service interoperability management.** **SO4.3. Put in place the needed agile organization structure (responsibilities, authorization…) so that service interoperability can be established dynamically 'on the fly'.**

EI Maturity level	**Level 4**
EI Aspect	**Conceptual**
EI Concern	**Data**
ID	**DC4**
Purpose	**The purpose of the DC4 interoperability area is to verify to which extent enterprise data models (both syntax and semantics) are adaptive**
Expected results	**Adaptive data models (both syntax and semantics)**
Assessment Indicators	Assessors have to verify to which extent the enterprise data models are adaptive. For that they have to verify if a) the enterprise has already changed/adapted its data model for a specific need and whether this was done rapidly, b) elements that can be changed and/or adjusted in data models are identified c) data models elements that cannot be modified are identified.
Best Practices	**DC4.1. Define data models elements that can be modified** **DC4.2. Identify data model elements that cannot be modified** **DC4.3 Identify the main changes that can be undertaken for the identified elements to collaborate with future partners.**

EI Maturity level	**Level 4**
EI Aspect	**Technical**
EI Concern	**Data**
ID	**DT4**
Purpose	**The purpose of the DT4 interoperability area is to verify to which extent direct database exchanges are possible and that technical assets supporting full data conversion are in place.**
Expected results	**Direct database exchanges capability and full data conversion tool.**
Assessment Indicators	Assessors have to verify to which extent any-to-any data exchanges and conversion are possible. For that they have to verify if: a) the database can communicate with multiple heterogeneous databases, b) direct data exchanges between databases is possible, c) data is shared in a networked databases, d) full data convention (format, syntax and semantics) tool used
Best Practices	**DT4.1. Define and build a federation (through federated approach) of heterogeneous databases to ease interoperability.** *Note 1*: "A federated database architecture is a collection of independent database systems, united into a loosely coupled federation, in order to share and exchange information." (Heimbigner and McLeod, 1985)[18] **DT4.2. Develop or acquire full data conversion tools to support dynamic (on-the-fly) data conversion**

[18] Dennis Heimbigner and Dennis McLeod. 1985. A federated architecture for information management. ACM Trans. Inf. Syst. 3, 1985.

EI Maturity level	**Level 4**
EI Aspect	**Organizational**
EI Concern	**Data**
ID	**DO4**
Purpose	**The purpose of the DO4 interoperability area is to verify to which extent enterprise data management rules and methods are adaptive**
Expected results	**Adaptive data management rules and methods**
Assessment Indicators	Assessors have to verify to which extent data management rules and methods are adaptive. For that they have to verify if a) those rules and methods exist and used, b) they allow adapting data models dynamically, c) procedures to guide dynamic negotiation and accommodation to adapt data elements are defined.
Best Practices	**DO4.1. Define data rules and methods that support dynamic adaptation of data models.** **DO4.2. Identify data elements that are subject of potential adaptation and accommodation** **DO4.3. Identify responsible persons to manage the change and define what to do in case of problems.** **DO4.4. Identify and define the main actions to undertake for data model dynamic adaptation**.

Annex 2: MMEI Fuzzy Rules

Fuzzy Rules[19] – R_C –							
r_{x1} :	IF XC_L is NA	AND	XT_L is NA	AND	XO_L is NA	THEN	X_L = NA
r_{x2} :	IF XC_L is NA	AND	XT_L is NA	AND	XO_L is PA	THEN	X_L is NA
r_{x3} :	IF XC_L is NA	AND	XT_L is PA	AND	XO_L is NA	THEN	X_L is NA
r_{x4} :	IF XC_L is NA	AND	XT_L is PA	AND	XO_L is PA	THEN	X_L is PA
r_{x5} :	IF XC_L is PA	AND	XT_L is NA	AND	XO_L is NA	THEN	X_L is NA
r_{x6} :	IF XC_L is PA	AND	XT_L is NA	AND	XO_L is PA	THEN	X_L is PA
r_{x7} :	IF XC_L is PA	AND	XT_L is PA	AND	XO_L is NA	THEN	X_L is PA
r_{x8} :	IF XC_L is PA	AND	XT_L is PA	AND	XO_L is PA	THEN	X_L is PA
r_{x9} :	IF XC_L is NA	AND	XT_L is NA	AND	XO_L is LA	THEN	X_L is PA
r_{x10} :	IF XC_L is NA	AND	XT_L is LA	AND	XO_L is NA	THEN	X_L is PA
r_{x11} :	IF XC_L is NA	AND	XT_L is LA	AND	XO_L is LA	THEN	X_L is PA
r_{x12} :	IF XC_L is LA	AND	XT_L is NA	AND	XO_L is NA	THEN	X_L is PA
r_{x13} :	IF XC_L is LA	AND	XT_L is NA	AND	XO_L is LA	THEN	X_L is PA
r_{x14} :	IF XC_L is LA	AND	XT_L is LA	AND	XO_L is NA	THEN	X_L is PA
r_{x15} :	IF XC_L is LA	AND	XT_L is LA	AND	XO_L is LA	THEN	X_L is LA
r_{x16} :	IF XC_L is NA	AND	XT_L is NA	AND	XO_L is FA	THEN	X_L is PA
r_{x17} :	IF XC_L is NA	AND	XT_L is FA	AND	XO_L is NA	THEN	X_L is PA
r_{x18} :	IF XC_L is NA	AND	XT_L is FA	AND	XO_L is FA	THEN	X_L is LA
r_{x19} :	IF XC_L is FA	AND	XT_L is NA	AND	XO_L is NA	THEN	X_L is PA
r_{x20} :	IF XC_L is FA	AND	XT_L is NA	AND	XO_L is FA	THEN	X_L is LA
r_{x21} :	IF XC_L is FA	AND	XT_L is FA	AND	XO_L is NA	THEN	X_L is LA
r_{x22} :	IF XC_L is FA	AND	XT_L is FA	AND	XO_L is FA	THEN	X_L is FA
r_{x23} :	IF XC_L is PA	AND	XT_L is PA	AND	XO_L is LA	THEN	X_L is PA
r_{x24} :	IF XC_L is PA	AND	XT_L is LA	AND	XO_L is PA	THEN	X_L is PA
r_{x25} :	IF XC_L is PA	AND	XT_L is LA	AND	XO_L is LA	THEN	X_L is LA
r_{x26} :	IF XC_L is LA	AND	XT_L is PA	AND	XO_L is PA	THEN	X_L is PA
r_{x27} :	IF XC_L is LA	AND	XT_L is PA	AND	XO_L is LA	THEN	X_L is LA
r_{x28} :	IF XC_L is LA	AND	XT_L is LA	AND	XO_L is PA	THEN	X_L is LA
r_{x29} :	IF XC_L is PA	AND	XT_L is PA	AND	XO_L is FA	THEN	X_L is LA
r_{x30} :	IF XC_L is PA	AND	XT_L is FA	AND	XO_L is PA	THEN	X_L is LA
r_{x31} :	IF XC_L is PA	AND	XT_L is FA	AND	XO_L is FA	THEN	X_L is LA

[19] R_C fuzzy rules are those related to EI concerns. In order to avoid redundancy the rules are defined in a general form using X to denote an EI concerns. In order to use a rule, X and x need to be replaced by the appropriate EI concern to evaluate (i.e. B for Business, P for Process, S for Service and D for data).

r_{x32} :	IF XC_L is FA	AND	XT_L is PA	AND	XO_L is PA	THEN	X_L is LA
r_{x33} :	IF XC_L is FA	AND	XT_L is PA	AND	XO_L is FA	THEN	X_L is LA
r_{x34} :	IF XC_L is FA	AND	XT_L is FA	AND	XO_L is PA	THEN	X_L is LA
r_{x35} :	IF XC_L is LA	AND	XT_L is LA	AND	XO_L is FA	THEN	X_L is LA
r_{x36} :	IF XC_L is LA	AND	XT_L is FA	AND	XO_L is LA	THEN	X_L is LA
r_{x37} :	IF XC_L is LA	AND	XT_L is FA	AND	XO_L is FA	THEN	X_L is FA
r_{x38} :	IF XC_L is FA	AND	XT_L is LA	AND	XO_L is LA	THEN	X_L is LA
r_{x39} :	IF XC_L is FA	AND	XT_L is LA	AND	XO_L is FA	THEN	X_L is FA
r_{x40} :	IF XC_L is FA	AND	XT_L is FA	AND	XO_L is LA	THEN	X_L is FA
r_{x41} :	IF XC_L is NA	AND	XT_L is PA	AND	XO_L is LA	THEN	X_L is PA
r_{x42} :	IF XC_L is NA	AND	XT_L is LA	AND	XO_L is PA	THEN	X_L is PA
r_{x43} :	IF XC_L is LA	AND	XT_L is NA	AND	XO_L is PA	THEN	X_L is PA
r_{x44} :	IF XC_L is LA	AND	XT_L is PA	AND	XO_L is NA	THEN	X_L is PA
r_{x45} :	IF XC_L is PA	AND	XT_L is LA	AND	XO_L is NA	THEN	X_L is PA
r_{x46} :	IF XC_L is PA	AND	XT_L is NA	AND	XO_L is LA	THEN	X_L is PA
r_{x47} :	IF XC_L is NA	AND	XT_L is LA	AND	XO_L is FA	THEN	X_L is LA
r_{x48} :	IF XC_L is NA	AND	XT_L is FA	AND	XO_L is LA	THEN	X_L is LA
r_{x49} :	IF XC_L is LA	AND	XT_L is NA	AND	XO_L is FA	THEN	X_L is LA
r_{x50} :	IF XC_L is LA	AND	XT_L is FA	AND	XO_L is NA	THEN	X_L is LA
r_{x51} :	IF XC_L is FA	AND	XT_L is NA	AND	XO_L is LA	THEN	X_L is LA
r_{x52} :	IF XC_L is FA	AND	XT_L is LA	AND	XO_L is NA	THEN	X_L is LA
r_{x53} :	IF XC_L is PA	AND	XT_L is LA	AND	XO_L is FA	THEN	X_L is LA
r_{x54} :	IF XC_L is PA	AND	XT_L is FA	AND	XO_L is LA	THEN	X_L is LA
r_{x55} :	IF XC_L is LA	AND	XT_L is PA	AND	XO_L is FA	THEN	X_L is LA
r_{x56} :	IF XC_L is LA	AND	XT_L is FA	AND	XO_L is PA	THEN	X_L is LA
r_{x57} :	IF XC_L is FA	AND	XT_L is PA	AND	XO_L is LA	THEN	X_L is LA
r_{x58} :	IF XC_L is FA	AND	XT_L is LA	AND	XO_L is PA	THEN	X_L is LA
r_{x59} :	IF XC_L is NA	AND	XT_L is PA	AND	XO_L is FA	THEN	X_L is PA
r_{x60} :	IF XC_L is NA	AND	XT_L is FA	AND	XO_L is PA	THEN	X_L is PA
r_{x61} :	IF XC_L is PA	AND	XT_L is NA	AND	XO_L is FA	THEN	X_L is PA
r_{x62} :	IF XC_L is PA	AND	XT_L is FA	AND	XO_L is NA	THEN	X_L is PA
r_{x63} :	IF XC_L is FA	AND	XT_L is NA	AND	XO_L is PA	THEN	X_L is PA
r_{x64} :	IF XC_L is FA	AND	XT_L is PA	AND	XO_L is NA	THEN	X_L is PA

Fuzzy rules[20] – R'–									
$r'_{X\,1}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is LA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,2}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is FA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,3}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is FA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,4}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is FA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,5}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is PA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,6}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is PA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,7}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is PA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,8}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is PA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,9}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is LA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,10}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is LA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,11}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is LA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,12}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is LA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,13}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is LA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,14}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is NA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,15}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is NA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,16}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is NA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,17}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is NA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,18}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is FA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,19}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is FA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,20}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is FA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,21}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is FA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,22}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is PA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,23}$:	IF XC_1 is LA	AND	XC_2 is LA	AND	XC_3 is LA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,24}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is PA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,25}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is PA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,26}$:	IF XC_1 is LA	AND	XC_2 is NA	AND	XC_3 is PA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,27}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is LA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,28}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is LA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,29}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is LA	AND	XC_4 is FA	THEN	XE = 1
$r'_{X\,30}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is LA	AND	XC_4 is PA	THEN	XE = 1
$r'_{X\,31}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is NA	AND	XC_4 is LA	THEN	XE = 1
$r'_{X\,32}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is NA	AND	XC_4 is NA	THEN	XE = 1
$r'_{X\,33}$:	IF XC_1 is LA	AND	XC_2 is FA	AND	XC_3 is NA	AND	XC_4 is FA	THEN	XE = 1

[20] R' fuzzy rules are those related to the EI concerns level determination. In order to avoid redundancy the rules are defined in a general form using X to denote an EI concerns. In order to use a rule, X needs to be replaced by the appropriate EI concern to evaluate (i.e. B for Business, P for Process, S for Service and D for data). X_E is the determined level of the considered EI concern based on the corresponding rule.

$r'_{X\ 34}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is LA AND XC_4 is PA THEN XE = 1
$r'_{X\ 35}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is NA AND XC_4 is PA THEN XE = 1
$r'_{X\ 36}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is FA AND XC_4 is LA THEN XE = 1
$r'_{X\ 37}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is FA AND XC_4 is NA THEN XE = 1
$r'_{X\ 38}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is FA AND XC_4 is FA THEN XE = 1
$r'_{X\ 39}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is FA AND XC_4 is PA THEN XE = 1
$r'_{X\ 40}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is PA AND XC_4 is LA THEN XE = 1
$r'_{X\ 41}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is PA AND XC_4 is NA THEN XE = 1
$r'_{X\ 42}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is PA AND XC_4 is FA THEN XE = 1
$r'_{X\ 43}$: IF XC_1 is LA AND XC_2 is FA AND XC_3 is PA AND XC_4 is PA THEN XE = 1
$r'_{X\ 44}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is LA AND XC_4 is LA THEN XE = 1
$r'_{X\ 45}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is NA AND XC_4 is LA THEN XE = 1
$r'_{X\ 46}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is LA AND XC_4 is NA THEN XE = 1
$r'_{X\ 47}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is LA AND XC_4 is FA THEN XE = 1
$r'_{X\ 48}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is LA AND XC_4 is PA THEN XE = 1
$r'_{X\ 49}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is NA AND XC_4 is LA THEN XE = 1
$r'_{X\ 50}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is NA AND XC_4 is NA THEN XE = 1
$r'_{X\ 51}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is NA AND XC_4 is FA THEN XE = 1
$r'_{X\ 52}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is NA AND XC_4 is PA THEN XE = 1
$r'_{X\ 53}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is FA AND XC_4 is LA THEN XE = 1
$r'_{X\ 54}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is FA AND XC_4 is NA THEN XE = 1
$r'_{X\ 55}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is FA AND XC_4 is FA THEN XE = 1
$r'_{X\ 56}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is NA AND XC_4 is NA THEN XE = 1
$r'_{X\ 57}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is FA AND XC_4 is PA THEN XE = 1
$r'_{X\ 58}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is PA AND XC_4 is LA THEN XE = 1
$r'_{X\ 59}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is PA AND XC_4 is NA THEN XE = 1
$r'_{X\ 60}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is PA AND XC_4 is FA THEN XE = 1
$r'_{X\ 61}$: IF XC_1 is LA AND XC_2 is PA AND XC_3 is PA AND XC_4 is PA THEN XE = 1
$r'_{X\ 62}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is NA AND XC_4 is FA THEN XE = 1
$r'_{X\ 63}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is NA AND XC_4 is PA THEN XE = 1
$r'_{X\ 64}$: IF XC_1 is LA AND XC_2 is LA AND XC_3 is FA AND XC_4 is LA THEN XE = 1
$r'_{X\ 65}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is LA AND XC_4 is LA THEN XE = 2
$r'_{X\ 66}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is LA AND XC_4 is NA THEN XE = 2
$r'_{X\ 67}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is LA AND XC_4 is FA THEN XE = 2
$r'_{X\ 68}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is LA AND XC_4 is PA THEN XE = 2
$r'_{X\ 69}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is NA AND XC_4 is LA THEN XE = 2
$r'_{X\ 70}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is NA AND XC_4 is NA THEN XE = 2
$r'_{X\ 71}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is NA AND XC_4 is FA THEN XE = 2
$r'_{X\ 72}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is NA AND XC_4 is PA THEN XE = 2
$r'_{X\ 73}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is FA AND XC_4 is LA THEN XE = 2

$r'_{X\ 74}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is FA AND XC_4 is NA THEN XE = 2

$r'_{X\ 75}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is FA AND XC_4 is FA THEN XE = 2

$r'_{X\ 76}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is FA AND XC_4 is PA THEN XE = 2

$r'_{X\ 77}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is PA AND XC_4 is LA THEN XE = 2

$r'_{X\ 78}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is PA AND XC_4 is NA THEN XE = 2

$r'_{X\ 79}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is PA AND XC_4 is FA THEN XE = 2

$r'_{X\ 80}$: IF XC_1 is FA AND XC_2 is LA AND XC_3 is PA AND XC_4 is PA THEN XE = 2

$r'_{X\ 81}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is LA AND XC_4 is LA THEN XE = 1

$r'_{X\ 82}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is LA AND XC_4 is NA THEN XE = 1

$r'_{X\ 83}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is LA AND XC_4 is FA THEN XE = 1

$r'_{X\ 84}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is LA AND XC_4 is PA THEN XE = 1

$r'_{X\ 85}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is NA AND XC_4 is LA THEN XE = 1

$r'_{X\ 86}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is NA AND XC_4 is NA THEN XE = 1

$r'_{X\ 87}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is NA AND XC_4 is FA THEN XE = 1

$r'_{X\ 88}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is NA AND XC_4 is PA THEN XE = 1

$r'_{X\ 89}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is FA AND XC_4 is LA THEN XE = 1

$r'_{X\ 90}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is FA AND XC_4 is NA THEN XE = 1

$r'_{X\ 91}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is FA AND XC_4 is FA THEN XE = 1

$r'_{X\ 92}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is FA AND XC_4 is PA THEN XE = 1

$r'_{X\ 93}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is PA AND XC_4 is LA THEN XE = 1

$r'_{X\ 94}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is PA AND XC_4 is NA THEN XE = 1

$r'_{X\ 95}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is PA AND XC_4 is FA THEN XE = 1

$r'_{X\ 96}$: IF XC_1 is FA AND XC_2 is NA AND XC_3 is PA AND XC_4 is PA THEN XE = 1

$r'_{X\ 97}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is LA AND XC_4 is LA THEN XE = 3

$r'_{X\ 98}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is LA AND XC_4 is NA THEN XE = 3

$r'_{X\ 99}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is LA AND XC_4 is FA THEN XE = 3

$r'_{X\ 100}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is LA AND XC_4 is PA THEN XE = 3

$r'_{X\ 101}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is NA AND XC_4 is LA THEN XE = 2

$r'_{X\ 102}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is NA AND XC_4 is NA THEN XE = 2

$r'_{X\ 103}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is NA AND XC_4 is FA THEN XE = 2

$r'_{X\ 104}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is NA AND XC_4 is PA THEN XE = 2

$r'_{X\ 105}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is FA AND XC_4 is LA THEN XE = 4

$r'_{X\ 106}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is FA AND XC_4 is NA THEN XE = 3

$r'_{X\ 107}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is FA AND XC_4 is FA THEN XE = 4

$r'_{X\ 108}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is FA AND XC_4 is PA THEN XE = 3

$r'_{X\ 109}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is PA AND XC_4 is LA THEN XE = 2

$r'_{X\ 110}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is PA AND XC_4 is NA THEN XE = 2

$r'_{X\ 111}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is PA AND XC_4 is FA THEN XE = 2

$r'_{X\ 112}$: IF XC_1 is FA AND XC_2 is FA AND XC_3 is PA AND XC_4 is PA THEN XE = 2

$r'_{X\ 113}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is LA AND XC_4 is LA THEN XE = 1

$r'_{X\ 114}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is LA AND XC_4 is NA THEN XE = 1

$r'_{X\ 115}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is LA AND XC_4 is FA THEN XE = 1

$r'_{X\ 116}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is LA AND XC_4 is PA THEN XE = 1

$r'_{X\ 117}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is NA AND XC_4 is LA THEN XE = 1

$r'_{X\ 118}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is NA AND XC_4 is NA THEN XE = 1

$r'_{X\ 119}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is NA AND XC_4 is FA THEN XE = 1

$r'_{X\ 120}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is NA AND XC_4 is PA THEN XE = 1

$r'_{X\ 121}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is FA AND XC_4 is LA THEN XE = 1

$r'_{X\ 122}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is FA AND XC_4 is NA THEN XE = 1

$r'_{X\ 123}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is FA AND XC_4 is FA THEN XE = 1

$r'_{X\ 124}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is FA AND XC_4 is PA THEN XE = 1

$r'_{X\ 125}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is PA AND XC_4 is LA THEN XE = 1

$r'_{X\ 126}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is PA AND XC_4 is NA THEN XE = 1

$r'_{X\ 127}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is PA AND XC_4 is FA THEN XE = 1

$r'_{X\ 128}$: IF XC_1 is FA AND XC_2 is PA AND XC_3 is PA AND XC_4 is PA THEN XE = 1

$r'_{X\ 129}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is LA AND XC_4 is PA THEN XE = 0

$r'_{X\ 130}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is NA AND XC_4 is LA THEN XE = 0

$r'_{X\ 131}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is NA AND XC_4 is NA THEN XE = 0

$r'_{X\ 132}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is NA AND XC_4 is FA THEN XE = 0

$r'_{X\ 133}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is NA AND XC_4 is PA THEN XE = 0

$r'_{X\ 134}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is FA AND XC_4 is LA THEN XE = 0

$r'_{X\ 135}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is FA AND XC_4 is NA THEN XE = 0

$r'_{X\ 136}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is FA AND XC_4 is FA THEN XE = 0

$r'_{X\ 137}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is FA AND XC_4 is PA THEN XE = 0

$r'_{X\ 138}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is PA AND XC_4 is LA THEN XE = 0

$r'_{X\ 139}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is PA AND XC_4 is NA THEN XE = 0

$r'_{X\ 140}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is PA AND XC_4 is FA THEN XE = 0

$r'_{X\ 141}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is PA AND XC_4 is PA THEN XE = 0

$r'_{X\ 142}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is LA AND XC_4 is LA THEN XE = 0

$r'_{X\ 143}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is LA AND XC_4 is NA THEN XE = 0

$r'_{X\ 144}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is LA AND XC_4 is FA THEN XE = 0

$r'_{X\ 145}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is LA AND XC_4 is PA THEN XE = 0

$r'_{X\ 146}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is NA AND XC_4 is LA THEN XE = 0

$r'_{X\ 147}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is NA AND XC_4 is NA THEN XE = 0

$r'_{X\ 148}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is NA AND XC_4 is FA THEN XE = 0

$r'_{X\ 149}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is NA AND XC_4 is PA THEN XE = 0

$r'_{X\ 150}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is FA AND XC_4 is LA THEN XE = 0

$r'_{X\ 151}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is FA AND XC_4 is NA THEN XE = 0

$r'_{X\ 152}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is FA AND XC_4 is FA THEN XE = 0

$r'_{X\ 153}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is FA AND XC_4 is PA THEN XE = 0

$r'_{X\ 154}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is PA AND XC_4 is LA THEN XE = 0
$r'_{X\ 155}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is PA AND XC_4 is NA THEN XE = 0
$r'_{X\ 156}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is PA AND XC_4 is FA THEN XE = 0
$r'_{X\ 157}$: IF XC1 is NA AND XC_2 is PA AND XC_3 is PA AND XC_4 is PA THEN XE = 0
$r'_{X\ 158}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is LA AND XC_4 is LA THEN XE = 0
$r'_{X\ 159}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is LA AND XC_4 is NA THEN XE = 0
$r'_{X\ 160}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is LA AND XC_4 is FA THEN XE = 0
$r'_{X\ 161}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is LA AND XC_4 is PA THEN XE = 0
$r'_{X\ 162}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is NA AND XC_4 is LA THEN XE = 0
$r'_{X\ 163}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is NA AND XC_4 is NA THEN XE = 0
$r'_{X\ 164}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is NA AND XC_4 is FA THEN XE = 0
$r'_{X\ 165}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is NA AND XC_4 is PA THEN XE = 0
$r'_{X\ 166}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is FA AND XC_4 is LA THEN XE = 0
$r'_{X\ 167}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is FA AND XC_4 is NA THEN XE = 0
$r'_{X\ 168}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is FA AND XC_4 is FA THEN XE = 0
$r'_{X\ 169}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is FA AND XC_4 is PA THEN XE = 0
$r'_{X\ 170}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is PA AND XC_4 is LA THEN XE = 0
$r'_{X\ 171}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is PA AND XC_4 is NA THEN XE = 0
$r'_{X\ 172}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is PA AND XC_4 is FA THEN XE = 0
$r'_{X\ 173}$: IF XC1 is NA AND XC_2 is LA AND XC_3 is PA AND XC_4 is PA THEN XE = 0
$r'_{X\ 174}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is LA AND XC_4 is LA THEN XE = 0
$r'_{X\ 175}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is LA AND XC_4 is NA THEN XE = 0
$r'_{X\ 176}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is LA AND XC_4 is FA THEN XE = 0
$r'_{X\ 177}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is LA AND XC_4 is PA THEN XE = 0
$r'_{X\ 178}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is NA AND XC_4 is LA THEN XE = 0
$r'_{X\ 179}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is NA AND XC_4 is NA THEN XE = 0
$r'_{X\ 180}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is NA AND XC_4 is FA THEN XE = 0
$r'_{X\ 181}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is NA AND XC_4 is PA THEN XE = 0
$r'_{X\ 182}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is FA AND XC_4 is LA THEN XE = 0
$r'_{X\ 183}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is FA AND XC_4 is NA THEN XE = 0
$r'_{X\ 184}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is FA AND XC_4 is FA THEN XE = 0
$r'_{X\ 185}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is FA AND XC_4 is PA THEN XE = 0
$r'_{X\ 186}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is PA AND XC_4 is LA THEN XE = 0
$r'_{X\ 187}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is PA AND XC_4 is NA THEN XE = 0
$r'_{X\ 188}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is PA AND XC_4 is FA THEN XE = 0
$r'_{X\ 189}$: IF XC1 is NA AND XC_2 is NA AND XC_3 is PA AND XC_4 is PA THEN XE = 0
$r'_{X\ 190}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is LA AND XC_4 is LA THEN XE = 0
$r'_{X\ 191}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is LA AND XC_4 is NA THEN XE = 0
$r'_{X\ 192}$: IF XC1 is NA AND XC_2 is FA AND XC_3 is LA AND XC_4 is FA THEN XE = 0
$r'_{X\ 193}$: IF XC1 is PA AND XC_2 is LA AND XC_3 is LA AND XC_4 is LA THEN XE = 0

$r'_{X\,194}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is LA AND XC_4 is NA THEN XE = 0

$r'_{X\,195}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is LA AND XC_4 is FA THEN XE = 0

$r'_{X\,196}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is LA AND XC_4 is PA THEN XE = 0

$r'_{X\,197}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is NA AND XC_4 is LA THEN XE = 0

$r'_{X\,198}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is NA AND XC_4 is NA THEN XE = 0

$r'_{X\,199}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is NA AND XC_4 is FA THEN XE = 0

$r'_{X\,200}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is NA AND XC_4 is PA THEN XE = 0

$r'_{X\,201}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is FA AND XC_4 is LA THEN XE = 0

$r'_{X\,202}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is FA AND XC_4 is NA THEN XE = 0

$r'_{X\,203}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is FA AND XC_4 is FA THEN XE = 0

$r'_{X\,204}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is FA AND XC_4 is PA THEN XE = 0

$r'_{X\,205}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is PA AND XC_4 is LA THEN XE = 0

$r'_{X\,206}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is PA AND XC_4 is NA THEN XE = 0

$r'_{X\,207}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is PA AND XC_4 is FA THEN XE = 0

$r'_{X\,208}$: IF $XC1$ is PA AND XC_2 is LA AND XC_3 is PA AND XC_4 is PA THEN XE = 0

$r'_{X\,209}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is LA AND XC_4 is LA THEN XE = 0

$r'_{X\,210}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is LA AND XC_4 is NA THEN XE = 0

$r'_{X\,211}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is LA AND XC_4 is FA THEN XE = 0

$r'_{X\,212}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is LA AND XC_4 is PA THEN XE = 0

$r'_{X\,213}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is NA AND XC_4 is LA THEN XE = 0

$r'_{X\,214}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is NA AND XC_4 is NA THEN XE = 0

$r'_{X\,215}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is NA AND XC_4 is FA THEN XE = 0

$r'_{X\,216}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is NA AND XC_4 is PA THEN XE = 0

$r'_{X\,217}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is FA AND XC_4 is LA THEN XE = 0

$r'_{X\,218}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is FA AND XC_4 is NA THEN XE = 0

$r'_{X\,219}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is FA AND XC_4 is FA THEN XE = 0

$r'_{X\,220}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is FA AND XC_4 is PA THEN XE = 0

$r'_{X\,221}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is PA AND XC_4 is LA THEN XE = 0

$r'_{X\,222}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is PA AND XC_4 is NA THEN XE = 0

$r'_{X\,223}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is PA AND XC_4 is FA THEN XE = 0

$r'_{X\,224}$: IF $XC1$ is PA AND XC_2 is NA AND XC_3 is PA AND XC_4 is PA THEN XE = 0

$r'_{X\,225}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is LA AND XC_4 is LA THEN XE = 0

$r'_{X\,226}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is LA AND XC_4 is NA THEN XE = 0

$r'_{X\,227}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is LA AND XC_4 is FA THEN XE = 0

$r'_{X\,228}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is LA AND XC_4 is PA THEN XE = 0

$r'_{X\,229}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is NA AND XC_4 is LA THEN XE = 0

$r'_{X\,230}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is NA AND XC_4 is NA THEN XE = 0

$r'_{X\,231}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is NA AND XC_4 is FA THEN XE = 0

$r'_{X\,232}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is NA AND XC_4 is PA THEN XE = 0

$r'_{X\,233}$: IF $XC1$ is PA AND XC_2 is FA AND XC_3 is FA AND XC_4 is LA THEN XE = 0

$r'_{X\ 234}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	FA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 235}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	FA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 236}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	FA	AND	XC_4 is PA	THEN XE = 0
$r'_{X\ 237}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	PA	AND	XC_4 is LA	THEN XE = 0
$r'_{X\ 238}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	PA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 239}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	PA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 240}$:	IF XC1 is	PA	AND	XC_2 is	FA	AND	XC_3 is	PA	AND	XC_4 is PA	THEN XE = 0
$r'_{X\ 241}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	LA	AND	XC_4 is LA	THEN XE = 0
$r'_{X\ 242}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	LA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 243}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	LA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 244}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	LA	AND	XC_4 is PA	THEN XE = 0
$r'_{X\ 245}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	NA	AND	XC_4 is LA	THEN XE = 0
$r'_{X\ 246}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	NA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 247}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	NA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 248}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	NA	AND	XC_4 is PA	THEN XE = 0
$r'_{X\ 249}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	FA	AND	XC_4 is LA	THEN XE = 0
$r'_{X\ 250}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	FA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 251}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	FA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 252}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	FA	AND	XC_4 is PA	THEN XE = 0
$r'_{X\ 253}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	PA	AND	XC_4 is LA	THEN XE = 0
$r'_{X\ 254}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	PA	AND	XC_4 is NA	THEN XE = 0
$r'_{X\ 255}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	PA	AND	XC_4 is FA	THEN XE = 0
$r'_{X\ 256}$:	IF XC1 is	PA	AND	XC_2 is	PA	AND	XC_3 is	PA	AND	XC_4 is PA	THEN XE = 0

Annex 3: MMEI Questionnaire

MMEI questionnaire
Q1. Is there a defined business model? ***Q2. In this business model, what are the main defined objectives of the enterprise?*** ***Q3. What are the products of the enterprise?*** ***Q4. What are the main activities of the enterprise?*** ***Q5. What are the main resources that are used to realize these activities?*** ***Q6. Who are the enterprise clients?*** ***Q7. Who are the enterprise partners?*** ***Q8. How is the enterprise achieving its objectives (strategy)?*** ***Q9. Is the defined business model documented?*** ***Q10. Who knows the business model and has access to it?*** ***Q11. Who is responsible for ensuring that the defined business model is followed?*** ***Q12. Is there a defined organization structure?*** ***Q13. Is it easy to make changes in the organization structure?*** ***Q14. Does the business model use standards? If yes what are these standards?*** ***Q15. How is communication delivered within the enterprise?*** ***Q16. Are there any minutes for these meetings? If yes, are they dematerialized?*** ***Q17. How is communication ensured with partners (clients, providers, suppliers, etc)?*** ***Q18. How does the company manage its relationships with partners? With customers? And with suppliers?*** ***Q19. How do you exchange documents inside the enterprise?*** ***Q20. How are documents shared within the enterprise?*** ***Q21. How can you find a document? Is it always easy?*** ***Q22. Is there document/data management system that facilitates the search of documents?*** ***Q23. Does everyone use the same format of documents?*** ***Q24. How is the access to information controlled?*** ***Q25. What are these rules?*** ***Q26. Can you communicate or share information with all employees or are there pre-formed groups that only communicate together?***

Q27. Are there implemented databases? If yes, how can you access them?

Q28. Are there defined models for data?

Q29. Are the defined data models documented?

Q30. Are the defined data models based on standards?

Q31. Is there an enterprise local network?

Q32. Is there any data accessible from outside the company?

Q33. Could you share an IT application within the enterprise?

Q34. Can you introduce a new IT application or service if needed?

Q35. Are your applications home-made or do you use other ones?

Q36. In case of a technical problem, can your IT department develop new applications or solutions quickly?

Q37. Can they re-purpose or upgrade the existing infrastructure, when needed?

Q38. Are there parts of the existing applications that you can use to re-implement other applications?

Q39. Are the enterprise services and applications defined?

Q40. Are there documentation for the services and applications?

Q41. Are the enterprise processes defined?

Q42. Are the defined process models documented?

Q43. Are the main processes well-known? Are the activities modeled and/or formalized well known?

Q44. Are there automated processes in place?

Q45. Are there components of the existing processes that you can reuse for other ones?

Q46. Are the work methods defined? Are they known by all the employees of the enterprise?

Q47. Are they applied in everyday use?

Q48. Do the process models use standards?

Q49. Do you know if the main processes use reusable activities or parts of other processes?

Q50. Does each employee know what he has to do? What are his responsibilities and what are not?

Q51. Does the company manage its resources?

Q52. How is the resources management and allocation done?

Q53. Do you think that your company is sufficiently using standards allowing it to

interoperate?

Q54. Will there be any problem if the company is led to use new standards? Is this planned?

Q55. How do you react if a partner asks for a re-structuring of information? This can be of course related to business, processes, services or data.

Q56. How does the enterprise react in case of a new partner? Is it easy to make changes, if needed?

Q57. In case of launching a new product, what are the difficulties that can be faced?

Q58. Has the company already faced relational problems/communication problems with a customer or a supplier or a partner? If yes, what is the cause?

Q59. What does the company do to manage the unexpected (i.e. management of change in the short-term)? (E.g. withdrawal from a customer, supplier, partner)

Q60. Is there a procedure for the monitoring of the change (i.e. management of long-term change)?

Q61. Is the preservation of knowledge and skills ensured? What happens if an employee leaves the company? Are all employees replaceable?

Q62. In case of a new partner, what are the changes that are undertaken by the enterprise? Is the enterprise aware of these changes? Is it prepared for them?

Q63. Can we easily modify, add/delete a task/activity in a business process of the enterprise? If yes, who is responsible for that?

Q64. Is training for employees organized?

Q65. Is there training dedicated to interoperability?

Q66. Is there anything you want to improve in the management system or in operational business? If yes, will this take many changes? Will this have an impact on business?

Annex 4: Interview

Interview for the evaluation of METS company

Q1. Is there a defined business model?

R9 : *Yes, there is a model that describes the enterprise business and all related elements.*

Q2. In this business model, what are the main defined objectives of the enterprise?

R10 : *Meet/Respect delivery deadlines, have a good quality to minimize customer complaints, reduce costs, maximize its profile and of course to be a leader in the market.*

Q3. What are the products of the enterprise?

R11 : *The company is specialized in the production of electrical auto wires for exportation to the headquarters for the assembly and redirection to the final clients (i.e. car manufacturers), it has a continuous production*

Q4. What are the main activities of the enterprise?

R12 : *Design of the technical sheets received from the headquarters using specific software.*

Purchasing raw materials: wires, accessories (connectors, accessories, etc.)

Cables cutting, Cable assembling: some accessories are connected by special machines and others are only connected manually (cannot be connected using machines), mounting, Etc.

Q5. What are the main resources that are used to realize these activities?

R13 : *Cable coils, accessories, computers, machinery, iron, human resources, etc.*

Q6. Who are the enterprise clients?

R14 : *Car manufacturers: General Motors (Opel), Volkswagen, Audit, etc.*

Q7. Who are the enterprise partners?

R15 : *Raw material supplier (i.e. mainly "KBE" company); accessories' supplier, Headquarters.*

Q8. How is the enterprise achieving its objectives (strategy)?

R16 : *There are three workstations: 24 hours a day and sometimes 7 days a week if needed.*

There are always some extra employees in case of necessity. For example, when the number of employees needed in the production chain is N, we usually find N+2 employees (variable number) allocated. In case of a production delay, it is compensated with extra hours on

Saturdays and Sundays.

It is also to note that the company is investing heavily to reach its objectives : employees' training, motivating employees (money or otherwise), developed materials, acquisition of the latest versions of software, etc.

Q9. Is the defined business model documented?

R17 : *I know that it is easily understandable, clear and there is no problem with it. When the director was changed, the new one didn't have any problems understanding it. Sometimes, the headquarters requires that we change something in our business and we do it without any problem and for sure the model is modified also without problems.*

Q10. Who knows the business model and has access to it?

R18 : *Direction department and some of the concerned persons (department directors, managers, etc)*

Q11. Who is responsible for ensuring that the defined business model is followed?

R19 : *Each manager is responsible for its "part of the business" and ensures that the model is followed.*

Q12. Is there a defined organization structure?

R20 : *The enterprise has an organization chart and a defined organizational structure : in a responsibility descendent order, they are as follows : the general manager, the chief executive officer, the head of service, the chief operator, the team leader, the chain manager and workers.*

Q13. Is it easy to make changes in the organization structure?

R21 : *This kind of change is very rare in the company. It has happened before and some of the departments' names have changed and some other departments have been deleted for the creation of other ones like training department, quality department, etc.*

Q14. Does the business model use standards? If yes what are these standards?

R22 : *I know that the business model is defined using standard files that are used also by other enterprises like: WORD, PDF, etc.*

Q15. How is communication delivered within the enterprise?

R23 : *Telephone, intranet, e-mails (outlook), regular meetings, etc.*

Q16. Are there any minutes for these meetings? If yes, are they dematerialized?

R24 : *Yes. It's called "PV". It is dematerialized and subsequently sent to those concerned.*

The minutes of meeting contain the allocation of tasks that will be discussed again in future meetings until completion of those tasks.

There is also a document called: Portfolio Management : it is a document that tracks all the tasks in general and everything about the company. This document is made in Germany by the headquarters and updated each time there is a progress.

Q17. How is communication ensured with partners (clients, providers, suppliers, etc)?

R25 : *With headquarters: by satellite, e-mails, telephone, videoconference meetings and on site meetings if needed.*

With suppliers : e-mails, telephone

With clients: through the headquarters.

Q18. How does the company manage its relationships with partners? With customers? And with suppliers?

R26 : *The orders come from headquarters. But innovative proposals are always welcome*

Q19. How do you exchange documents inside the enterprise?

R27 : *By e-mails, on server, intranet, USB devices, etc.*

Q20. How are documents shared within the enterprise?

R28 : *The documents are available on the company servers. The access is done through access rights*

Q21. How can you find a document? Is it always easy?

R29 : *The documents are not named in an ad hoc manner, a standard is used. So the documents' names facilitate the ranking and the search of documents. Of course it is always difficult to find a document if we don't have any information about it.*

Q22. Is there document/data management system that facilitates the search of documents?

R30 : *Yes, it is the DFM system (DräXElmaier Formular Manager).*

Q23. Does everyone use the same format of documents?

R31 : *Yes. We mainly use : Word, Excel and PDF.*

Q24. How is the access to information controlled?

R32 : *By access control rules.*

Q25. What are these rules?

R33 : *The information is classified into three categories : public information, limited information (access restricted to those involved and responsible) and secret information* *(only accessed by the direction).*

Q26. Can you communicate or share information with all employees or are there pre-formed groups that only communicate together?

R34 : *It depends on the information. There is information that we can share with all employees and that we can only share with a group of employees.*

Q27. Are there implemented databases? If yes, how can you access them?

R35 : *Yes. Databases are mainly related to IT applications. The access can be done directly or through an IT application. There are, of course, rules that control this access.*

Q28. Are there defined models for data?

R36 : *Yes of course, we use UML and Merise design tools to design models.*

Q29. Are the defined data models documented?

R37 : *Yes we always have the documentation to make data models understandable.*

Q30. Are the defined data models based on standards?

R38 : *Yes. Use of UML and Merise*

Q31. Is there an enterprise local network?

R39 : *Yes*

Q32. Is there any data accessible from outside the company?

R40 : *The headquarters in Germany can access the enterprise portal, intranet, documents, etc. Only the webpage is accessible for those external to the company www.draexlmaier.de; which is logic*

Q33. Could you share an IT application within the enterprise?

R41 : *Yes. There are a lot of applications that we share as well as databases. We have a collaborative portal with an access control centralized in Germany. Each employee can access the portal from home via VPN.*

Q34. Can you introduce a new IT application or service if needed?

R42 : *Yes. This has already happened. The company is trying to be "up to date". Then, using new software, etc. then, we're really used to this kind of change, update, etc. There is sometimes some training with new software or a version update organized for concerned employees.*

Q35. Are your applications home-made or do you use other ones?

R43 : *There are the two cases. For the main tasks of productions we use standard* *applications that are installed in the computers that assist the production machinery. For other purposes, we use applications that are implemented by our IT department or by another site of the company.*

Q36. In case of a technical problem, can your IT department develop new applications or solutions quickly?

R44 : *Yes we have a maintenance service and the main problems are solved quickly. There was a case in the past where a problem was not solved due to lack of competence and headquarters sent a person to solve it.*

Q37. Can they re-purpose or upgrade the existing infrastructure, when needed?

R45 : *Yes we do it if needed.*

Q38. Are there parts of the existing applications that you can use to re-implement other applications?

R46 : *Yes. If there is a part of the code or an algorithm that we can use to implement another one, for sure we do it.*

Q39. Are the enterprise services and applications defined?

R47 : *Yes for the IT services, we have a file that describes all of them, with their functionality. For the services that the enterprise offer (i.e. production), there is also models that describes them and the requirements (especially for the quality). For the custom side, there is a defined catalogue which includes information about the products, prices, contact points, ordering and request processes.*

Q40. Are there documentation for the services and applications?

R48 : *For the IT applications, there is always the IT documentation included with them. For the products we have to include descriptive documents and documentation within the package to export.*

Q41. Are the enterprise processes defined?

R49 : *There is a production model. It is formalized using a conceptual model (MERISE) and saved on the server in order to be accessed by all employees. Each manager is responsible for its "part of business" and controls that the process model is followed.*

Q42. Are the defined process models documented?

R50 : *R : Yes. Each process has its documentation where we find more details on activities and used resources.*

Q43. Are the main processes well-known? Are the activities modeled and/or formalized well known?

R51 : *Yes by the concerned persons.*

Q44. Are there automated processes in place?

R52 : *Yes. Almost all processes are automated, even management processes like expense report, application for leave, purchasing request, travel reservation, customer complaint, etc. However, there are specific production activities that should be done manually. This depends on the king of the cable and the command, etc.*

Q45. Are there components of the existing processes that you can reuse for other ones?

R53 : *Yes. Especially for production processes' parts that are repeatable.*

Q46. Are the work methods defined? Are they known by all the employees of the enterprise?

R54 : *Yes. The work methods are called "consignes de travail". They are defined and validated by the quality service. These "consignes" are known, applied, automated and classified by service. They are well known by employees but only the head of service has access to them.*

Q47. Are they applied in everyday use?

R55 : *Yes, for sure!*

Q48. Do the process models use standards?

R56 : *Yes. We use standards that are predefined by the headquarters and sometimes we make some modifications that are required by partners.*

Q49. Do you know if the main processes use reusable activities or parts of other processes?

R57 : *When we have some repeated parts, it is normal that we use the same process definition and details. We don't redefine.*

Q50. Does each employee know what he has to do? What are his responsibilities and what are not?

R58 : *Within each employee file, we find his role with details of the associated activities, responsibilities and authorities to the role. We can also find a list of the persons that are able to replace him in case of his absence.*

All the employees' files are automated and classified by role.

These files are accessed by the unit head who can verify e.g. in case of conflict the associated activities to an employee based on its role description.

Q51. Does the company manage its resources?

R59 : *Yes.*

Q52. How is the resources management and allocation done?

R60 : *For the raw material, it is the manager of the store who controls the access and the use of resources.*

Regarding the offices' resources, each request is controlled via a withdrawal slip, that has to be signed by the applicant's responsible and which is then signed by the store manager.

Q53. Do you think that your company is sufficiently using standards allowing it to interoperate?

R61 : ***Actually, o****ur company has many certifications. Among them I can cite TÜV which is a client certification: the harder to obtain. We also use the TÜV standard at all levels.*

Q54. Will there be any problem if the company is led to use new standards? Is this planned?

R62 : *To be honest, I don't think so. Indeed* **the** *company had faced a lot of problems that it solved and adopted new formats, etc. without major problems to cite.*

Q55. How do you react if a partner asks for a re-structuring of information? This can be of course related to business, processes, services or data.

R63 : *Our documents are easily understandable and well structured. However if a partner asks for a modification we can do it without problems.*

Q56. How does the enterprise react in case of a new partner? Is it easy to make changes, if needed?

R64 : *This has already happened and we had changes to make. This had taken some time but it was manageable.*

Q57. In case of launching a new product, what are the difficulties that can be faced?

R65 : *Yes it is normal to have problems at the beginning and mainly a low yield for the production. But this is planned and in this case, the headquarters affects the urgent production to other production sites (e.g. Poland, Mexico, etc.). The Production department starts by producing samples of the new product before launching mass production.*

Q58. Has the company already faced relational problems/communication problems with a customer or a supplier or a partner? If yes, what is the cause?

R66 : *No*

Q59. What does the company do to manage the unexpected (i.e. management of change in the

short-term)? (E.g. withdrawal from a customer, supplier, partner)

R67 : *The company has many suppliers and many transporters in case of problem. Moreover, we predict a margin for the production and the export; in worst cases, we send the order by plane.*

Q60. Is there a procedure for the monitoring of the change (i.e. management of long-term change)?

R68 : *Yes, of course, we even have a service dedicated to forecasts' management.*

Q61. Is the preservation of knowledge and skills ensured? What happens if an employee leaves the company? Are all employees replaceable?

R69 : *At 100%! Indeed, the company operates on a "Vier Augen Prinzip" (in english : the four eyes principle) that works as follows : any information is known by at least two people. This holds for managers and executives. They are always replaceable and there is always a "reserve of human elements".*

Q62. In case of a new partner, what are the changes that are undertaken by the enterprise? Is the enterprise aware of these changes? Is it prepared for them?

R70 : *Yes, this has already happened many times. There are always some changes to undertake but it's manageable.*

Q63. Can we easily modify, add/delete a task/activity in a business process of the enterprise? If yes, who is responsible for that?

R71 : *I think so; at least I have already done it. The person responsible for the activity has to manage the change with the help of concerned persons.*

Q64. Is training for employees organized?

R72 : *Yes. There is always training for the employees. There is even a department that is dedicated to trainings and which elaborates yearly a training catalogue.*

Q65. Is there training dedicated to interoperability?

R73 : *I don't know if we can call them "interoperability training", we don't really use this term!!!*

I know that in addition to technical training there is management training (project management, risk management, etc) that allows attendants to learn how to deal with problems, what to do, how to behave and how to manage risk as well.

Q66. Is there anything you want to improve in the management system or in operational business? If yes, will this take many changes? Will this have an impact on business?

R74 : *There is a specific service for business improvement. Its function is to identify things to improve in the enterprise (i.e. concerning business, process, service, etc.) and plan what to do and when, whilst continuing to function.*

Résumé

Cette thèse entre dans le cadre de la problématique générale du développement de l'interopérabilité d'entreprise. De nombreux modèles, méthodes, méthodologies et outils existent pour aider une organisation, une entreprise, ou plus généralement un système, à développer son interopérabilité avec ses partenaires. Cependant, la plupart des approches existantes portent principalement sur les solutions informatiques. Des recherches fondamentales en amont permettant de caractériser et mesurer le potentiel d'une entreprise à interopérer sont encore largement insuffisantes. En conséquence, cette thèse vise à aborder les problématiques suivantes, considérées comme des priorités de recherche :

- L'absence d'une approche de mesure satisfaisante pour l'interopérabilité d'entreprise et la nécessité d'élaborer un ensemble de métriques (sous forme d'un modèle de maturité) qui permet de mesurer le potentiel d'une entreprise à interagir avec un partenaire futur. Les mesures proposées doivent permettre à une entreprise de gérer le développement de l'interopérabilité en fonction de ses besoins et de couvrir les différents aspects et dimensions de l'interopérabilité d'entreprise.

- L'absence d'une compréhension commune de l'interopérabilité d'entreprise et la nécessité de fonder le développement des mesures sur une base rigoureuse et non ambiguë. En particulier, une représentation globale et formelle du domaine de l'interopérabilité d'entreprise afin de couvrir les concepts de base déjà définis dans les travaux existants devra être élaborée.

- Le manque de fondement scientifique et théorique dans la recherche sur l'interopérabilité d'entreprise et la nécessité d'étudier et d'appliquer les concepts et les principes pertinents d'autres domaines scientifiques. L'objectif est de fonder l'élaboration du modèle de maturité sur des considérations scientifiques/théoriques déjà établies et de contribuer ainsi à développer une base scientifique pour l'interopérabilité d'entreprise, une initiative déjà proposée par la Commission Européenne.

La principale contribution de cette thèse est de définir un modèle de maturité pour mesurer le potentiel de l'interopérabilité d'entreprise.

De manière générale, la maturité de l'interopérabilité d'entreprise peut être mesurée de deux façons: *A priori*, où la mesure se rapporte au potentiel d'un système à être interopérable avec un partenaire éventuel dont l'identité n'est pas connue au moment de l'évaluation *; A posteriori* lorsque la mesure concerne la compatibilité entre deux (ou plusieurs) systèmes connus, ou la performance d'une relation d'interopérabilité existante entre deux systèmes.

Dans la littérature, plusieurs modèles de maturité ont été proposés. Nous pouvons citer par exemple: LISI (Levels of Information System Interoperability), NMI (NC3TA reference Model for Interoperability), OIM (Organizational Interoperability Model), LCIM (Levels of Conceptual Interoperability Model) et EIMM (Enterprise Interoperability Maturity Model).

Aucun des ces modèles de maturité n'est dédié à l'évaluation de l'interopérabilité d'entreprise *a priori*. De plus chaque modèle se focalise sur seulement une partie des problèmes de l'interopérabilité d'entreprise (i.e. technique, organisationnel, conceptuel, modélisation d'entreprise, etc.). Ainsi, pour une évaluation globale de l'interopérabilité d'une entreprise, plusieurs modèles de maturité doivent être utilisés (i.e. un modèle pour chaque partie concernée).

Le modèle de maturité proposé dans cette thèse se focalise sur la mesure *a priori*. Il couvre les différents aspects de l'interopérabilité, étudiés par les principaux modèles de maturité existants. Le modèle de maturité proposé doit se baser sur un ensemble de concepts et de définitions non ambigus. Il doit aussi être fondé sur une base théorique et scientifique. À cette fin, et avant d'élaborer le MMEI[21], les concepts de base de l'interopérabilité d'entreprise sont modélisés à l'aide d'une ontologie ; d'autres concepts pertinents émanant de théories scientifiques existantes sont aussi étudiés et intégrés dans celle-ci.

Plus précisément, cette thèse contribue également au développement d'une compréhension commune du domaine de l'interopérabilité d'entreprise. Sur la base de certaines approches existantes, telles que l'ontologie de l'interopérabilité (OoI) développée par INTEROP NoE, une ontologie de l'interopérabilité d'entreprise (OoEI) est proposée intégrant des concepts importants issus des modèles existants dans le domaine de l'interopérabilité d'entreprise.

La troisième contribution de la thèse porte sur le développement d'une base scientifique pour l'interopérabilité d'entreprise. En se basant sur l'étude des théories scientifiques proches, en particulier la Théorie générale des systèmes, les concepts et principes pertinents qui peuvent être

[21] MMEI pour Maturity Model for Enteroprise Interoperability en anglais

utilisés pour l'interopérabilité d'entreprise sont identifiés et intégrée à l'OoEI. Cette OoEI étendue (avec l'enrichissement des concepts de la théorie des systèmes) nous sert ensuite pour construire le modèle de maturité pour l'interopérabilité d'entreprise.

Ces travaux de recherche sont présentés dans cette thèse de la manière suivante :

- Le chapitre 1 décrit les contextes économiques et de la recherche qui ont conduit au développement de l'interopérabilité. Les définitions et concepts de base sont ainsi présentés. Ce chapitre décrit également les principaux problèmes d'interopérabilité auxquels une entreprise peut être confrontée. Suite à cela, les concepts relatifs aux approches d'évaluation de l'interopérabilité sont revus. Sur cette base, nous présentons les défis et priorités de recherche, ainsi que les objectifs de la thèse.

- Le chapitre 2 identifie des concepts pertinents pour l'interopérabilité d'entreprise à partir de modèles existants. Les entités opérationnelles où les interopérations peuvent avoir lieu au sein d'une entreprise sont tout d'abord étudiées. Une analyse de ces modèles ainsi que les concepts pertinents sont présentés. Par la suite, l'ontologie de l'interopérabilité de l'entreprise (OoEI) est proposée comme une extension de l'OoI (Ontologie de l'Interopérabilité), initialement élaboré par INTEROP NoE.

- Le chapitre 3 est consacré au fondement de l'interopérabilité d'entreprise dans une base scientifique. Tout d'abord, nous donnons un aperçu des théories scientifiques pertinentes à l'interopérabilité et discutons du choix de la «théorie des systèmes». Par la suite, nous étudions les concepts de base de la théorie générale du système et nous identifions les concepts systémiques pertinents pour le domaine de l'interopérabilité. Les concepts sélectionnés sont ensuite pris en compte dans l'OoEI.

- Le chapitre 4 est consacré à la définition du modèle de maturité pour l'interopérabilité d'entreprise (MMEI). Le modèle définit des métriques pour mesurer le potentiel des entreprises à interopérer avec des partenaires futurs. La définition des métriques du MMEI est basée sur les approches d'évaluation existantes. Une analyse des principaux modèles de maturité de l'interopérabilité est présentée et les concepts pertinents sont identifiés. La méthodologie d'évaluation associée montrant comment appliquer le MMEI est également élaborée. Cette méthodologie est basée sur la théorie des sous-ensembles flous et des variables linguistiques. Cette approche a pour but de faciliter la quantification à partir du langage naturel dans lequel les utilisateurs du MMEI expriment leurs évaluations. Les scores proposés par les évaluateurs sont par la suite agrégés à l'aide de l'opérateur d'agrégation OWA (Ordered Weighted Average). Ce dernier a l'avantage d'établir un compromis entre les évaluations proposées par plusieurs évaluateurs. A partir du résultat de l'agrégation, les règles floues préalablement définies sont appliquées afin de déterminer le niveau de maturité de l'interopérabilité de l'entreprise. Des bonnes pratiques sont, par la suite, proposées, pour donner à l'entreprise les directives à suivre pour améliorer son potentiel à interopérer et ainsi se préparer à ses interopérations futures.

- Enfin, le chapitre 5 présente l'application du modèle de maturité MMEI et de sa méthodologie à une entreprise multinationale: METS (Manufacture Electro-Technical of Sousse), qui est une filiale du groupe industriel allemand Draxelmaier spécialisée dans l'industrie automobile (systèmes électroniques, harnais de câblage, systèmes intérieurs et modules intégrés). Tout d'abord, l'OoEI a été utilisé pour décrire formellement les principaux éléments et les relations de l'entreprise. Par la suite, le processus d'évaluation et les résultats ont été détaillés à travers deux cas: i) une évaluation individuelle réalisée en grandeur réel dans l'entreprise et ii) un exemple d'évaluation avec trois évaluateurs dans le but de montrer la faisabilité de la méthodologie proposée. L'évaluation est réalisée à l'aide d'un questionnaire prédéfini (semi-structuré). Les bonnes pratiques sont ensuite proposées pour améliorer l'interopérabilité de cette entreprise avec comme objectif d'atteindre le niveau de maturité supérieur.

Le modèle de maturité proposé dans cette thèse permet à une entreprise de connaitre ses points forts et faibles sur son potentiel de l'interopérabilité. Les bonnes pratiques pour atteindre un niveau de maturité désiré sont évolutives en fonction de l'avancement de la recherche et de la technologie. Développer l'interopérabilité a un coût et nécessite des améliorations continues dans la durée. L'entreprise doit choisir un niveau de maturité approprié en fonction de sa stratégie et ses besoins afin de trouver un meilleur compromis entre l'investissement et le risque d'une non-interopérabilité avec ses futurs partenaires potentiels.

Résumé :

Ce travail entre dans le cadre de la problématique générale du développement de l'interopérabilité d'entreprise. De nombreux modèles, méthodes, méthodologies et outils existants pour aider une organisation, une entreprise, ou plus généralement un système, à développer l'interopérabilité avec ses partenaires. Cependant, la plupart des approches existantes portent principalement sur les solutions informatiques. Des recherches fondamentales en amont permettant de caractériser et mesurer le potentiel d'une entreprise à interopérer sont encore largement insuffisantes. Cette thèse s'intéresse en particulier à la définition des métriques pour évaluer le potentiel de l'interopérabilité d'une entreprise. En se focalisant spécifiquement sur la maturité d'interopérabilité, un modèle de maturité pour l'interopérabilité d'entreprise (MMEI) a été élaboré. Le MMEI est basé sur les modèles de maturité existants et couvre les principaux aspects et dimensions de l'interopérabilité d'entreprise. Les théories scientifiques existantes, notamment la théorie générale du système, considérée comme la plus pertinente pour l'interopérabilité, ont été étudiées et leurs concepts de base ont été pris en compte. Une ontologie, permettant de définir formellement le domaine de l'interopérabilité d'entreprise, a été également proposée. C'est sur cette ontologie que le MMEI a été construit et développé.

Mots clés : *Interopérabilité d'entreprise, potentiel d'interopérabilité, modèle de maturité, métrique, évaluation, ensembles flous, Bonnes pratiques.*

Abstract :

This work fits within the framework of the general problematic of the enterprise interoperability development. Many models, methods, methodologies and tools exist to help an organization, an enterprise, or more generally a system, to develop interoperability with its partners. However, most of existing works in this domain have been done to develop operational solutions to solve interoperability problems. Basic and fundamental researches, allowing characterizing and measuring the potential of an enterprise to interoperate, are still missing. In particular, this thesis deals with the definition of metrics for evaluating enterprise interoperability. By focusing specifically on interoperability maturity, a Maturity Model for Enterprise Interoperability (MMEI) is elaborated. The proposed MMEI is based on existing relevant maturity models and extends existing works to cover all main aspects and dimensions of enterprise interoperability. Possible contribution from existing scientific theories, in particular General System Theory considered as most relevant, are investigated and core concepts are brought into MMEI. An ontology of enterprise interoperability is also proposed to formalize basic concepts of enterprise interoperability. Based on this ontology, the MMEI has been, thereafter, developed.

Key words: *Enterprise interoperability, interoperability potential, maturity model, metric, assessment, fuzzy sets, best practices.*