Conceptual Interoperability Barriers Framework (CIBF)
A Case Study of Multi-organizational Software Development

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Abstract: This paper identifies conceptual barriers to enterprise interoperability and classifies them along interoperability levels of concern. The classification is based on the enterprise interoperability framework by Interop NoE and introduces the concepts of horizontal and vertical interoperability. From the initial classification a new conceptual interoperability barriers framework is proposed. The goal of the framework is to present generic conceptual barriers to interoperability and show where they are interrelated. The proposal has been validated in a case study of multi-organizational software development.

1 INTRODUCTION

In business it is common knowledge that enterprises no longer operate as single entities. Instead, supply chains and supply networks of enterprises endeavour to deliver the best possible value to their customers.

The current situation dominated by globalization forces competence between enterprises. As a result, supply chains and networks are now looking to enforce collaborative agreements, which would produce more efficient workflow, flexibility, effectiveness, agility and coordination between chain links (Vargas et al., 2013; 2014). Things become even more complex when chains need to be flexible to react to changing requirements to the products or services they deliver (Grefen and Dijkman, 2013).

Information Technology (IT) becoming an increasingly important determinant of an enterprise's competitiveness, compatibility between enterprise information systems is of utmost importance to ensure the competitiveness of supply chains and networks. According to ISO 15704, an enterprise is defined as "one or more organizations sharing a definite mission, goals and objectives to offer an output such as a product or a service" (ISO, 2000). A supply chain can then be perceived as a chain of enterprises, all with their own missions, goals and objectives, where each member adds value at a particular stage to offer a final output to the end customer. For enterprises, it is still a hard task to identify best practices and improvements to start implementing collaboration and interoperability practices inside different types of networked environments (Alonso et al., 2010).

A business collaboration network (BCN) enables companies to communicate and collaborate with their customers, partners and suppliers in a productive way (Sterling, 2010). This cooperation takes different forms, from simple information exchange, to business processes interoperability among independent enterprises (Sun, 2007; Shishkov, 2009).

Enterprise systems are, like the enterprises they belong to, heterogeneous systems which need to work together. The heterogeneity of enterprises is a key characteristic because it implies that their IT systems are also heterogeneous. Therefore there is a need for interoperability between enterprises and their IT systems.

The paper is structured as follows; section two presents the theoretical foundation of the proposal. Main concepts are defined in section three. Section four depicts a review of the literature used as a basis for this research. A more thorough description of the Enterprise Interoperability Framework by Interop is given first, then the interoperability frameworks developed in the 2000's are discussed, before concluding with the other relevant material encountered. Section five presents the analysis and classification of conceptual barriers along the four

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levels of concern. After that, a new framework is proposed and elaborated on section six, which is meant to identify generic conceptual barriers and depict interrelations. The validation of the proposal is included in section seven. The paper is concluded with conclusions and references.

2 THEORETICAL FOUNDATION

To explain the phenomena of non-interoperability that can be observed in various situations, the following hypotheses can be made (Ducq et al, 2012).

- Enterprise systems are not interoperable because there are barriers to interoperability that obstruct exchange of information and services.
- Barriers are different kinds of incompatibilities and can be found at different levels and sub-domains in an enterprise.
- Barriers can be specifically linked to a particular application in a specific domain; however there are generic barriers which are common to all situations of non-interoperability.

A better understanding of non-interoperability problems might lead to development of adequate solutions to solve these problems.

Philosopher Karl Popper (1902-1994) considered that a statement is only scientific if this is open to the logical possibility of being found false. This means that interoperability problems and solutions must be therefore tested in real systems and situations.

One of the requirements to develop a science base is to define an "instrument" to use for observing the phenomena of non-interoperability. However this is difficult because non interoperability problems are not always directly observable.

According to Guedria (2012) based on the relevant concepts from the General System Theory (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.

This paper contributes to define, conceptualize and structure the phenomena of conceptual non-interoperability. It provides a sound theoretical foundation for understanding of the nature and characteristics of the conceptual interoperability barriers.

3 CONCEPTUALIZATION

A variety of frameworks for enterprise interoperability have been developed in the 2000's. As part of a project meant to structure research on interoperability, the Enterprise Interoperability Framework by Interop developed using these earlier frameworks. In the Interop framework, enterprise interoperability is defined as "the ability to (1) communicate and exchange information; (2) use the information exchanged; (3) access the functionality of a third system" (Chen, 2005). This definition is not limited to different organisations, but can also refer to different enterprise systems within the same organization.

According to Vernadat (2010), it is important that interoperability is not confused with integration. When enterprise systems are integrated, they function in a coordinated and uniform way, in other words they become homogeneous systems. Interoperability does not require that, only that the otherwise autonomous systems be able to exchange and use each other's information and functions.

Enterprise Interoperability (EI) is a well-established area of applied research that addresses the problems related with the lack of systems and applications' interoperability in organisations and proposes novel solutions for EI problems (Jardim-Gonzalves et al., 2013). The framework presented by Chen (2005) identifies three categories of obstacles that inhibit interoperability, known as barriers to interoperability. They are the conceptual-, technical- and organisational barriers. "Barriers are 'incompatibilities' or 'mismatches' which obstruct the sharing and exchanging of information". "The barriers of a conceptual nature relate to the syntactic and semantic differences of information to be exchanged as well as the expressivity of the information" (Interop, 2006).

Conceptual interoperability aims to ensure that information exchanged shares the same meaning and syntax to enable systems to process information exchanged. This requires definition of a common semantic on the basis of structured language (Boza et al., 2014). Also relevant are the four levels or concerns of interoperability defined in the framework. They are Data, Processes, Services and Business concerns.

For enterprise systems to be interoperable, the barriers to interoperability must first be identified and removed.

However, no comprehensive list of any type of barriers is available for enterprises to consult when designing new- or connecting existing enterprise

systems. Therefore, taking conceptual barriers as the point of interest, the objective of this research is to identify conceptual barriers to enterprise interoperability and classify them along the four levels of concern developed in the enterprise interoperability framework as developed by (Chen et al., 2005) and to develop the basis of conceptual barriers that enables users to identify generic conceptual barriers and their interrelations and apply them to any particular situation.

4 LITERATURE REVIEW

In order to identify conceptual barriers it was necessary to conduct a literature survey of existing works on interoperability. Using scientific search engines like Scopus, ScienceDirect, Springerlink, relevant articles were queried for. The main search keys used were "enterprise interoperability", "interoperability barriers", "conceptual barriers", "measures interoperability barriers", "case study interoperability barriers" and "criteria for interoperability".

Research into interoperability requirements and formalization of measures for interoperability added new insights into conceptual barriers, as these could be translated back to the barriers they were initially meant to overcome.

The first section of this literature review explores the enterprise interoperability framework that is the basis for this paper in more detail.

The second section deals with the other interoperability frameworks developed in the past decade and a half. Unless stated otherwise, that part of the review is based on the literature review on interoperability frameworks performed by (Chen. 2005) and (Jardim-Gonzalves, 2013).

To conclude, previous work by various authors focused on interoperability barriers is presented.

4.1 Enterprise Interoperability Framework by INTEROP NoE

The EIF by Interop was first presented to structure research on enterprise interoperability (Interop, 2006). Until then, research efforts on interoperability were mostly uncoordinated because there was no common understanding of the domain.

The framework presents three main dimensions along which interoperability issues can be classified.

Interoperability barriers: Conceptual barriers occur when there is no common understanding of concepts. These different understandings can pertain to a number of causes according to this framework. Syntax: the structures used by people to represent information, known as the syntax, may not coincide. An example is the chosen modelling language to represent business processes. Semantics: this second difference pertains to the meaning assigned to words. A customer order may be defined simply as 'order' in one enterprise, and as 'customer order' or 'product order' in another. Misunderstanding may arise. Expressivity: concerns the ability to communicate information in a pragmatic way that is easy to understand. An example is that information can be shown graphically for easier understanding, but is only offered in text. The lack of expressivity thus causes conceptual misunderstanding. The barriers of technological nature are concerned with the use of ICT i.e. problems relating to the incompatibility of IT architecture & platforms, infrastructure (Interop, 2006). A lack of compatible technologies for systems to interact is a technological barrier. Organisational barriers relate to the definition of responsibility and authority within an enterprise, i.e. the human and organizational behaviour.

Interoperability concerns: Since one of the objectives is to classify conceptual barriers along the interoperability concerns, some further clarification as to what they entail is appropriate. Business: the concern of working in a harmonised way at the highest level of the organisation. Issues like corporate culture, business mission, vision and objectives and commercial strategies are important at this level. Processes: how they are defined and connected to other processes. A process is the set of activities that transforms an input into a desirable output. Services: concerns the identification, composition and operating of applications that make an enterprise or network function. This concern is not limited to computer applications and also includes services performed in general within in an enterprise. Data: the lowest level of abstraction simply involves organising and use of data by various services to perform their functions. The database structure used is an example.

The third dimension in the framework is related to interoperability approaches, or ways in which barriers can be removed.

4.2 Other Interoperability Frameworks and Barriers

Over the years there have been different interoperability frameworks, we can find between other:

Levels of Information Systems Interoperability (LISI): The first effort towards an interoperability framework was LISI, developed by the U.S. C4ISR Architecture Working Group (AWG) in 1997 (C4ISR, 1998). It is actually a maturity model that prescribes which capabilities a set of systems must possess to be interoperable, on four different levels known as PAID (Procedures, Applications, Infrastructure and Data). It focuses however, largely on technological capabilities of the systems needing to interact. Conceptual barriers were therefore not included in LISI.

IDEAS Interoperability Framework: The first European effort was the IDEAS interoperability framework which also harnessed the idea that interoperability is achieved in multiple layers. The content of these layers formed the basis for the interoperability concerns defined in the Interop Enterprise Interoperability Framework (Chen, 2005; Interop, 2006).

ATHENA Interoperability Framework (AIF): The AIF in was considered complementary to the IDEAS framework, as it provides relevant research elements and solutions to interoperability issues, instead of stopping at defining these issues. It is structured into three parts (Athena, 2010).

e-Health Interoperability Framework: The E-health interoperability framework distinguishes between areas in which enterprises can be interoperable (Nehta, 2005). It defines three levels of interoperability across health organizations: Organizational layer which provide a shared policy and process framework across the E-Health interoperability agenda covering each NEHTA initiative. Information layer which provide shared building blocks for semantic (information) interchange. Technical layer is concerned with the connectivity of systems for information exchange and service use.

European Interoperability Framework (EIF): This framework proposes yet another categorization of interoperability areas. Within these areas, policies, standards and guidelines are presented to which enterprises should adhere to achieve interoperability. Outside of the EIF, the author also identifies five further possible barriers to enterprise systems interoperability. They are in no particular order: Trust, Security, Confidentiality, Legal and Linguistic issues. In a collaborative effort, (Yahia et al., 2012) formalised semantic relationships between enterprise systems. (Lezoche et al., 2012) propose a conceptualisation approach for semantics discovery and management in enterprise information systems models, based on applying fact-oriented transformation rules. An interesting distinction not made by other authors, is that between horizontal and vertical interoperability as noted by (Panetto, 2007). When interoperability between two elements at the same level of abstraction is being considered, one talks of horizontal interoperability.

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.

Morris et al., (2004) developed the SOSI model, which addresses technical interoperability, operational interoperability and programmatic concerns between organizations building and maintaining interoperable systems.

The semiotic interoperability framework is a new concept that defines a set of interoperability levels, and provides a sound foundation by explaining how signs can be successfully communicated in different levels (Li et al., 2013)

5 ANALISYS

In the forthcoming analysis, all barriers identified in the literature review will first be classified along the four interoperability concerns. The end result of this classification can be found in Table 1 at the end of Section 5.1. Then, a new framework for the conceptual barriers is proposed. This new framework contains generic conceptual barriers and the relationships between them and is shown in Figure 1 in Section 6.

5.1 Classification by Concern of Conceptual Barriers to Interoperability

Business: At the business level of abstraction, the researchers in the Interop project marked the enterprise's mission, vision, objectives and strategies as potential conceptual barriers. These conceptual elements are defined at high level and are thus applicable to the business concern. Now let us check if they are barriers. Using Chen's definition of enterprise interoperability, the first requirement of accessing information will not necessarily be inhibited if mission, vision and/or objectives are different. However, the use of this information and

the use of functionalities may be quite pointless because the information is created with the aforementioned mission, vision and objectives in mind. As a result, these can definitely be barriers. Also consider two enterprise strategies that are not aligned, one being a low cost strategy and the other a differentiation strategy through high product quality. The enterprises may not be able to use each other's functionalities because one may not require a particular functionality at the lowest cost, but one of the highest quality. Corporate culture is also recognised as a conceptual barrier by both Interop and the IDEAS framework. Cultures greatly influence how business is conducted, and thus also how enterprises are able to interoperate on the business level. One only needs to imagine the differences in the way European firms and Chinese firms operate to see that culture is a valid potential barrier. The IDEAS framework also deems the relationships between the enterprise and the market to be important concepts. They need to be viewed similarly for enterprises to offer value together to their market. One can extend this aspect to the relationships with all stakeholders. It then becomes obvious that enterprise's stakeholders need to be clearly defined for the relationships to be clear as well.

Process: A process is defined as "sequence of interdependent and linked activities which consume one or more resources to convert inputs into outputs. The definition of the involved activities, resources, inputs, outputs and end results have to be compatible for processes to be interoperable. To group the above, the meaning assigned to words describing the concepts, i.e. the semantics, must all be the same. The ATHENA framework proposes Enterprise Architectures: models, meta-models, languages etc. as quintessential solutions for the conceptual integration of processes and lower levels of abstraction. These solutions all pertain to the syntax, which is the structure used to represent concepts captured in the semantics. The modelling language to design business processes comes to mind as an example. Related to that, is the way that business processes are connected to form a value chain/network. Uniformity in this is also inhibited by different models, or syntaxes. One organization using IDEF0 to represent its processes, and the other using process flow charts is an example of different syntaxes.

Service: Similarly to what has been identified at process level, the names, descriptions and purposes of services must be similarly defined in terms of semantics and syntaxes. The IDEAS framework adds to that the procedures, norms, rules and references that either compose or support the services. These too can be easily misunderstood, so extra care needs to be taken regarding semantics, syntax but also expressivity. How does one get the correct meaning across to the other party, so both have the same ideas about what the services should do and how do they should be doing it. Each service has an associated declarative policy that specifies quality of service, availability, and other attributes necessary to meet the overall business process goal (Cuenca et al., 2014).

Data: Up to now, most research effort on conceptual barriers has gone into interoperability at data level, because it is the least abstract. Regarding semantics, the terms used need to have exact similar meanings. Any difference at all is what (Yahia et al., 2012) referred to as a semantic gap. Two terms can have no common meaning, i.e. they are 'disjoint'. When two terms have a partially common meaning, and a unique part of meaning then the terms 'intersect'. 'Include' occurs when one term completely encompasses another, with former still possessing additional meaning that is unique. Finally, two equal terms is the preferred state, where no semantic gap is present. Note that a semantic gap can occur at any level of concern. The syntactic barriers then pertain to the way data is structured. This can mean the use of different modelling languages to model the data structure, but also the choices made within the language are important. Data on a given product with a certain weight is stored in a database. The weight is measured in a unit. Assume that the semantics are the same. The data is modelled using simple UML classes, so the modelling language is the same. However, on the left, weight and the unit of measurement are represented as attributes, whilst on the right the weight is represented as a related class. The database structure is not the same so interoperability problems may arise when trying to exchange data. Last but not least, care must be taken concerning the validity of data. Data may be specific to locations and therefore not valid in other systems. An example is productivity rates for machines. In one factory, this can be higher than in another. If the location restriction is not clear, then data that is invalid in another environment might be used elsewhere anyway, leading to incorrect results. This is known as the data restriction rule and was identified in the EIF by Interop.

Miscellaneous: Of the five other potential barriers to interoperability, trust, security and confidentiality do not qualify as conceptual barriers. They are choices to be made by organisations, but more in an

organisational context. The legal environment influences how organisations interoperate, including the conceptual part. E.g., if legislation requires foreign enterprises to offer information in a certain language that is not the enterprise's, the definition of concepts, i.e. the semantics, is influenced by legal constraints. This legal environment is actually an example of a relationship with a stakeholder, the government in this case. To conclude, linguistics in general is clearly a potential conceptual barrier. The legislation example already showed that. Because the choice for linguistics is made for the entire entity or organisation, it is positioned at the business level.

Table 1: Conceptual barriers to interoperability classified along the interoperability concerns.

Concerns	Conceptual barriers to interoperability	Reference
Business	Mission, vision Business objectives, Business strategy Linguistics, Corporate culture Relationships with stakeholders (customers, suppliers, government, etc.)	Vernadat, 2010 Interop, 2006 Chen et al., 2008 Ullberg et al., 2009
Process	Process definition (semantics): -procedures, resources, inputs, outputs Process representation (syntax): -which enterprise architecture employed -connections between business processes	Chen, 2010 Vernadat, 2010 Interop, 2006 Athena, 2010 Chen et al., 2008 Ullberg et al., 2009
Service	Service definition (semantics): -name, description, purpose -procedures, norms, rules, references Service representation (syntax)	Interop, 2006 Chen et al., 2008 Ullberg et al., 2009
Data	Semantics (disjoint, intersect, include, equal) Data characteristics (definition and structuring) Data description rule	Yahia, 2012 Ullberg et al., 2009

6 CONCEPTUAL INTEROPERABILITY BARRIERS FRAMEWORK (CIBF)

This new framework for the conceptual barriers to interoperability is meant to identify generic conceptual barriers and also show relationships between them. The Interop classification of barriers along the interoperability levels of concern is employed, which are the business, process, service and data levels. At process, service and data level, the barriers are further divided into two categories, those being semantics and syntax. This division is not employed at the business level, because it cannot be applied to all barriers.

The conceptual interoperability barriers framework (CIBF) is shown in Figure 1. Within an organisational entity, processes are designed to carry out an enterprise's business. The services in turn support the processes and the data is used by the services. For two entities e.g., interoperability at data level is thus required first, before interoperability at service level can be realised. The same applies across all levels with interoperability at business level being the highest form of interoperability. For this reason, the framework is designed as a house structure. The business level is placed in the roof to show it encompasses the lower levels. The process, service and data levels are placed in three stories beneath the roof of business, to show they act as the foundations upon which interoperability at higher levels is built. The barriers at business level are divided into two parts. The top part contains the mission, vision and corporate culture. These are very abstract barriers which do not directly influence lower levels. Business objectives, strategies, definition of stakeholders and relationships, and the linguistics are conceptual barriers at the business level that do influence lower levels more directly. The objectives and strategies e.g. clearly influence the way processes are designed. Therefore, they are positioned closer to the lower levels.

The conceptual barriers concerning processes, services and data basically consist of concepts definitions and their structuring. Therefore they are divided into a semantics section and a syntax section. Examples of definitions and structures are given in the framework at the corresponding levels. Location validity of data is one conceptual barrier that needs some explanation. Recall that data can be specific to locations and therefore not valid in other systems. Because this location validity is part of a complete data definition, it is placed in the semantics column.

Horizontal and Vertical Interoperability. Two organisational entities are depicted in the framework, each containing the identified conceptual barriers. The horizontal arrows between them show that conceptual barriers must be overcome at different levels for two entities to achieve enterprise interoperability. The predominant view among researchers is that the barriers impede

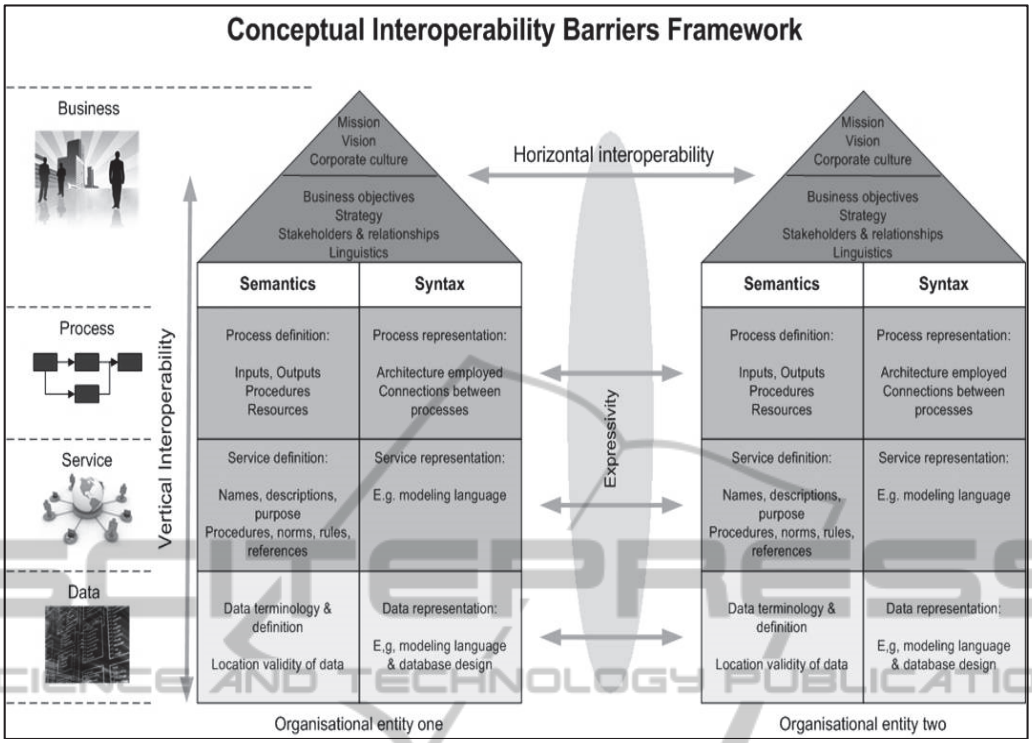

Figure 1: Conceptual interoperability barriers framework (CIBF) (Adapted from Hegeman and Cuenca (2013).)

this horizontal interoperability between two entities. An additional conceptual barrier is what the Interop project identified as expressivity. The way the semantics and the syntax are communicated greatly influence if the interoperability barriers can be removed. It is therefore placed in between the two organisational entities. Now, borrowing from Panetto's definition of vertical interoperability, the definitions and structures used at the business, process, service and data levels inside an entity must also be interoperable with each other. That is to say, within the organisational entity, definitions at business level must be interoperable with definitions at process level, these with definitions at service level and so on until the data level. This might be stating the obvious, but focusing on removing barriers to horizontal interoperability could cause vertical interoperability issues inside an organisational entity. Mission, vision and culture are not essential for vertical interoperability, therefore the vertical interoperability arrow stops at business objectives.

The introduction of vertical interoperability offers an invaluable view of the relationships between barriers at different levels of concern. The definitions of concepts and structures used to represent them are interdependent. A definition at any level automatically requires the other definitions of the same concept at other levels to be similar. If that is not the case, vertical interoperability issues occur. The same applies to structures to avoid misconceptions of important concepts.

7 APPLICATION TO THE PROCESS OF MULTI-ORGANIZATIONAL SOFTWARE DEVELOPMENT

7.1 Conceptual Semantic Barriers

The process of multi-organizational sofware development is a clear example where we can identify the interoperability barries at several levels. The different stakeholders work at different and distributed sites, with different specialities and background (Mohtashamia et al., 2006). This matter results in complex barriers to be avoided or removed.

We can classify the problems identified in multi-organizational software development through the proposed CIBF in section 6 as follow:

Table 2: Generic conceptual barriers to interoperability in the process of multi-organizational software development.

Conceptual Semantic Barriers
Business level:
Diverse organizational cultures
Multiples sets of business practices
Differing organizational goals
Nationalities and Languages
Lack of mediation and resolution
Different Rewards and compensation programs
Process level:
Expectation of behaviour
Multiple management models
Higher degree of uncertainty
Lower level of trust
One set of resources per partner plus shared resources
Multiply risk management plan
Some variation in professional standards
Independent plans
Biased risk identification
Service level:
Duplicate services
Deficiencies of partner's practices
Failure to establish or use compatible services
Failure to establish proper boundaries between components
Lack in version control
Data level:
Data sharing
Shared data security
Third-party information

Legal, political and intellectual data properties are included in miscellaneous level. Once we have identified the generic barriers, we will investigate their appearance in practice on the basis of a descriptive case study.

7.2 Case Study

The generic barriers have been investigated in a business network of DEKRA Certification B.V. The Netherlands.

7.2.1 The Business Situation

The business network (set of collaborating organizations) is an educational value network, in which different types of organizations are collaborating in the development of exam (assessment) materials (i.e. examinations). The customers are the employees of large organizations in the energy (30.000 persons), the finance (150.000 persons) and the real estate domain (8000 persons). All these employees have to do trainings and examinations, on a one to three yearly basis, to stay certified for doing their work (with respect to financial safety, energy safety, and real estate valuation safety). The collaborating organizations in the network are:

- DEKRA Certification (the certification body: quality assurance tasks in training, examination, certification),
- The Exam Consultancy Office (ECO) (the central party in the network): development and maintenance of examination systems, both custom made examination systems and examination databases, and making these systems available for Examination Institutes.
- Examination Institutes: where customers can do their exams (20-30 all over the country).
- Software providers (A) of examination databases.
- Software providers (B) of custom made examination systems.
- Customer organizations (such as Bank companies (e.g. ABN AMRO), and energy suppliers (such as Enexis, Alliander, etc.)

7.2.2 The Methodology

The goal was to identify how the set of barriers could be recognized in a business situation, and to what extent their importance and relevance could be discussed with representative practitioners. The methodology to conduct the case study consisted of three interviews with three experts (CIO level) of three distinct companies in the network. The semi-structured interviews consisted of a limited number of open questions (15-20). Subjects of the questions were respectively the collaboration and interaction between companies (e.g. data sharing) in the network, the joint development process on the business level and the operational level, the boundaries between the network components and their implications regarding service orientation.

7.2.3 The Results, i.e. the Identification and Discussion of the Generic Barriers in a Real-life Situation

Regarding the multi-organizational software development that takes place in the network, the following collaborations could be distinguished::

1: The Exam Consultancy Office (ECO) and the software providers (B) are involved in on-going continuous development of the custom-made examination systems (e.g. adding functionality, improving performance etc.). The process consists of: joint requirements engineering, iterative agile development and testing, deployment, etc.)

2: Regarding requirements specification ECO receives input from the various Examination institutes (and input from their own employees working with the systems).

3: ECO and software providers (B) both have to collaborate (periodically) with software providers (A) regarding the interfaces between the examination systems and the examination databases.

4: DEKRA has to assess the examination systems and databases regarding correctness, security, etc.

Regarding the generic conceptual barriers to interoperability in the process of multi-organizational software development (identified in table 2 the following instantiations could be identified in the business network (n.b.: text in italic refers to Table 2).

On the Business Level: ECO and software providers (B) have quite different *organizational cultures* (e.g. software technology vs examination business) and *organizational goals* (e.g. customer satisfaction vs efficiency (cost/benefit)), etc. Currently ECO is trying to set up an internal business function 'IT-application management' to improve the collaboration with the software providers, and to be able to fulfill the requirements of DEKRA.

On the Process Level: ECO is unsure about the *level of trust* regarding the collaboration with software providers (e.g. they speak different languages and have different business goals).

They need a consistent and transparent *multiple risk management plan* (regarding the comparison and the balancing of the risks of the involved software providers and their own risks).

On the Service Level: Regarding the barrier '*proper boundaries between components*': ECO's custom made examination systems are in different business domains in different ways connected to the internal/external examination database systems. E.g. in the finance domain their custom made system is connected to external examination databases (which means: NO collaboration with the provider), in the energy domain their custom-made system is connected to an internal examination database (managed by themselves in intensive collaboration with a provider).

Further: a software provider (B) is hosting the custom-made examination system of ECO. But there are currently no SLAs, e.g. regarding availability and performance of these systems. So, ECO is being held responsible in case an examination system goes down (*'Deficiencies of partner's practices'*).

On the Data Level: Regarding the barrier '*Data sharing'*: examination candidates, e.g. from Bank firms in the Finance domain, have to fill in their personal data (incl. identity number) in case they are going to do an assessment (exam). These data are then becoming available to respectively: the examination institutes, ECO, the software providers and DEKRA. Currently a sound *data security* program (rules, restrictions) is being redeveloped regarding the storage and the management of these data.

Although the case study was descriptive and qualitative the application of the proposed CIBF (Conceptual Interoperability Barriers Framework) has resulted in the identification of the organizational entities involved in the multi-organizational software development process and the conceptual interoperability barriers at the different levels (business, process, service and data).

The conceptual barriers could be identified explicitly during the interviews, and consensus could be reached on their importance and/or relevance. As such the results offer a sound basis for more in-depth, and preferably quantitative, case study research for a further operationalization of the CIBF framework.

8 CONCLUSIONS

The paper has characterized and identified a wide selection of conceptual interoperability barriers, taking them from relevant scientific articles on enterprise interoperability. The most cited interoperability frameworks; LISI, IDEAS, ATHENA, E-health and the European interoperability framework provided the most conceptual barriers. Further work on developing barriers and developing formal measures for interoperability completed the set of conceptual barriers.

Coinciding barriers were grouped and eventually classified by interoperability concern as defined in the Enterprise Interoperability Framework by Interop. The main barriers were the following. Business level: Mission, vision, business objectives, business strategy, linguistics, corporate culture and relationships with stakeholders. Process level: Process definition (semantics), process representation (syntax) and connections between business processes. Service level: Service definitions (semantics) and service representations (syntax). Data level: Data terminology definitions

(semantics), data structuring (syntax) and the data restriction rule.

With the four levels of concern as a basis, a new conceptual barriers framework was developed. It included the general conceptual barriers to enterprise interoperability, and introduced the concepts of horizontal and vertical interoperability. Concepts at the same level of abstraction in two organisational entities need to be similar in semantics and syntax if they are not to be barriers. This is the horizontal direction. Apart from that, concepts also need to be interoperable along a vertical dimension because they are interrelated by default. Data is used by Services to support processes that carry out the business of an enterprise, so different semantics and/or syntax would cause interoperability problems within the organisational entity. The last element added was the expressivity, i.e. how information is communicated for understanding.

The proposal has been validated in a case study of multi-organizational software development at the business network of DEKRA Certification. Identification is a required step towards removing these barriers. We need to identify the problem with the aim of being able to tackle it

Future research lines can be to analyze how the interoperability levels of concern identified in the framework relate to maturity levels of interoperability, identify whether horizontal and vertical interoperability barriers are interrelated and thus affect each other.

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