The Business Interoperability Decomposition Framework to analyse buyer-supplier dyads

Abstract
The current competitive environment demands cooperative arrangements like buyer-supplier dyads to struggle for the success of supply chains. Managing inter-firm relationships is a decisive and highly demanding activity, whereas business interoperability (BI) is key to achieve meaningful interactions to create value. Nonetheless, cooperation issues due to lack of interoperability constrain the success buyer-supplier dyads. Problems ranging from technical to strategical perspectives of BI may lead to problems like lack of coordination which decrease the supply chain surplus. Interoperability literature provides several contributions and frameworks to deal with different interoperability issues. Nonetheless, it is missing a cohesive framework allowing one to address inter-firm relationships in the full scope of BI. The present paper proposes a framework to support the analysis of interoperability conditions in buyer-supplier dyads. A case study was conducted to demonstrate the framework, and what decisions are required to improve or scale-up cooperation.

Keywords: Business interoperability, supply chain management, supply chain collaboration, buyer-supplier dyads, inter-firm relationships

1. Introduction

Managing inter-firm relationships remains one of the key challenges to achieve a successful supply chain (SC). Through supply chain management (SCM), distinct firms plan and coordinate processes, share resources, information and knowledge, and use technology to work as a singular business entity [1]. Though, to cope with uncertainty and increasing competition, firms went further and started working collectively in cooperation arrangements, which come from a direct peer-to-peer collaboration (dyad) to all the SC Network. Buyer-supplier dyads are distinguished among those kinds of cooperation as the most elementary form of interaction to achieve effective management upstream SC [2]. This relationship is emphasized under the concept of collaborative advantage, whereas the dyad struggles for win-win relationships with mutual benefits achieving competitive synergy [3]. Nevertheless, to cooperate effectively one has to deal with the time-consuming task of managing inter-firm relationships. Business Interoperability (BI) is the key condition to support inter-firm relationships to fulfil their objectives and to create value [4,5]. According to Huhns, Stephens, & Ivezic (2002) BI is considered as an enabler that makes possible to execute the SC operations seamlessly, easing their alignment and the information flow, guaranteeing high performance and competitiveness.

The ability of a business to be interoperable means that it is capable to cooperate with business partners and to efficiently set up, conduct and develop digital businesses with the objective to create value [7]. BI covers all the inter-firm issues from technical to organization perspectives of interaction [8]. Like so, faulty inter-firm management is reflected differently in each of its perspectives. For instance, at strategic level, problems are reflected in misaligned objectives and conflicts; at operational level, those problems may result in process incoordination; and, in IT perspective, miscommunications or incompatibility may occur in data exchange. In SCs, the impact of lack of interoperability is pronounced. Problems in business partnering and in IT that supports such relationships may result in incoordination of processes, inefficiencies, redundant operations that subtract the value-added for the final customer. Interoperability problems may propagate to all SC and can result in phenomena as the unpredictable demand that may lead to the Bullwhip effect. Extant literature on interoperability and BI mostly provide frameworks and models to help in problem identification and quantification. Nonetheless, despite the emerging accomplishments in interoperability, there is even now the need for a unified framework that addresses the ample scope of BI in an integrated manner that allows detailing interoperability in business relationships, such in the case of buyer-supplier dyads. Accordingly, the objective of this research is to propose a framework to describe the interoperability perspectives under the scope of BI. Therefore, a research question is proposed: “How may buyer-supplier dyad be decomposed to reflect the business interoperability requirements and problems?” (RQ). To accomplish the research question, we initially investigated the theoretical background of Business interoperability, were we reviewed the existing definitions that led to the present notion of Business Interoperability (BI), the existing interoperability frameworks and other relevant research articles on the subject, to identify the key issues that allow to systematically address interoperation in dyads. Based on literature findings, we propose a framework to describe the interoperability perspectives beneath the concept of BI. Next, our research focused on addressing interactions in buyer-supplier dyads. We aimed at reviewing SCM, and supply chain collaboration to identify SCM constructs that rule buyer and supplier interaction and proposed a framework adapted to the buyer-supplier key subjects. In order to validate the applicability of the proposed framework in the buyer-supplier context, a case study was conducted in two North American companies operating in Portugal belonging to an automotive supply chain.

The article is structured in the following sections: in section 2, we review literature in interoperability definitions, interoperability frameworks, buyer-supplier dyads; in section 3 we propose a framework to help in systemizing the detail of interoperability issues; in section 4, a case study is presented whereas the proposed framework was tested; last, in section 5 the conclusions of this research are presented.

2. Literature review:

2.1 Business Interoperability definition

BI is a concept rooted in information technology (IT), derived from the initial concept of interoperability. Interoperability was first reported in 1965, when the United States Department of Defense (DoD) detected a "communication fiasco", regarding the incompatibility between the air force and army radios [9]. However, only 25 years far ahead of the concept was defined by IEEE (1990) as "the ability of two or more systems or components to exchange information and to utilize the information that has been exchanged."

Since the inception of interoperability, the relevance of this subject has grown. As it is reinforced by [8,11], interoperability it has been studied in diverse perspectives by numerous researchers and practitioners. From the IEEE (1990) initial definition, other ones were made reflecting the complexity of interoperability in areas which use IT to perform their activities. The first closest definition to the actual concept of BI was established by [12], which defined it 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 so exchanged to enable them to operate effectively together." Although this definition was stated on a military perspective, it became relevant because it was the first that incorporates the already considered technical perspective ("systems") and introduced the organizational ("forces") and human ("units") perspectives of interoperability.

The integration of the organizational perspective in interoperability research remains a cornerstone for this field. The presence of IT in every business context triggered more advanced types of cooperation that require alignment. Interoperability requires a more proper understanding of business context issues [13]. The organizational and knowledge became a trend for researchers that approached interoperability beyond the technical perspective. In the works Organizational Interoperability Maturity Model (OIM) [14], IDEAS interoperability framework [15], enterprise interoperability maturity model [16], Business Interoperability Framework [17] and INTEROP framework [18], the non-technical interoperability aspects constitute the basis for achievements that contributed to the vision of business interoperability (BI), in its current perspective. Hence, the definition of BI that we advocate in this research is the one introduced by Legner & Wende (2006), which defined it as "the organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business with the objective to create value." This top-down vision emphasizes the business perspective of interoperability, maintaining in consideration the IT infrastructure and subsequent aspects that allow electronic business to be performed.

2.2 Interoperability frameworks and related work

Interoperability frameworks provide the primary drivers for companies' interaction and diverse perspectives on the subject. According to Vernadat (2010), they are useful instruments to position and relate to one another and to compare concepts, principles, methods, standards, models and tools in a certain domain of concern. In this research, we address the interoperability frameworks and models that are relevant for the BI definition, and that address the primary functions of business relationships: the direct impacts of companies on one another (dyads) [20]. The secondary function, known as network effect, was not considered, since they go beyond the relationship between peers (e.g. [11,21]). To contextualize the interoperability frameworks, they are presented in an evolutionary context, reflecting the key features and contributions, and where an alternative framework complemented the prior vision, but also, when a novel approach was provided.

2.2.1 *Levels of Information Systems Interoperability*

The Levels of Information Systems Interoperability (LISI) was proposed by [12] "as a guide to develop and improve a system's general capability to interoperate with other systems without predefined or formal sets of requirements necessarily established between them." LISI combines maturity levels with the attributes of the system. Each level recommends the capabilities that should cover the enabling attributes known as PAID [18]: procedures (P); application (A); infrastructure (I); and data (D). The LISI "Maturity model" also traduces the increasing levels of sophistication of systems [22]. LISI ultimately deals with the time-consuming task of dealing with interoperability complexity, by putting in scale the maturity of the system and the scenario on which the first one was valid. The procedure defines, measures, assesses and certifies the degree of interoperability required or achieved by and between organizations or systems [8]. The assessment process using metrics (generic, expected and special) allows mapping the system evolution between the existing and the ideal scenario, which may be the optimal interoperability or the sufficient degree of interoperability for the system. The result is summed up in an interoperability profile that characterizes the level of interoperability and allows determining the interoperability setting of a system towards another.

2.2.2 *Organizational Interoperability Maturity Model*

While LISI approaches the technical aspect of interoperability, the Organizational Interoperability Maturity Model (OIM) [14] addresses the human and organizational aspects of interoperability, by proposing five levels of organizational maturity. Also, similar to the LISI's PAID attributes, OIM provides four attributes of organizational interoperability [9]: preparedness; understanding; command and coordination, and ethos. LISI combined with OIM, provide a high-level vision of interoperability problems regarding organizational, knowledge and technical interoperability perspectives. Being built on the same perspective as LISI, correlating two distinct factors, OIM allows one to assess qualitatively interoperability and may contribute to trace interoperability profiles of dyads.

2.2.3 *Interoperability Assessment Methodology*

Leite (1998) introduced the interoperability assessment methodology (IAM) that provided a methodology to assess qualitatively and quantitatively interoperability in systems. IAM proposes seven qualitative measures as "degrees of interconnection", which are connectivity, availability, interpretation, understanding, utility, execution, and feedback [9]. These measures are presented as levels, which intend to achieve interoperability as a progression of steps in a ladder [23]. IAM has the novelty of proposing actual tangible metrics that permit to infer about the systems interoperability: node connectivity, capacity, overload, underutilization, undercapacity, and data latency. Also, the proposed qualitative attributes and checklists provide requirements for systems. Though, like in case of LISI, this portrays only a technical part in interoperability, while contributing to earliest performance measures for interoperability.

2.2.4 *Layers of Coalition Interoperability*

The Layers of coalition interoperability (LCI) [24], introduced a low level (high detail) framework when compared with LISI and OIM. Nine layers of interoperability are proposed by LCI, and shows through his reference model that there is a continuum between technical interoperability and operational interoperability rather than a distinct breakpoint between the two [9]. Four levels reflect a more detailed vision of the technical aspects of interoperability - physical, protocol, data/object model and information interoperability. Another four levels reflect the organizational interoperability aspects - political objectives, harmonized strategy/doctrines, aligned operations and aligned procedures -, related with strategy and process interoperability. At the centre of the model, the knowledge/awareness level provides a transition between technical interoperability and organizational interoperability [22].
Though this model was presented in its most initial stages of development, like was stated by Morris et al. (2004), it offered valuable insights to facilitate discussion on technical and organizational (political and military) support required for interoperable solutions.

2.2.5 *IDEAS interoperability framework*

The IDEAS interoperability framework [15] extended the concepts of interoperability to the business perspective, proposing three main layers - Business, Knowledge and ICT - with two transversal dimensions - Semantics and Quality attributes [25]. On a business-centred perspective, IDEAS defends that interoperability should be seen as the organizational and operation ability of enterprises to cooperate with other enterprises [18]. The business perspective is supported by knowledge, which can be internal or external, and by ICT systems, like earlier visions of technical interoperability. Though one could look at each layer as a particular perspective of interoperability, there are continuously areas that will depend, reciprocally, on each other.

2.2.6 European Interoperability Framework

The European interoperability framework (EIF) [26] considers three aspects of interoperability: technical, semantic and organization interoperability [27]. The three considered aspects are like earlier frameworks. Notwithstanding, EIF provides decomposition in these three factors addressing the critical problems presented on public administration, through an exposition of the general services and their underlying business processes, specification and publication of information elements and dictionaries, and open standards for technical interoperability of both front- and back-office services [28]. Accessibility, security, privacy and multilingualism, remain some of the relevant contributions of this framework. Technical aspects (accessibility, security and privacy) include the prime requirements for access of users to systems guaranteeing security and privacy. Cultural aspects are ensured considering the notion that EU represents a fusion of numerous countries, where the individuality must be respected. The underlying information architectures should be linguistically neutral so that multilingualism is not a blocking issue for the delivery of e-Government services [26].

2.2.7 Enterprise Interoperability Maturity Model

The Enterprise Interoperability Maturity Model (EIMM), developed by [16], is a method to scale-up interoperability using an enterprise modelling approach. The novelty of this maturity model represents the three-dimensional model complemented by a set of interoperability practices that establish the path to improve interoperability. Applying the EIMM involves two tasks: identifying the core areas of concern on which an enterprise need to work to achieve interoperability both internally and externally, and defining the maturity levels that describe the improvement path for each area of concern [25]. The areas of concern involve [8,16,29]: the alignment of business strategy (strategy perspective); pursuing and improving collaborative processes inside and outside companies (process perspective); identifying the external entities to collaborate with each other, specifying the networked organization topology, and its improvement and deployment (organizational perspective); identify players skills and knowledge (knowledge perspective); identification of further opportunities and specification of the same aspects for new products and services that require use of networked technologies for its delivery (product/service life-cycle perspective); research and evolution of enterprise systems to embrace innovative technologies that foster interoperability (technical perspective); and the identification of legal, trust and security requirements (legal rules and external environment perspectives).

The EIMM maturity levels rank interoperability from level 1 (enterprise modelling is performed, but in an ad-hoc and chaotic manner) to 5 (optimizing, i.e. Enterprise models allow the organization to react and adapt to changes in the business environment in an agile, flexible and responsive manner) [16]. For each maturity level, in a specific area of concern, EIMM provides the adequate objectives and best practices that permit achieve better interoperability between companies. That is valuable if one intends improving interoperability in the present conditions, or scale-up to higher levels of interoperability (in terms of maturity) allowing mapping each evolution step and planning the implementation procedure.

2.2.8 Business Interoperability Framework

The business interoperability framework (BIF) [7,17] is a framework dedicated to organizational and management layers of interoperability. Although information systems represent an integrated sector on this framework, the approach is business-centred in opposition to earlier frameworks. BIF proposes a qualitative assessment model to verify interoperability in dyads, emphasizing on non-technical issues by identifying four main categories of interoperability (information systems, collaborative business process interoperability, employees and culture interoperability, and management of external relationships) [30], and contingencies (internal and external) [17]. BIF provides criteria that outline the key business decisions companies have to solve when establishing interoperable digital business [7]. Each criterion is addressed in the scope of the product or service life-cycle (approach, deploy and assess & review) and in five levels of interoperability (from none to fully interoperable). For each of these variables, BIF describes the business interoperability settings that correspond to a business maturity state for a specific category, criterion and life-cycle stage. That not only serves the purpose of assessing business interoperability, but also to determine what decisions one must implement to scale-up interoperability.

2.2.9 Interoperability Impact Assessment Model

The Interoperability impact assessment model (IIAM) [27] supports the objective of assessing how interoperability generates value and quantifies the benefits resulting from interoperability improvements, due to significant investment [27]. Adopting a cost-based approach, authors track the effect of cultural, organizational and technical investments, on the performance of the organization or the entire value chain. To achieve that, IIAM measures direct and indirect impacts, in the customer and supplier perspective.

2.2.10 Enterprise Interoperability Framework

The Enterprise Interoperability Framework (INTEROP) [31] supports the underlying assumption that enterprises are not interoperable because of barriers to interoperability [31], considering in this vision that barriers represent incompatibilities of various kinds and at various enterprise levels. Hence, INTEROP defines three essential dimensions concerning enterprise interoperability [32]: interoperability concerns, which define the content of interoperation that may take place at various levels of the enterprise (data, service, process, business); interoperability barriers identified in various obstacles to interoperability in three categories (conceptual, technological, and organizational); and interoperability approaches that represent the alternative ways in which barriers can be removed (integrated, unified, and federated). In a two-dimensional perspective, INTEROP allows organizing interoperability knowledge that enables interoperability. A piece of knowledge is considered as relevant to interoperability if it contributes removing at least one barrier at one level [31]. From a three-dimensional perspective, the broad scale of INTEROP is implemented, and the interoperability knowledge is organized in concerns, barriers and approaches. The solutions achieved in the two-dimensional model are organized by kind of approach, being it integrated, unified or federated. Although the applicability of the framework fits beneath EI and enterprise architectures (EA), it is an appropriate methodology to identify interoperability concerns, characterize problems and identify subsequent solutions that enable interoperability.

Throughout the proposed frameworks, it is remarked that, despite interoperability is defined as an ability of systems and organizations, authors primarily refer to it as a problem that must be dealt with every time a system or a business relationship needs to be set-up or improved. This paradigmatic perspective paved way for several interpretations of the subject in diverse areas of knowledge, from the computer sciences to knowledge and organizational perspectives.

Interoperability decomposition embodies another trend identified in those frameworks and other literature. Authors frequently propose a decomposition framework enforcing the idea that, accomplishing these narrower terms, interoperability is achieved [33]. That culminated in several definitions of interoperability and derivate types. As a result, the interoperability frameworks vary significantly in the way they address interoperability issues [8]. This occurs, mostly, due to technological evolution and the awareness of interoperability problems affecting subsequent structures of business interaction. That is remarked in earlier frameworks that address IT architectures and interfaces of communication [34], and subsequent framework begun to incorporate business areas like organizational and knowledge issues (e.g. [15,17]), as well as recent tendencies in IT like cloud interoperability, social networks interoperability and ecosystems interoperability [8,35].

2.3 Inter-firm relationships: the buyer-supplier dyads

Inter-firm relationships are characterized by the interaction design and the kind of coordination mechanism. A complex business market can be perceived as a network where the nodes are business units. Each node or business unit, with its unique technical and human resources, is bound together with many others in a variety of alternative ways through its relationships [36]. The dyad is distinguished as the elementary form of interaction. Through the direct interaction with partners (primary function), the firms struggle to achieve higher efficiency through interconnecting activities, creative leveraging of resource heterogeneity and mutuality. Nevertheless, a single dyad influences and is also influenced by other firms operating in the same network (secondary function – network effect) [20]. In this paper we

analyse direct interactions in a dyad (primary function). The influence of firms external to the focal relationship wasn't considered.
Regarding the coordination mechanism where the business relationship occurs, supply chain management (SCM) is distinguished from innovation, relationship management and infrastructure mechanisms, as a form to integrate suppliers and customers, enabling the flow of materials through efficient planning and process execution [37].
SCM looks for the execution of SC operations seamlessly, easing their alignment and information flow addressing two perspectives of SC: internal and external. The external perspective is where inter-firm relationships occur and is referred to as supply chain collaboration (SCC). The collaborative perspective of SCM looks at a set of approaches to efficiently integrate suppliers, manufacturers, warehouse, and stores, so that merchandise is produced and distributed at precise quantities, to exact locations, and at the right time, to minimize system-wide cost while satisfying the service level requirements [38]. In turn, collaboration in SCs is shaped in the form of dyads and the broad SC Network, where the dyad is seen as the most elementary interaction in SC. Mondini, Machado, & Scarpin (2014) stresses the importance of the strategic relationship between buyers and suppliers. Buyer-supplier dyads are distinguished as one of the utmost importance to effective management of SC (I. J. Chen & Paulraj, 2004).
Cooperation in dyads is settled on the notion of "collaborative advantage" defended by [2,39–41]. In opposition to the competitive advantage [42], SC suppliers and customers are viewed as partners instead of adversaries with the objective of maximizing competitiveness and profit for the particular company as well as the entire SC network [43]. Mondini et al. (2014) adds that buyer-supplier relationships must be fostered to achieve a process of competitive synergy, where both plot a horizon of opportunities.
Literature in buyer-supplier dyads set the strategic aim of these relationships towards win-win situations supported by partners collaboration and, ultimately, achieve synergies to compete with other chains [44]. Authors in this area focus on SCM constructs or practices that allow achieving better performance individually, on buyer and supplier perspective, and on the dyad.
At a strategic level, buyer-supplier literature refers to mutual benefits, strategy alignment, contractual clauses, incentive alignment and buyer-supplier financing alignment as practices for effective collaboration [2,45–47]. Aligned with those, strategic sourcing is addressed by authors [3,48–50]. This practice comes in orientation with the need to achieve beneficial relationships, promoting open communication between suppliers and buyers [2,48].
On the relationship management perspective, I. J. Chen & Paulraj (2004) refer to supplier-base reduction, supplier involvement and the creation of cross-functional teams. These do part of the management of long-term relationships between buyers and suppliers, where a vaster volume of business is placed in limited number of strategic suppliers [51,52]. Still, strategic sourcing leads to the need for supplier evaluations systems [48]. Strategic alliances are a result of the articulation of effective supplier selection as well as adequate power distribution to go beyond contractual issues, setting an environment of cooperation [3]. Resources of effective collaboration include monitoring, supplier involvement, cross-functional teams, joint relationship effort, trust and resource sharing [2,3,47,52–57]. Those refer to activities that promote interaction between buyers and suppliers. Cannon et al. (2010) additionally includes cultural issues as a conditioning factor that has impact in buyer's long-term orientation.
Knowledge in cooperation is addressed in terms of joint knowledge creation [45] and knowledge sharing [54,58].
The information perspective of buyer-supplier interaction is promoted by the collaborative communication and information sharing practices [2,3,45–47,53,54,58,59].
The strategic aim and the existence of SCM constructs that support interaction in buyer-supplier dyads share similarities to business interoperability approaches between peers. Nevertheless, while the literature regarding buyer-supplier dyads solely refers to the perspective of collaboration and practices that allow achieving higher performance, formal approaches regarding processes, material and information flows between buyer-suppliers are missing, together with the IT that support SC activities. Interoperability is seen as a substantial asset to achieve competitivity in SCM [4]. The BI approach provides this comprehensive vision by aiming at the same objectives, and tracing systematically subsequent assets from strategic foundations for collaboration to the IT that support the interaction.

3. Business interoperability decomposition framework for buyer-supplier dyads

The buyer-supplier dyads are settled on the collaborative advantage, which relies on win-win relationships, mutual benefits and competitive synergy. Effective cooperation establishment and management allow the dyad to achieve higher performance and value added to the customer. The condition that makes possible to fulfil those objectives is that the dyad is interoperable. Our research aims at identifying what are the interoperability issues that rule interaction in dyads, and how to improve them to achieve optimal interoperability. In that sense, we propose three methodological steps:

1. The first step is to determine the interoperability perspectives that rule dyad's interaction. A framework that systemizes the problem identification will allow capturing the dyad's functionality and identify issues that may constrain the cooperation.
2. The second step is to identify the requirements to ensure cooperation. The objective herein is to establish the dyad's design, determining the solutions the companies deployed to fulfil the requirements. For this step is required that both the decision-making and dependencies among interoperability perspectives are captured.
3. The third step is to measure the dyad's performance. This one will allow qualifying and quantify interoperability and will permit to check if the interoperability requirements are adequately met. Optimal interoperability will be achieved through new scenario generation and determining which one guarantees higher dyad's performance.

The proposal of a BI decomposition framework is the first step that we address in this paper to achieve dyad's interoperability. Despite the valuable insights provided in existing interoperability contributions, it is missing a single approach to allow detailing interoperability, assess its conditions and allow to improve it or scaling it up. To achieve that, a single set of interoperability features, that provide the pillars for sustainable interoperability, should be proposed. The decomposition of the concept of business interoperability (BI) is a crucial factor if one attempts deepening a particular interoperability area. Further, the same decomposition of BI should provide criteria and performance metrics to assess interoperability and to ensure interoperability is maintained during cooperation. Another feature is the establishment of interoperability requirements. Looking at cooperation from different BI perspectives, from a cohesive point of view, it will allow mapping requirements to specific business needs, at different perspectives of interoperability, considering different levels of interoperability and different maturities of businesses and systems. Business interoperability should be seen as a whole rather than a fragmented piece, and should permit the analysis, measurement, improvement and control of digital supported cooperation.

3.1 Business interoperability decomposition

To accomplish the so-called cohesive framework, in this paper, we propose the taxonomy of BI applying the following steps:

1. Define BI – review and analysis of interoperability definitions and trends along time.
2. Identify BI's elements - Identification of interoperability types related to BI.
3. Document relationships and dependencies between BI's elements.
4. Examine dependencies between BI's elements and rearrange them by hierarchies and levels of detail to investigate the impact on BI.
5. Compile relationships and hierarchies in a framework.

As a starting point, we analysed the existing interoperability definitions and observed the present trends in literature. In section 2.1 we reviewed the main interoperability definitions that led to the concept of BI. The fundamental emerging trend in the field was the incorporation of the organizational perspective. This led to other interoperability fields as BI itself and Enterprise Interoperability (EI), which approach the organizational side in dissimilar depths. While the first approaches the organizational perspective of interoperability, EI focuses more on the technical aspects of the organizations, being directly related to integration and enterprise integration [53].

There are, moreover, some significant differences on the BI definitions. Parallel to Legner & Wende's BI definition, Guo (2007) [60] defines it as "the business interoperability that can be defined as the capability of business collaboration between business partners for the fulfilment of certain business functions at certain cost and efficiency." The latter definition only focuses on the organizational perspective of cooperation. The digital era affected the way business relationships are established and conducted. Like so, organizations and technology should be seen as a duality. Improvements in organizations may require improving technology and vice-versa. Hence, to address BI in cooperation one should have to address every aspect that produces impact in digital-supported businesses.

The second step was to analyse existing interoperability types and decompositions that are related to the definition of BI. Each analysed framework provides a decomposition of interoperability, either in interoperability types, as well as assessment criteria, requirements and interoperability metrics. Though, one of the problems when dealing with interoperability nomenclature is the diverse perspectives portrayed in several frameworks by different authors. Depending on the period the framework was proposed, and in the kind of approach and even the knowledge area (for instance, IT or business), different decompositions and various levels of detail are provided in the frameworks. Some terms complement each other, but other ones overlap and sometimes vary in the definition of the same interoperability perspective.

We registered the interoperability types related to BI the relationships between those documented in literature in the matrix presented in Table 1.

Table 1. Relationships between interoperability perspectives by reference.

	BI	OI	KI	TI	BS	RM	RI	HR	CI	PI	DI	SSI
OI	[15,18,34]											
KI	[15,18]	[15,18,19]										
TI	[15,34]	[61]	[15]									
BS	[17]	[17,19,62]	[33,63]	[34,64]								
RM		[19,28,32,33]	[15,33,36,63,65]		[7,66]							
RI	[18]	[19,28,32]	[33]	[16]								
HR		[16,18,19]	[15,33,67–71]	[16,17,72]								
CI	[18]	[19,61]	[70,73]		[30,70]		[74]	[68,71]				
PI	[15,17]	[17,19,26,32,33,62]	[16,33,68]	[15,33]	[16,72,75]	[16,17,72,76]	[12,14,16]	[16,72]	[70,73,74]			
DI	[15,17]	[12,32,77]	[15,68,69,71,73]	[17,26,28,61,62,78,79]		[17]	[16,26]	[8,17,62]	[14,30,73,74,80]	[8,17,22,65,68,77,81]		
SSI		[17–19]	[71]	[17,26,28,78,79]						[16]	[19,26,31,82–84]	
OHI			[71]	[17,26,78]						[16]	[31,81,83]	[62,84]

Acronyms: BI – Business Interoperability; OI – Organizational Interoperability; KI – Knowledge Interoperability; TI – Technical Interoperability; BS – Business Strategy; RM - Relationship Management; RI – Rules Interoperability; HR – Human resources; CI – Cultural Interoperability; PI – Process interoperability; DI – Data interoperability; SSI – Software and services interoperability; OHI – Objects and hardware interoperability.

We divided the interoperability types in levels of detail depending on the type of dependency. Two main dependencies were found: the first is the inclusion of a certain subject inside the definition of the previous one; and the second one is the interaction between subjects.

Since BI includes the types organizational interoperability (OI), knowledge interoperability (KI) and technical interoperability (TI), we removed the relationships between BI and business strategy (BS), rules interoperability (RI), cultural interoperability (CI), process interoperability (PI) and data interoperability (DI), because they are already included by OI, KI and TI. In succession, OI, KI and TI additionally include the definitions of relationship management (RM), human resources (HR), software and services interoperability (SSI) and objects and hardware interoperability (OHI).

By addressing primary dependencies, a hierarchy may be established with three levels of detail: level 0, where BI is addressed; level 1, portraying OI, KI and TI; and level 2, with the subjects BS, RM, RI, HR, CI, PI, DI, SSI and OHI. In Figure 1 we propose the Business Interoperability Decomposition Framework (BIDF). Each type of interoperability should not be seen as an independent one. Relationships between subjects inside level 1 and level 2 are documented in Table 1. For instance, processes permit companies to fulfil their objectives, which makes PI depend on BS. Though, to operationalize internal and interface processes, technical and human resources are required, as well as adequate data needs identification and correct interoperability requirements. While relationships inside each level of interoperability provide a relevant inside to problem definition, in this paper we don't explore further these interactions.

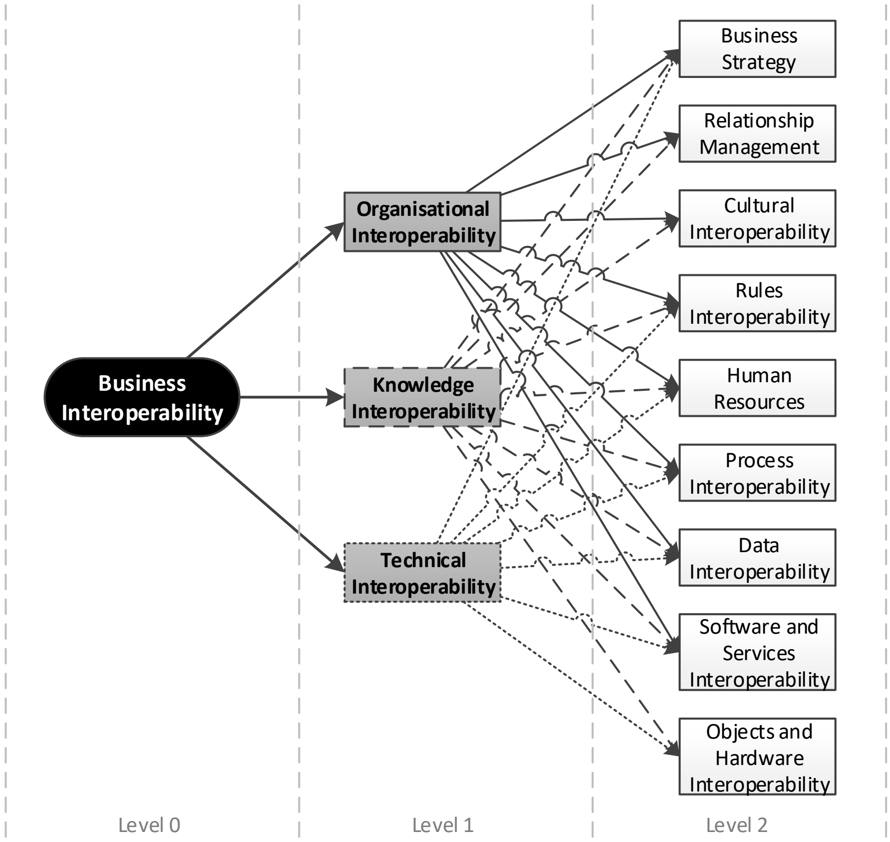

Figure 1. Business Interoperability Decomposition Framework (BIDF).

At the highest level, BI can be address by the perspectives:

- Organizational interoperability (OI) concerns the definition of business goals, modelling business processes, that expect to perform information exchanging, considering the inherent organizational structures and individual processes [26]. It relies on the successful exchange of information through the successful interoperability of the technical, syntactic, and semantic aspects [9,85]. OI deals with different human and organizational behaviours, distinct senses of value creation networks, conflicting business goals, dissimilar legal bases, legislations, cultures or methods of work and different decision-making approaches [19].
- Knowledge interoperability (KI) is perceived in the ability of two or more distinct entities to share their intellectual assets, gaining primary advantage of the mutual knowledge and utilize it, and to more significantly extend them through cooperation [8,68]. Interoperability at knowledge level should be seen as the compatibility of the skills, competencies, and knowledge assets of an enterprise with those of other enterprises [33]. KI concerns three levels: organization level (organization roles, skills and competencies, knowledge assets, human resources management, laws and regulations, legal obligations and relationships with government institutions); technical level (knowledge data); and Semantics (knowledge ontologies) [15,86].
- Technical Interoperability (TI) is the most generic form of interoperability and the support for electronic interaction. It refers to technical issues of linking computers systems and services, and it is associated with hardware and software, systems, platforms, that enable machine-to-machine and human-to-machine interaction [8,26,64]. Also, include key aspects like open interfaces, interconnection services, data integration and middleware, data presentation and exchange, accessibility and security services [26].

In a second level of detail, OI, KI and TI are addressed by the perspectives:

- Business strategy (BS) concerns with how companies set up the collaboration by the formalization of business objectives. Critical factors in BS include the identification companies' individual goals [14,24], strategy alignment or harmonization [16,24], and the establishment of cooperation goals [17], settled by an agreement specifying the conditions and liabilities. In a collaborative perspective of BS, firms should aim at win-win situations where all participants collaborate to achieve business synergy to compete with other chains or networks [44], and failure to establish cooperation goals may result in faulty relationships. For this reason, BS should be considered reflecting the utmost interoperability level. This top governance interoperability aspect addresses the harmonization between individual and collective objectives, which subsequently impacts interoperability dimensions and the value chain.

- Relationship management (RM) accompanies the life-cycle of the cooperation, encompassing all aspects of realizing and sustaining the relationship until its termination [17]. Apart from the relationship life cycle, it also deals with relationship governance [87] and trust [17,88] that may leverage or constraint the decision-making between partners. Furthermore, the intellectual identity of companies remains another issue addressed in RM. Since companies' competencies to generate and exchanged knowledge, knowledge should be managed and assessed in terms of knowledge quality [65] and the competencies reviewed [15].
- Cultural Interoperability (CI) concerns the impact of companies' individual culture in business activities. Various languages and cultural diversity impact business, aiming at diverse objectives that may limit collaboration [30]. CI aims at understanding cultural diversity, enabling trust building, efficient team-working and constructive communication [89]. Faulty CI may lead to "us and them" attitude [17] culture clash phenomena and unclear agreements and conflicting expectations [70]. So, to be interoperable the exchange of knowledge and data across dissimilar cultures in diverse native languages is a necessity [14,73].
- Rules interoperability (RI) concerns the rules that constraint or enable business in two perspectives: internal and external rules. Internal rules refer to the ability of business entities of aligning and matching their business and legal rules for conducting automated transactions, which are also compatible with the internal business operation rules of each other [68,85]. From the external perspective, is considered the influence of legislation (government or cross-borders) in processes [12,14,16].
- Human resources (HR) perspective is one of the key areas to accomplish BI. Relationships between people and teams are what provide organizations their added value and build collective competencies [90]. While IT evolution allowed to shift most of the human tasks shifting them into automated ones, most activities are still performed by users, and interoperability problems may occur because information is neither perfectly available nor fully processable for the human actors (bounded rationality) [27]. Issues like trust, visibility, responsibility and motivation characterize the behavioural and organizational perspective of HR. On the KI perspective, when HR interprets, understands and believes in the message communicated information, it becomes knowledge [70]. The capability to deal with information and IT tasks is affected to the role and responsibility assigned to the employee, as well as the competencies and knowledge skills to deal both with the performed task and IT (TI perspective).
- Process Interoperability (PI) represents the core of BI. Strategic objectives, relationship set up, and the use of technical (IT and tools) and human resources are bound together by the processes that permit to accomplish individual and collective objectives [16,72]. Processes allow gathering knowledge, recognize improvement opportunities, align practices with business objectives, and measure performance [16]. Internally, processes are established and sequenced according to the specific needs of a company to accomplish their objectives [18]. Nevertheless, when two companies cooperate, the internal business processes of the cooperative enterprises should interact to pursue mutual objectives that will be profitable for all the parts [75]. Interface processes alignment becomes a crucial task to achieve PI. This will allow exchanging data and conduct business in a seamless way [68].
- Data interoperability (DI) engages in making work together different data models with different query languages to exchange information coming from heterogeneous systems [79,82]. At a TI perspective, DI deals with both the data format (syntactic interoperability) and its meaning (semantic interoperability) [12]. Past semantic and syntactic representation of data, TI deals also with the wrong instantiation of data models and different data restrictions [29].
- Software and services interoperability (SSI) deals with the identification, composition and making function together various applications (designed and implemented independently), by resolving the

syntactic and semantic differences as well as finding the connections to the various heterogeneous databases [29,82]. Though the term software concerns applications in computer systems, the term ‘service’ is not limited to this notion, and equally considers functions of companies and networked enterprises [18]. Services represent an abstraction and an encapsulation of the functionality provided by an autonomous entity [72]. Hence, SSI concerns the “soft” part of TI and the interaction between diverse companies’ systems and the applications and services that support this interaction.

- Last, objects and hardware interoperability (OHI) concerns the physical infrastructure that support and enables electronic data input, output, exchange, storage and processing. It refers to the networked interconnection and cooperation of devices and hardware components [8]. Apart from computer processing, the use of handheld devices (e.g. barcode and RFID) and recent developments in The Internet of Things [91], extended the use of IT hardware to most human tasks that required parallel computer processing. Simultaneously, the coexistence of modern systems with legacy systems, forces the backward compatibility and limits the technological evolution [92].

3.2 Interoperability criteria: further decomposition of interoperability

One branch of interoperability literature is dedicated to the characterization and measurement of interoperability. Measuring interoperability allows a company to know its strengths and weaknesses to interoperate with a third company and prioritize actions to improve their collaboration ability [93,94]. Though, interoperability is not measured as an absolute property, but in relation to another interoperability state. The so-called “as-is” to “to-be” benchmarking allows companies to define the current interoperability setting and the define the desired state to interoperate with another companies [27]. Razavi & Aliee (2009) emphasizes the value of the transition from the “as-is” to “to-be” states, where the decision analysis required for that portrays a crucial part do improve interoperability.

Interoperability characterization and measurement are possible through the application of interoperability criteria. Several interoperability criteria are proposed to describe and qualify interoperability in several contexts. They refer to specific area under a certain perspective of interoperability and serve to describe, measure interoperability, or, in some situations, serve as design requirement. We reviewed 127 publications where criteria are proposed to describe or measure interoperability. In Figure 2 we present an analysis of the existing publications that provide criteria fitting the scope of BIDF. We observed that 64% of the interoperability research was published addressing DI, PI, SSI and RM perspectives.

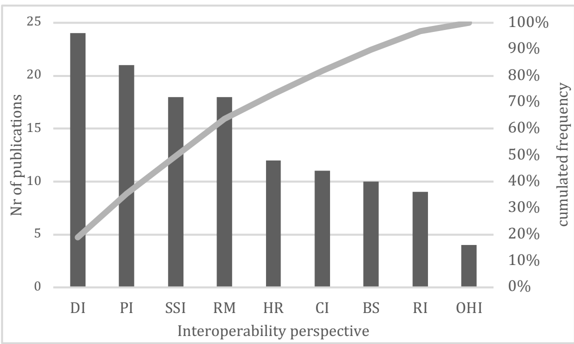

Figure 2. Interoperability publications proposing criteria by interoperability type.

In table 1 we present in detail the collected criteria addressing the BIDF perspectives.

Table 2. Interoperability criteria by business interoperability perspective.

BI criteria		Business interoperability perspective – 1st level		
		Organizational interoperability	**Knowledge interoperability**	**Technical interoperability**
Business interoperability	**BS**	Business goals identification [1],[2],[3],[4],[5],[6] Clarity in strategic goals [1],[2],[3],[5] Business strategy alignment [1],[2],[3],[7],[8],[9]	IPR protection [5]	Agreed security [10]
	RM	Partner selection [1],[2],[3],[5],[6] Definition of the cooperation model[1],[2],[3],[11] Compatibility of organizational structures[5],[12] Cooperation realization management[1],[2],[3] Collaboration termination management[5],[13] Cooperation monitoring[1],[2],[3] Role and responsibility assignment[1],[2],[3],[5]	Knowledge management[1],[2],[3],[5],[11] Competencies revision[6],[7],[11],[21] Knowledge quality[22]	

	Definition of contact points[2],[3],[5] Conflict and risk management[1],[2],[3],[4],[5] Governance distribution[2],[14],[15],[16],[17],[18],[19],[20]		
CI	Culture harmonization[1],[23],[24],[25],[26],[27],[28] Language barriers[4],[5],[8],[25],[28],[29]		
RI	Applicable legislation[2],[3],[23],[24] Rules incompatibility[7],[8] Rules alignment[8],[30]	IPR protection[5]	Alignment of security requirements[6]
HR	Trust[2],[3],[31] Visibility[2],[3],[31] Responsibility assignment[5],[12],[32] Human factors[1],[8],[12],[29],[32]	Knowledge and skills[6],[33],[34]	Skills for interoperation/IT[6],[33]
PI	Process identification[6],[34] Process sequencing[23],[24] Process monitoring[1],[35],[36] Collaboration modelling[1] Process alignment[1],[2],[4],[5],[6],[7],[8],[23],[24],[30] Organizational alignment[12],[23],[32],[37]	Work methods[2],[3],[6],[23],[24],[34]	Process logic[11],[21]
DI	Semantic Alignment[2],[4] Product data[2],[11],[38] Process data[11] Semantic agreement[4],[8] Time of interoperation[1],[12],[32],[34],[35],[39] Information quality[2],[22],[40],[41] Communication paths[1],[2],[3] Contact points[3],[5]	Knowledge data[11] Knowledge ontologies[11] Communication methods[42]	Make heterogeneous databases work together[23],[24] Communication requirements[7] Syntax compatibility[1],[43] Protocol interoperability[7],[8],[41] Quality of interoperation[1],[12],[35],[44],[45] Cycle time[35],[44] Processability[44],[45] Connectivity[2],[8],[35],[41],[46] Connectivity costs[31] Data latency[8],[35],[41],[46] Cost of interoperation[12],[32],[35],[36],[47]
SSI			Application interoperability[5],[23],[24],[48] Security[1],[2],[4],[5],[10] Solution management [2],[11],[49] Application logic[2],[11],[49] Standards compatibility[2],[10],[29] Systems architecture[42] Applications ontology[11],[23],[49] Legacy systems[42] Technological compatibility[12],[43] Capacity[41],[46] Systems overload[41],[46] Underutilization[41],[46] Undercapacity[41],[46]
OHI			Types of interaction[2],[11],[45] Hardware compatibility[10]

References: [1] - [29]; [2] - [17]; [3] - [7]; [4] - [26]; [5] - [96]; [6] - [16]; [7] - [65]; [8] - [8]; [9] - [78]; [10] - [64]; [11] - [15]; [12] - [83]; [13] - [97]; [14] - [87]; [15] - [60]; [16] - [98]; [17] - [34]; [18] - [28]; [19] - [69]; [20] - [88]; [21] - [33]; [22] - [99]; [23] - [31]; [24] - [18]; [25] - [73]; [26] – [100]; [27] - [66]; [28] - [70]; [29] - [101]; [30] - [68]; [31] - [27]; [32] - [32]; [33] - [82]; [34] - [102]; [35] - [103]; [36] - [104]; [37] - [105]; [38] - [106]; [39] - [95]; [40] - [107]; [41] - [23]; [42] - [22]; [43] - [25]; [44] - [108]; [45] - [27]; [46] - [109]; [47] - [110].

The presented criteria provide an extra level of detail to the perspectives in BIDF. While BIDF allows one to look individually to an inter-firm interaction perspective, interoperability criteria permit to put in scale how two or more firms perform together.

Similar to interoperability perspectives in BIDF, each interoperability criterion may be related to other criteria. Improving interoperability in a specific criterion may require that other criteria must change. Examples of this are addressed by interoperability maturity models like LISI [12] or EIMM [16]. While we consider dependencies between criteria, in this paper, these are unaddressed.

Nevertheless, there are some limitations regarding existing criteria. In terms of BI coverage, some issues lack criteria to address interoperability. Knowledge interoperability (KI), for instance, is the 1st level perspective that has fewer criteria to address inter-firm interaction. Other issues lack completely criteria. An example is the cultural interoperability, only addressed in the organizational interoperability perspective, lacking criteria to address it at knowledge and technical perspectives of interoperability. Further developments should aim at missing criteria in the found gaps.

3.3 The BIDF applied to buyer-supplier dyads

SCM literature acts on the similar strategic foundations as BI, proposing collaborative practices or constructs that share similarities with the BI perspectives and criteria. In Table 3 we propose an alignment of those constructs with the corresponding BI perspectives.

Table 3. SCM practices and constructs correspondence to business interoperability perspectives.

SCM construct/practice	BI perspective
Strategy alignment [1],[2]	BS
Incentive alignment [1],[3]	BS, RM
Buyer-supplier financing alignment [2],[4]	BS, RM
Contractual clauses [3]	BS
Mutuality/mutual benefits [5],[6]	BS
Strategic sourcing [7],[8],[9],[10]	RM
Supplier evaluation systems [3],[7],[8],[9],[10]	RM
Supplier involvement [6],[12]	RM
Supplier-base reduction [3],[6],[12]	RM
Long-term relationships [5],[6],[7],[12],[13]	RM
Governance/power distribution [3],[7],[14]	RM
Monitoring [7],[11]	RM
Cross-functional teams [6]	RM, PI, HR
Joint relationship effort [4]	RM
Trust [3],[4],[5],[7],[13],[15],[16]	RM
Resource sharing [1]	RM, PI, SSI, OHI
Cultural issues [13]	CI
Joint knowledge creation [1]	KI
Knowledge sharing [3],[17]	KI
Information sharing [1],[2],[3],[4],[5],[17]	DI, SSI, OHI
Collaborative communication [1],[3],[5],[6],[7],[11]	SSI, OHI

References: [1] - [45]; [2] - [46]; [3] - [54]; [4] - [53]; [5] - [47]; [6] - [2]; [7] - [3]; [8] - [48]; [9] - [49]; [10] - [50]; [11] - [59]; [12] - [52]; [13] - [55]; [14] - [111]; [15] - [56]; [16] - [57]; [17] - [58].

The SCM constructs constitute a business-specific for the interaction setting between buyers and suppliers. With the strategic aim of collaborating, those constructs set the adequate priorities for the dyad interaction. With regards to the alignment of constructs with the BI perspectives, BIDF provides a richer coverage in detailing different interaction perspectives. Further, the BI criteria complement another level of detail to buyer-supplier dyads. They allow a more specific characterization of how firms perform in the interaction with each other, and what barriers should be overcome to achieve a successful cooperation.

In Figure 3 are represented the BI perspectives and the SCM constructs that are addressed in the buyer-supplier dyad's interaction context.

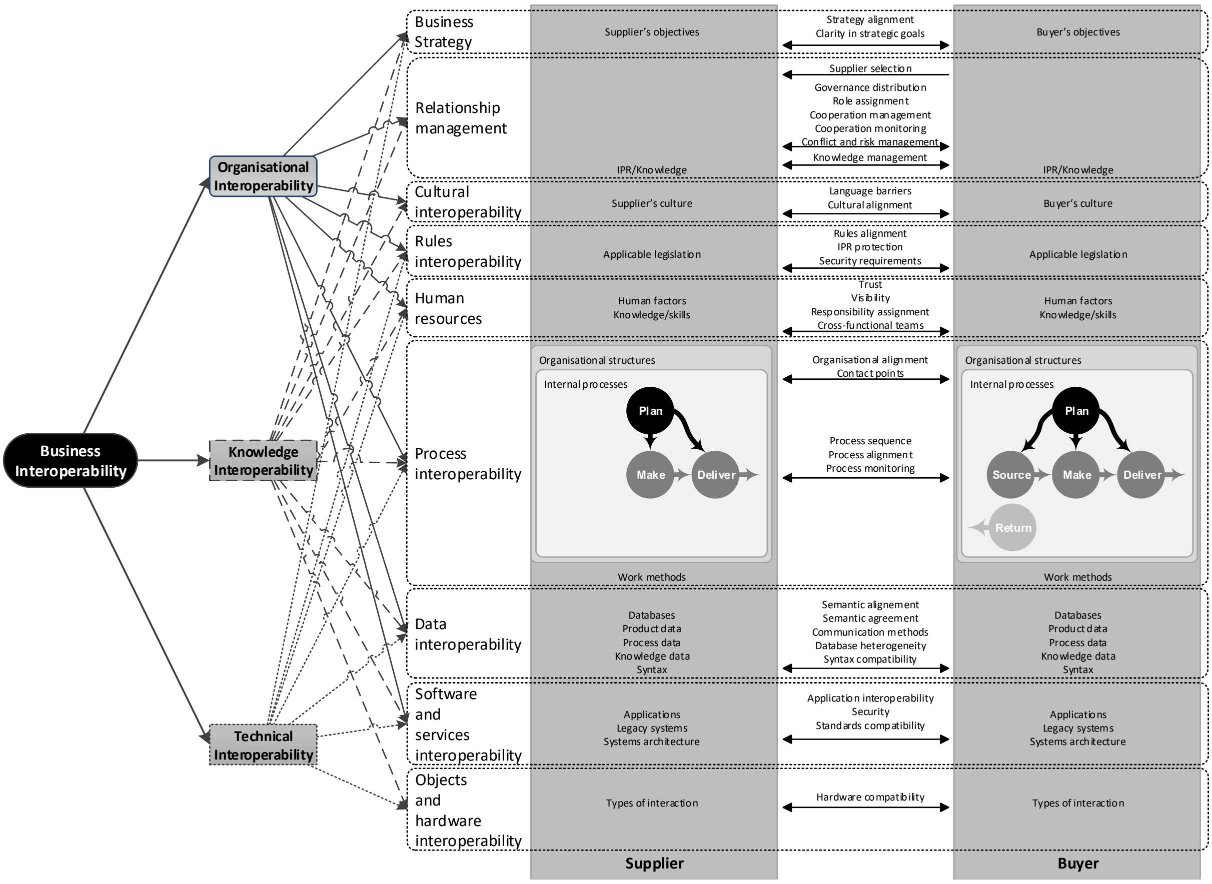

Figure 3. Representation of the buyer-supplier dyad in the main BI perspectives, BI criteria and SCM constructs.

This structured decomposition allows mapping the BI issues raised in the business set-up. The top-down layers (from BS to OHI), represent the different areas in which interoperation can be addressed. Regarding the interaction between buyers and suppliers, four points of view exist: the individual supplier and buyer perspectives, the interface, and the dyad as a whole. The decisions taken place in those perspectives aid us to set an interoperability profile, which features the characteristics that make the dyad unique with the specific interoperability properties that will result in a more or less interoperable scenario. BI criteria and contextual SCM constructs characterize those decisions at the different BI perspectives and in those four points of view.

Still, the underlying proposition herein contradicts the proposition of IDEAS framework. In IDEAS framework is proposed that, to achieve BI, is required to be achieved interoperability in all the layers of interoperability (business, knowledge and ICT systems). The defended position regarding this aspect is set on the notion of optimal versus maximum interoperability, posing that certain interoperability conditions may permit to achieve the optimal level of interoperability, resulting in better performance outcome than the maximum levels of interoperability, achieved in every BI perspective. In the proposed method, this position is enforced to determine the required interoperability conditions to achieve optimal performance and, in the case of intending to scale-up interoperability, what decisions are required, and what interoperability conditions provide higher performance and value creation that the current dyad's interoperability conditions.

Nevertheless, despite the model allows looking at individual BI perspectives, improving interoperability in a specific setting may require the change of interoperability conditions in associated BI perspectives. I.e., the need for one improvement may trigger changes in another areas. For instance, the implementation of a new information system to manage orders would require a new business process model to choreograph the order placement procedure, as well as the change in the supplier business processes that need to adapt to the new buyer's ordering procedure. In the resource point of view, employees would require more training for this new procedure and systems and, at a technical perspective, the new ordering system may need a new communication interface, protocols and standards to be implemented. On the perspective of optimal interoperability, the changes that companies could require should be as sufficient as needed to achieve successful interoperation and better performance results.

4. Case study: the analysis of an exceptional procedure for faulty order reception

In this section we present a case study where the BIDF was applied to analyse the buyer-supplier dyad characterized in Table 4. The first entity in the dyad is a first-tier supplier (buyer) that produces injection coils to 40 automotive manufacturers placed worldwide. The second company (supplier), is a second-tier supplier, with regards to the automotive SC it belongs to, and supplies the buyer with high specificity copper wire. The supplier is a long-term strategic partner of the buyer and has high integration in the development and conception of its products.

Table 4. Firms' profile

Company	Second Supplier (Supplier)	First Supplier (Buyer)
Product	Copper wire	Injection coils
Industry sector	Wire and cable manufacturer	Automotive electronic parts manufacturer
Interviewed	Supply chain responsible	Director of logistics Supplier quality engineer Quality engineer
Country of origin	United States of America	United States of America
Plant location	Portugal	Portugal

Despite their frequent cooperation, the occurrence of failures remarks this dyad. Occasionally the buyer is confronted with faulty deliveries from the supplier. This led to the need for the buyer to implement an exceptional procedure to detect missing items in the order.

4.1 Applied method

For the purpose of this case study, we implemented the BIDF to study the dyad's interoperability conditions ("as-is"). Subsequently, according to dyad conditions we explain the rationale for new cooperation settings ("to-be"), with the aim of improving interoperability in the dyad. Figure 4 presents the applied method.

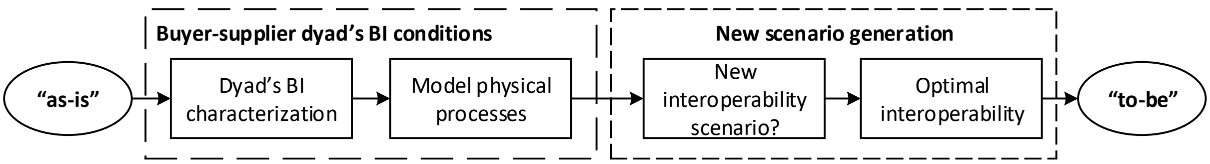

Figure 4. Proposed method to analyse interoperable buyer-supplier dyads and generate new scenarios towards interoperability optimization.

In the first stage, the dyad is characterized by analyzing the dyad's set-up conditions, addressing the BS and RM perspectives using the criteria in Table 2. For instance, to describe BS the scale in Table 5 was used.

Table 5. Business strategy assessment.

Criterion	Level of Interoperability				
	1	2	3	4	5
Levels of goals definition	Not established (Ad-hoc planning)	Verbal contract	Signed contract with the conditions specified by the governing company	All the objectives and ground rules were previously agreed upon	All the competencies and capabilities were discussed in order to establish a win-to-win situation
Levels of clarity in business goals	Not defined/not clear	Frequent failures in cooperation	Occasional failures in cooperation due to ill-defined objectives	Clear to both parties. All ground rules agreed and communicated	Comprehensive review of competencies
Levels of strategy alignment	Isolated	Occasional ad-hoc partnering	Established partnership without strategy alignment	Partners share the same business strategy	Regular review of competencies (fully aligned)

The second step is to address processes and resources implemented by companies to cooperate. While BS and RM set the ground rules for the cooperation, processes allow to execute the companies' objectives. Hence, to address PI, the criteria in Table 2 is used in complement to processes modelling. For the latter, we suggest using the Business Process Modelling Notation (BPMN). The dyad's characterization and process modelling occur simultaneously. Firms business processes are addressed in their internal perspectives (detailing the sequencing of activities and organizational alignment) and in the interface perspective (dyad's process alignment), where the cooperation occurs.

Afterwards, subsequent BI issues are described with regards to the business processes. In the present case study, DI, HR, SSI and OHI were analysed. Other subjects were left out since the companies operate in Portugal, and there were no issues regarding CI or RI.

After establishing the "as-is" scenario, new scenarios are proposed considering the "as-is" conditions and how higher interoperability may be achieved in each BI perspective. For instance, improvements in BS can follow the scale in Table 5. One should note that modifying interoperability perspectives may require changing other related interoperability perspectives. An example is the implementation of a new information system, which impacts directly DI, SSI and OHI, but also requires new business processes addressed in PI.

Although the ultimate aim of the method is to achieve optimal interoperability, in this paper, we address the dyad's characterization and the ability to generate alternative scenarios that can deliver better cooperation. To achieve optimal interoperability, one should select which scenario improves the dyad's performance, which will be explored in our future research.

4.2 The analysis of "as-is" conditions

The occurrence and handling of faulty orders are reflected in a distinct manner at different levels of BIDF.

First, we analysed the business set-up conditions to verify interoperability in terms of the agreed strategy and in terms of cooperation duration. Table 6 summarizes the main interoperability issues of the dyad.

Table 6. Dyad's set-up conditions.

BI perspective	Dyad's conditions
Business strategy	• Negotiation of conditions and liabilities applicable to purchasing and selling, agreed by a signed contract. • Cooperation strategy defined, but not aligned with individual objectives. • Poor business strategy clarity.
Relationship management	• Unilateral power distribution (the buyer is the governing firm). • Strategic long-term relationship. • Certified supplier. • Cooperation reviewed annually. • Contractual clause to keep steady supply after one year of cooperation breakdown. • Risk management measures: alternative supplier; alternative communication and procedure to handle faulty orders (missing parts and quality).

At the business strategy (BS) level, the establishment of the liabilities and conditions for failure to commitments was handled by a negotiated and signed contract. These ones were aligned with the companies' individual objectives. Both companies have dedicated sections to deal with faulty component reception. Though, conflicts occur due to lack of definition of how to handle complications, resulting in an ad-hoc negotiation of penalties.

In terms of relationship management (RM), the risk management systems put in action by both companies acting on this interaction. Though, the contingency plan for delays is strongly influenced by the governance position of the buyer. Contract obligations represent the selected approach, resulting in a set of consequences that the buyer may implement, depending on the situation.

In counterpart, the risk management measures set in motion exceptional procedures to ease the treatment of missing items on shipments.

With regards to process interoperability (PI), and its resources, Table 5 summarizes the main interoperability issues regarding these aspects.

Table 7. Dyad's processes and resources (human and technical).

BI Perspective	Dyad's conditions		
	Buyer	**Interface**	**Supplier**
PI	• Buyer's internal processes (see Figure 5):	• Procedure to communicate complaints, re-order, urgent	• Supplier's internal processes (see Figure 6).

	o Process of incoming orders inspection. o Complaint procedure. • Additional procedures added to reception and parts ordering sections.	delivery and issue a credit memo (see Figure 7).	o After-sales service. • Additional procedures added to sales and logistics section.
DI	• Data inserted manually • The use of internal software (MS Access) to manage manual inspection procedure.	• Alternative communication paths for complaints: phone or e-mail. • Data shared over phone/e-mail needs to be inserted manually.	• Manual insertion of phone/e-mail data into SAP.
HR	• Manual inspection process. • The sharing of users between regular and exceptional procedures to order and make complaints.		• The sharing of users between regular and exceptional procedures to procure materials, process incoming orders and handle complaints.
SSI	• The use of internal software (MS Access) to manage manual inspection procedure. • Alternative use of e-mail or phone to make complaints, due to lack of integration between firms SAP's systems (no EDI implemented).	• Systems not integrated. • Information is shared and inserted manually.	• The manual data entry on SAP to handle complaints due the lack of context modelling.
OHI	• User-dependent operations of manual inspection and data entry in MS Access.		

Acronyms: PI – Process interoperability; DI – Data interoperability; HR – Human resources; SSI – Software and services interoperability; OHI – Objects and hardware interoperability.

In addition to regular activities, both firms have to perform additional processes to manage faulty orders. The buyer's internal process is presented in Figure 5. Upon the detection of a faulty order, the employee from the buyer's parts ordering receives a missing parts report and has to contact supplier to formalize a complain, request missing parts and negotiate penalties. This process generates several constraints to internal and collaborative activities. In the process perspective, non-value-added activities are required to inspect and perform the complaint. Employees and additional systems are required for those activities. Nonetheless, systems were correctly undersigned to support the processes. The buyer developed a database in MS Access to support the manual inspection and, due to lack integration of SAP systems between the two firms, and also the lack of context (complaints) handling in SAP, employees have to resource to phone or e-mail to make complaints.

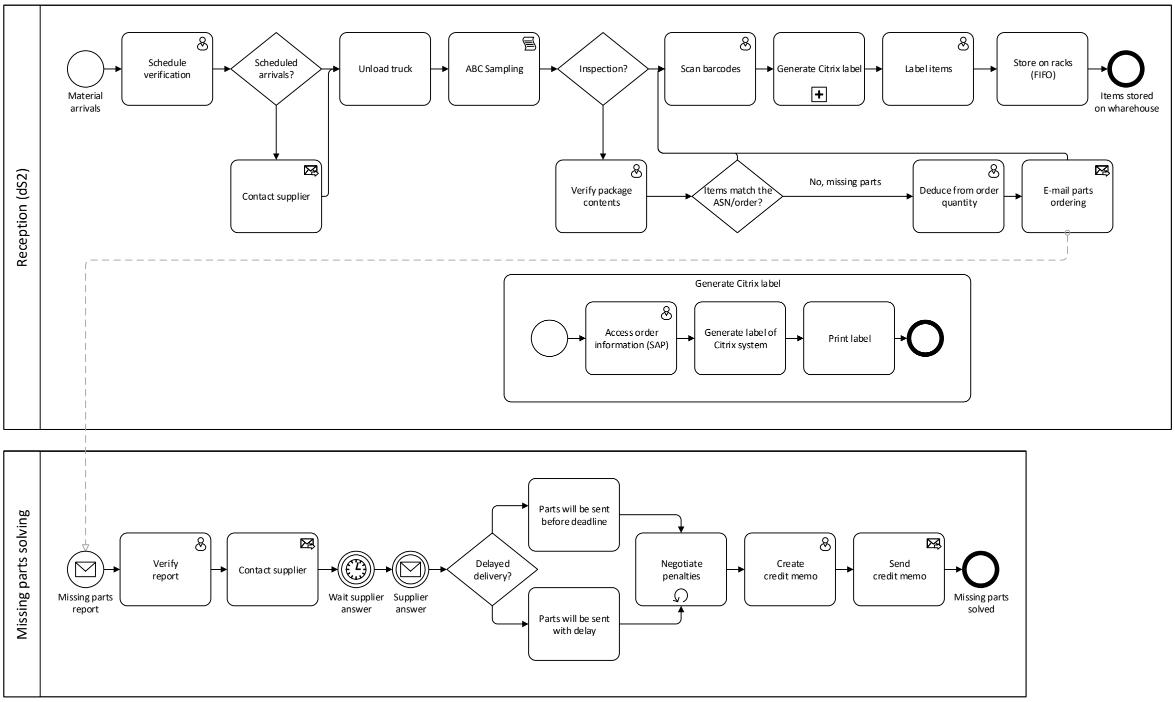

Figure 5. Buyer's procedures to inspect incoming orders and to make complaints.

On the supplier side, additional processes are required to handle the complaints (see Figure 6). The supplier has to reorder, dispatch the order urgently and negotiate penalties.

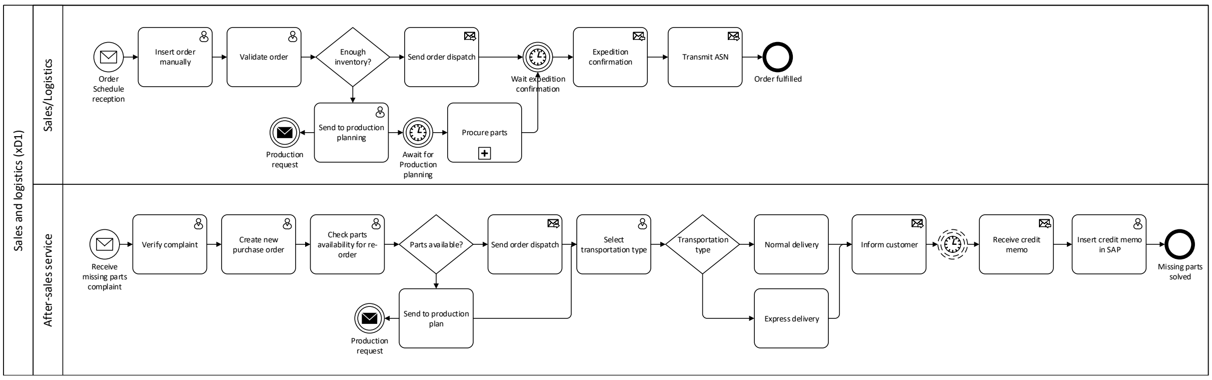

Figure 6. Supplier's after-sales service integrated on sales and logistics section.

On the interface (see Figure 7), the manual insertion of data (on MS Access) and firm-specific data handling by the Buyer led to the need of data conversion by the Supplier. Subsequent processes are the result of the work method implemented by the Supplier. A missing parts complaint is handled as a regular order. Therefore, this one is managed on SAP system but with a different delivery context.

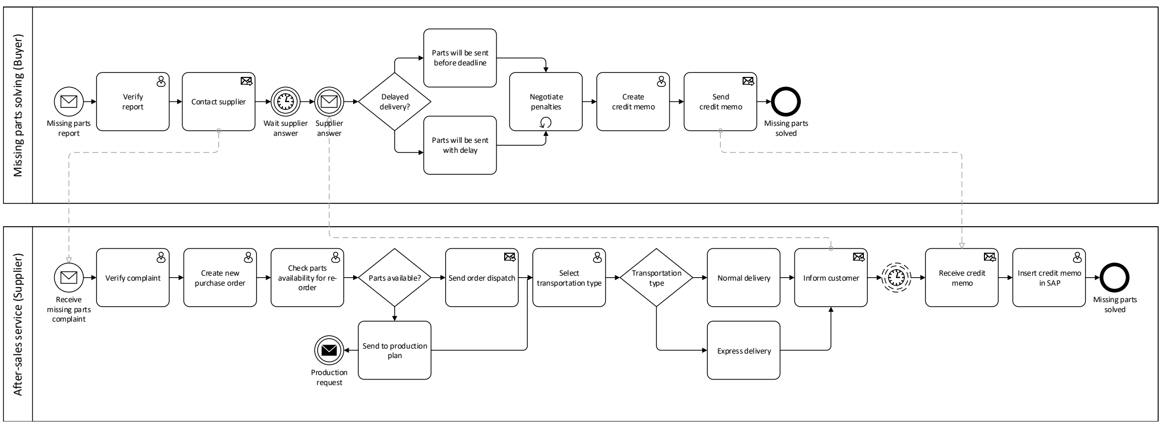

Figure 7. Collaboration BPM for missing parts solving.

4.3 The improvement of the dyad's conditions

Based on the dyad's present condition, is possible to devise solutions to the current problems. Those solutions could require the fine tuning of settings or the complete scale-up to a higher level of interoperability. In table 6 we propose solutions to the identified issues.

Table 8. Proposed improvements.

BI perspective	Identified problems	Proposed solutions	
		Low interoperability scenario	**High interoperability scenario**
Business strategy	Lack of cooperation strategy alignment and clarity.		Negotiation of new service levels and the implementation of integrated systems.
Relationship management	Selection of certified supplier instead of reviewing supplier capabilities. Annual revision of cooperation.		Review partner's capabilities. Frequent meetings to review cooperation. Redefined responsibilities to each actor.
Process interoperability	Overlapping business processes between regular and exceptional procedures.	Dedicated sections to deal with complaints (e.g. after-sales).	Dedicated sections to deal with complaints (e.g. after-sales). New procedure to perform complaints.
Human resources	Employees accumulate different functions in both companies.	Responsibility redistribution: additional employees for complaints and after-sales.	Responsibility redistribution: additional employees for complaints and after-sales.
Data interoperability	Incompatible data. Information exchanged via phone or verbally. Manual data introduction/conversion.		Integration of SAP systems via EDI.
Software and services interoperability	SAP systems not integrated. The use of internal solutions to manage complaints.		Integration of SAP systems via EDI.

The proposed solutions are categorized in low and high interoperable scenario. The low interoperable scenario would require few changes in the dyad's interaction to overcome some of the issues. For instance, a low interoperability scenario could be the redistribution of human resources and the redesign of processes, to avoid overlapping of regular and exceptional procedures.

On the other hand, a high interoperability scenario would require that firms review thoroughly their cooperation strategy. A partner's capabilities revision should reveal if the partner is capable to meet the business needs. If, currently, the supplier misses' orders, it is either not capable to meet demand or should review its internal operations. Other measures to investigate is the negotiation of service levels and the integration of firms SAP systems. Such kind of decisions would carry a great investment from firms, and would require changes at process, human resources and information systems levels. As such, the strategy redefinition in the high scenario would require the new responsibility assignment, more frequent meetings to review progress, dedicated sections to handle complaints and after-sales and the integration of SAP systems. The last one would replace the buyer's internal complaint management system (MS Access) with SAP, which, in turn, solves data incompatibility between firms. In Figure 8 we propose a new procedure for the integration of SAP systems with EDI.

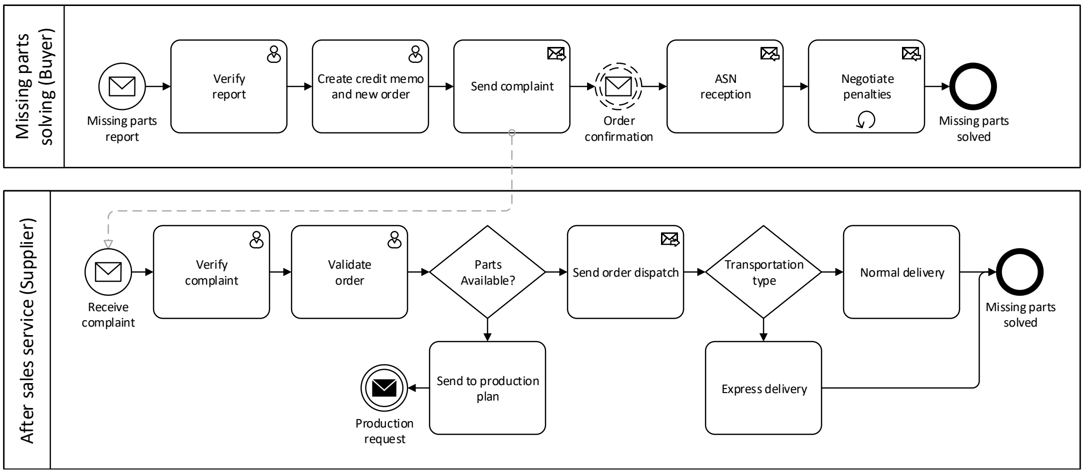

Figure 8. New procedure to handle complaints.

Table 9 and Table 10 summarize the changes to achieve the to-be scenario for the framework, considering a high interoperability scenario.

Table 9. To-be scenario for the dyad's set-up conditions.

BI perspective	Proposed improvements to the dyad's set-up conditions (to-be scenario)
Business strategy	• Negotiation of new service levels and the implementation of integrated systems.
Relationship management	• Partner's capability revision. • Frequent meetings to review cooperation. • Responsibility redefinition.

Table 10. To-be scenario for the dyad's processes and resources (human and technical).

BI	Proposed solutions to dyad's processes and resources by perspective (to-be scenario)		
Perspective	Buyer	Interface	Supplier
PI	• New procedure to perform complaints (see Figure 8).		
DI		Integration of SAP systems via EDI.	
HR	Additional users to handle complaints.		Additional users to after-sales service.
SSI	The use of SAP to place a re-order.	Integration of SAP systems via EDI.	
Acronyms: PI – Process interoperability; DI – Data interoperability; HR – Human resources; SSI – Software and services interoperability; OHI – Objects and hardware interoperability.			

5. Conclusions

The present paper contributes to business interoperability (BI) and supply chain management (SCM) literature, specifically related to buyer-supplier dyads. Accordingly, a research question (RQ) was raised: "How may buyer-supplier dyad be decomposed to reflect the business interoperability requirements and problems?".

To address the RQ, literature in BI was reviewed to determine how existing frameworks and models attempt to approach interoperability problems and the means to resolve them. In the analysis of those works, it was possible to conclude that existing frameworks and models address interoperability in different perspectives and at various levels of detail, having some overlapping concepts and gaps. To overcome this problem was proposed that the BI body-of-knowledge was organized using taxonomy. By relating the identified aspects, was proposed the Business Interoperability Decomposition Framework (BIDF). In BIDF were suggested two levels of detail in the BI decomposition. Moreover, literature in SCM was revised with regards to buyer-supplier dyads. It was accomplished that, according to the collaborative perspective of supply chains (SCs), the same unifying dimensions as in the BI are advocated in supply chain collaboration (SCC) literature. Hence, was possible to identify the main SCM constructs that support buyer-supplier relationships. These constructs help in answering RQ, by setting the perspectives under the SCM scope that establish a shared ground between SCM and BI. Those, in turn, can be employed to detail further the interoperability perspectives in buyer-supplier dyads, providing a business-context and existing solutions comprehended outside the BI body-of-knowledge (BoK).

In the realization of the case study, was possible to demonstrate the applicability of the BIDF to provide the interoperability setting in dyads and establish scenarios to either improve or scale-up collaboration. The proposed framework distinguishes from existing interoperability contributions by providing an integrated method to describe and solve BI interoperability problems. Despite existing literature provide several frameworks and models to characterize and assess interoperability, those contributions are either perspective-focused or provide their own decomposition of interoperability issues. The BIDF was proposed to reconcile the main interoperability perspectives that fit in BI. That allows a comprehensive view of interoperability permitting to relate BI aspects with existing literature and business-specific aspects.

Future work will concentrate in two parts. The first one will be the application of Axiomatic Design theory to work on interoperability perspectives' dependencies, and to provide a structured approach for interoperability problems solving. The last part aims at interoperability performance measurement. With this one, we are aiming at investigating the impact of interoperability in the dyad's performance. This will allow determining what are the best solutions to address the issues portrayed in BIDF perspectives and criteria. The systematic study of new interoperable solutions will permit to generate scenarios and, by measuring performance, one will be able to select the solution that delivers higher performance (optimal interoperability).

6. References

[1] K. Choon Tan, A framework of supply chain management literature, Eur. J. Purch. Supply Manag. 7 (2001) 39–48. doi:10.1016/S0969-7012(00)00020-4.

[2] I.J. Chen, A. Paulraj, Towards a theory of supply chain management: the constructs and measurements, J. Oper. Manag. 22 (2004) 119–150. doi:10.1016/j.jom.2003.12.007.

[3] L.C. Mondini, D.D.P.N. Machado, M.R.S. Scarpin, Dyad Buyer-Supplier and its Relation to Financial Performance, J. Oper. Supply Chain Manag. 7 (2014) 30–46.

[4] S. Blanc, Y. Ducq, B. Vallespir, Evolution management towards interoperable supply chains using performance measurement, Comput. Ind. 58 (2007) 720–732. doi:10.1016/j.compind.2007.05.011.

[5] G.S.S. Leal, W. Guedria, H. Panetto, Interoperability assessment: A systematic literature review, Comput. Ind. 106 (2019) 111–132. doi:10.1016/j.compind.2019.01.002.

[6] M.N. Huhns, L.M. Stephens, N. Ivezic, Automating supply-chain management, Proc. First Int. Jt. Conf. Auton. Agents Multiagent Syst. Part 3 - AAMAS '02. (2002) 1017. doi:10.1145/545058.545061.

[7] C. Legner, K. Wende, Towards an Excellence Framework for Business Interoperability, in: 19th Bled EConference EValues, Bled, Slovenia, 2006: pp. 1–16.

[8] R. Rezaei, T.K. Chiew, S.P. Lee, Z. Shams Aliee, Interoperability evaluation models: A systematic review, Comput. Ind. 65 (2013) 1–23. doi:10.1016/j.compind.2013.09.001.

[9] T.C. Ford, J.M. Colombi, S.R. Graham, D.R. Jacques, A Survey on Interoperability Measurement, 2003.

[10] IEEE, IEEE Standard Glossary of Software Engineering Terminology, (1990).

[11] I. Cabral, A. Grilo, Impact of Business Interoperability on the Performance of Complex Cooperative Supply Chain Networks : A Case Study, 2018 (2018).

[12] DoD, Levels of Information Systems Interoperability (LISI), 1998.

[13] A. Grilo, R. Jardim-Goncalves, V. Cruz-Machado, A framework for measuring value in business interoperability, 2007 IEEE Int. Conf. Ind. Eng. Eng. Manag. (2007) 520–524. doi:10.1109/IEEM.2007.4419244.

[14] T. Clark, R. Jones, L. Jones, C. Pty, Organisational interoperability maturity model for C2, in: Proc. 1999 Command Control Res. Technol. Symp., 1999. http://www.sei.cmu.edu/library/assets/orginteroper.pdf (accessed October 18, 2011).

[15] IDEAS, IDEAS project Deliverables (WP1-WP7), 2003. www.ideas-roadmap.net.

[16] ATHENA, DA1.4.1 Framework for the Establishment and Management Methodology, 2005.

[17] ATHENA, D.B3.1 Business Interoperability Framework, version 2.0, 2007.

[18] D. Chen, G. Doumeingts, F.B. Vernadat, Architectures for enterprise integration and interoperability: Past, present and future, Comput. Ind. 59 (2008) 647–659. doi:10.1016/j.compind.2007.12.016.

[19] F.B. Vernadat, Technical, semantic and organizational issues of enterprise interoperability and networking, Annu. Rev. Control. 34 (2010) 139–144. doi:10.1016/j.arcontrol.2010.02.009.
[20] J.C. Anderson, H. Håkansson, J. Johanson, Dyadic Business Relationships within a Business Network Context, J. Mark. 58 (1994) 1–15. doi:10.2307/1251912.
[21] I. Cabral, A. Grilo, A. Gonçalves-coelho, A. Mourão, An agent-based model for analyzing the impact of business interoperability on the performance of cooperative industrial networks, DATAK. (2015). doi:10.1016/j.datak.2015.08.001.
[22] E. Morris, L. Levine, C. Myers, P. Place, D. Plakosh, System of Systems Interoperability (SOSI), (2004) 67.
[23] M. Leite, Interoperability assessment, 1998. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA350577 (accessed October 23, 2013).
[24] A. Tolk, Beyond Technical Interoperability – Introducing a Reference Model for Measures of Merit for Coalition Interoperability, in: 8th Int. Command Control Res. Technol. Symp., 2003.
[25] D. Chen, N. Daclin, Barriers driven methodology for enterprise interoperability, Establ. Found. Collab. Networks. 243 (2007) 453–460. doi:10.1007/978-0-387-73798-0_48.
[26] IDABC, European Interoperability Framework - Version 2.0, 2010. http://ec.europa.eu/idabc/servlets/Doc4ee4.pdf?id=18060.
[27] ATHENA, D.B3.3 Interoperability Impact Analysis Model, 2007.
[28] NEHTA, Towards an Interoperability Framework Version 1.8, 2005.
[29] ATHENA, DA8.2 Guidelines and Best Practices for Applying the ATHENA Interoperability Framework to Support SME Participation in Digital Ecosystems, 2007.
[30] P. Kotzé, I. Neaga, Towards an Enterprise Interoperability Framework, Int. Jt. Work. Technol. Context. Bus. Process Manag. Adv. Enterp. Archit. Repos. Recent Trends SOA Based Inf. Syst. Conjunction with ICEIS 2010. (2010) 16–29. doi:10.1007/11552413_15.
[31] D. Chen, Enterprise Interoperability Framework, EMOI-INTEROP. (2006). http://ftp.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-200/19.pdf (accessed October 22, 2013).
[32] Y. Ducq, D. Chen, How to measure interoperability: Concept and Approach, 14th Int. Conf. …. (2008). http://www.ami-communities.net/pub/bscw.cgi/S4e4a7754/d494846/070 - 17.doc (accessed October 22, 2013).
[33] D. Chen, G. Doumeingts, European initiatives to develop interoperability of enterprise applications—basic concepts, framework and roadmap, Annu. Rev. Control. 27 (2003) 153–162. doi:10.1016/j.arcontrol.2003.09.001.
[34] C. Legner, B. Lebreton, Business interoperability research: Present achievements and upcoming challenges, Electron. Mark. 49 (2007) 176–186.
[35] G. Pedone, I. Mezgár, Model similarity evidence and interoperability affinity in cloud-ready Industry 4.0 technologies, Comput. Ind. 100 (2018) 278–286. doi:10.1016/j.compind.2018.05.003.
[36] H. Håkansson, D. Ford, How should companies interact in business networks?, J. Bus. Res. 55 (2002) 133–139. doi:DOI: 10.1016/S0148-2963(00)00148-X.
[37] H. Österle, E. Fleisch, R. Alt, Business Networking - Shaping Collaboration Between Enterprises, Second Rev, Springer Berlin Heidelberg, 2001.
[38] D. Simchi-Levi, P. Kaminsky, E. Simchi-Levi, Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies, 3rd Editio, McGraw-Hill/Irwin, New York, New York, USA, 2008.
[39] F. Contractor, P. Lorange, Why should firms cooperate? The strategy and economics basis for cooperative ventures, in: Coop. Strateg. Int. Bus., 1988: pp. 3–30. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Why+should+firms+cooperate?+The+strategy+and+economics+basis+for+cooperative+ventures#0.
[40] J.H. Dyer, N.W. Hatch, Relation-specific capabilities and barriers to knowledge transfers: creating advantage through network relationships, Strateg. Manag. J. 27 (2006) 701–719. doi:10.1002/smj.543.
[41] R. Nielsen, R. Nielsen, Cooperative strategy, Strateg. Manag. J. 9 (1988) 475–492. doi:10.1002/smj.4250090507.

[42] M.E. Porter, Competitive Advantage: creating and sustaining superior performance, First Edit, The Free Press, New York, New York, USA, 1998.
[43] J. Liu, S. Zhang, J. Hu, A case study of an inter-enterprise workflow-supported supply chain management system, Inf. Manag. 42 (2005) 441–454. doi:10.1016/j.im.2004.01.010.
[44] A. Paulraj, I.J. Chen, J. Flynn, Levels of strategic purchasing: Impact on supply integration and performance, J. Purch. Supply Manag. 12 (2006) 107–122. doi:10.1016/j.pursup.2006.08.002.
[45] M. Cao, Q. Zhang, Supply chain collaboration: Impact on collaborative advantage and firm performance, J. Oper. Manag. 29 (2011) 163–180. doi:10.1016/j.jom.2010.12.008.
[46] M. Wandfluh, E. Hofmann, P. Schoensleben, Financing buyer–supplier dyads: an empirical analysis on financial collaboration in the supply chain, Int. J. Logist. Res. Appl. 5567 (2015) 1–18. doi:10.1080/13675567.2015.1065803.
[47] A. Paulraj, A.A. Lado, I.J. Chen, Inter-organizational communication as a relational competency: Antecedents and performance outcomes in collaborative buyer-supplier relationships, J. Oper. Manag. 26 (2008) 45–64. doi:10.1016/j.jom.2007.04.001.
[48] K. Yeung, T.C.E. Cheng, P.K.C. Lee, Buyers' perceptions on the impact of strategic purchasing on dyadic quality performances, Int. J. Prod. Econ. 168 (2015) 321–330. doi:10.1016/j.ijpe.2015.07.005.
[49] A.S. Carr, J.N. Pearson, The impact of purchasing and supplier involvement on strategic purchasing and its impact on firm's performance, Int. J. Oper. Prod. Manag. 22 (2002) 1032–1053. doi:10.1108/01443570210440528.
[50] A. De Toni, Buyer-supplier operational practices, sourcing policies and plant performances: Results of an empirical research, Int. J. Prod. Res. 37 (1999) 597–619. doi:10.1080/002075499191698.
[51] C.K. Hahn, P.A. Pinto, D.J. Brag, Just-in-time production and purchasing, J. Purch. Mater. Manag. Fall (1983) 2–10.
[52] H. Shin, D.A. Collier, D.D. Wilson, Supply management orientation and supplier/buyer performance, J. Oper. Manag. 18 (2000) 317–333. doi:10.1016/S0272-6963(99)00031-5.
[53] G.N. Nyaga, J.M. Whipple, D.F. Lynch, Examining supply chain relationships: Do buyer and supplier perspectives on collaborative relationships differ?, J. Oper. Manag. 28 (2010) 101–114. doi:10.1016/j.jom.2009.07.005.
[54] R. Terpend, B.B. Tyler, D.R. Krause, R.B. Handfield, Buyer-supplier relationships: Derived value over two decades, J. Supply Chain Manag. 44 (2008) 28–55. doi:10.1111/j.1745-493X.2008.00053.x.
[55] J.P. Cannon, P.M. Doney, M.R. Mullen, K.J. Petersen, Building long-term orientation in buyer-supplier relationships: The moderating role of culture, J. Oper. Manag. 28 (2010) 506–521. doi:10.1016/j.jom.2010.02.002.
[56] V. Villena, N. H., E. Revilla, T.Y. Choi, The dark side of buyer-supplier relationships: A social capital perspective, J. Oper. Manag. 29 (2011) 561–576. doi:10.1016/j.jom.2010.09.001.
[57] K.S. Hald, C. Cordón, T.E. Vollmann, Towards an understanding of attraction in buyer-supplier relationships, Ind. Mark. Manag. 38 (2009) 960–970. doi:10.1016/j.indmarman.2008.04.015.
[58] M.-S. Cheung, M.B. Myers, J.T. Mentzer, The value of relational learning in global buyer-supplier exchanges: a dyadic perspective and test of the pie-sharing premise, Strateg. Manag. J. 32 (2008) 1061–1082.
[59] C. Prahinski, W.C. Benton, Supplier evaluations: Communication strategies to improve supplier performance, J. Oper. Manag. 22 (2004) 39–62. doi:10.1016/j.jom.2003.12.005.
[60] J. Guo, Business-to-business electronic market place selection, Enterp. Inf. Syst. 1 (2007) 383–419. doi:10.1080/17517570701648109.
[61] H. Van Der Veer, A. Wiles, Achieving Technical Interoperability - the ETSI Approach, Cedex, France, 2008.
[62] R. Rezaei, T. Chiew, S. Lee, A review of interoperability assessment models, J. Zhejiang Univ. Sci. C. 14 (2013). doi:10.1631/jzus.C1300013.
[63] A. Zutshi, A. Grilo, R. Jardim-Gonçalves, The Business Interoperability Quotient Measurement Model, Comput. Ind. 63 (2012) 389–404. doi:10.1016/j.compind.2012.01.002.
[64] J. Dahmann, M. Salisbury, HLA and beyond: Interoperability challenges, Inf. Secur. 3 (1999). http://kms1.isn.ethz.ch/serviceengine/Files/ISN/849/ichaptersection_singledocument/EA0AC5

B5-3B36-44E8-942B-30D3FDDE2A05/en/doc_851_259_en.pdf (accessed October 1, 2013).
[65] A. Tolk, J.A. Muguira, The levels of conceptual interoperability model, System. (2003) 1–11. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.76.8795&rep=rep1&type=pdf (accessed October 17, 2011).
[66] U. Greiner, C. Legner, S. Lippe, K. Wende, Business interoperability profiles: relating business interoperability issues to technical interoperability solutions, in: Enterp. Interoperability II, 2007: pp. 865–877.
[67] G.-W. Bock, R. Zmud, Y. Kim, J.-N. Lee, Behavioral intention formation in knowledge sharing: examining the roles of extrinsic motivators, social-psychological forces, and organization climate, MIS Q. 29 (2005) 87–111. doi:Article.
[68] S. Koussouris, F. Lampathaki, Digging into the real-life enterprise interoperability areas definition and overview of the main research areas, in: Proc. CENT 2011 Collab. Enterp. 2011 - Platforms, Process. Pract. Adv. Enterp. 2.0, 2011. http://www.iiis.org/CDs2011/CD2011SCI/CENT_2011/PapersPdf/ZB589UA.pdf (accessed October 25, 2013).
[69] P. Gottschalk, Maturity levels for interoperability in digital government, Gov. Inf. Q. 26 (2009) 75–81. doi:10.1016/j.giq.2008.03.003.
[70] S. Elfving, Managing Collaborative Product Development - A Model for Identifying Key Factors in Product Development Projects, 2007.
[71] C. Campos, R. Chalmeta, R. Grangel, R. Poler, Maturity Model for Interoperability Potential Measurement, Inf. Syst. Manag. 30 (2013) 218–234. doi:10.1080/10580530.2013.794630.
[72] A. Berre, B. Elvesæter, N. Figay, C. Guglielmina, G. Johnsen, D. Karlsen, T. Knothe, S. Lippe, The ATHENA Interoperability Framework, in: 3th Int. Conf. Interoperability Enterp. Softw. Appl. IESA 2007, Funchal, Madeira Island, Portugal, 2007: pp. 569–580.
[73] L.E. Whitman, H. Panetto, The missing link: Culture and language barriers to interoperability, Annu. Rev. Control. 30 (2006) 233–241. doi:10.1016/j.arcontrol.2006.09.008.
[74] M. Dassisti, D. Chen, Interoperability Analysis: General Concepts for an Axiomatic Approach, in: R. Meersman, T. Dillon, P. Herrero (Eds.), Move to Meaningful Internet Syst. OTM 2011 Work. SE - 13, Springer Berlin Heidelberg, 2011: pp. 49–60. doi:10.1007/978-3-642-25126-9_13.
[75] J.J. Alfaro, R. Rodriguez-Rodriguez, M.J. Verdecho, A. Ortiz, Business process interoperability and collaborative performance measurement, Int. J. Comput. Integr. Manuf. 22 (2009) 877–889. doi:10.1080/09511920902866112.
[76] K. Riemer, S. Klein, Network Management Framework, in: S. Klein, A. Poulymenakou (Eds.), Manag. Dyn. Networks, Springer, 2006: pp. 17–66.
[77] C.H. Asuncion, M. Van Sinderen, Pragmatic interoperability: A systematic review of published definitions, in: P. Bernus, G. Doumeingts, M. Fox (Eds.), Enterp. Archit. Integr. Interoperability, Springer Boston, 2010: pp. 164–175.
[78] D. Sarantis, Y. Charalabidis, J. Psarras, Towards standardising interoperability levels for information systems of public administrations, EJETA Spec. Issue “Interoperability Enterp. Adm. Worldwide.” (2008). http://pubs.mantisintel.com/ejeta-special-08may-5.pdf (accessed October 24, 2013).
[79] R. Jardim-goncalves, C. Agostinho, J. Sarraipa, A. Grilo, Reference framework for enhanced interoperable collaborative networks in industrial organisations, (2012) 37–41.
[80] M. Wulan, D. Petrovic, A fuzzy logic based system for risk analysis and evaluation within enterprise collaborations, Comput. Ind. 63 (2012) 739–748. doi:10.1016/j.compind.2012.08.012.
[81] L.Y. Pang, R.Y. Zhong, J. Fang, G.Q. Huang, Data-source interoperability service for heterogeneous information integration in ubiquitous enterprises, Adv. Eng. Informatics. (2015). doi:10.1016/j.aei.2015.04.007.
[82] W. Guédria, Y. Naudet, D. Chen, Maturity model for enterprise interoperability, Enterp. Inf. Syst. (2013) 1–28. doi:10.1080/17517575.2013.805246.
[83] D. Chen, B. Vallespir, N. Daclin, An Approach for Enterprise Interoperability Measurement, Proc. MoDISE-EUS 2008 Concepts. (2008) 1–12.
[84] F.B. Vernadat, Interoperable enterprise systems: Principles, concepts, and methods, Annu. Rev. Control. 31 (2007) 137–145. doi:10.1016/j.arcontrol.2007.03.004.

[85] G. Gionis, Y. Charalabidis, Enabling Cross-Border Interoperability: Modelling Legal Rules for Electronic Transactions in the European Union, Enterp. Interoperability II New Challenges Approaches. (2007) 361–364. http://link.springer.com/content/pdf/10.1007/978-1-84628-858-6_40.pdf (accessed November 8, 2013).
[86] P. Espadinha-Cruz, M. do R. Cabrita, Integrating Knowledge Management and Business Interoperability: A Scenario Framework, in: 19th Eur. Conf. Knowl. Manag., 6–7 September 2018, Padua, Italy, 2018.
[87] T. Ritter, A framework for analyzing relationship governance, J. Bus. Ind. Mark. 22 (2007) 196–201. doi:10.1108/08858620710741904.
[88] D.T. Wilson, An integrated model of buyer-seller relationships, J. Acad. Mark. Sci. 23 (1995) 335–345.
[89] M. Wulan, D. Petrovic, A fuzzy logic based system for risk analysis and evaluation within enterprise collaborations, Comput. Ind. (2012).
[90] G. Harmel, E. Bonjour, M. Dulmet, Product, processes and organization architectures modeling: from strategic expectatiosn to strategic competences, in: 12th IFAC Symp. Inf. Control Probl. Manuf. INCOM'06., Saint- Etienne Fr., 2006: pp. 1–8.
[91] N. Gershenfeld, R. Krikorian, D. Cohen, The Internet of things., 2004. doi:10.1038/scientificamerican1004-76.
[92] E. Curry, System of systems information interoperability using a linked dataspace, 2012 7th Int. Conf. Syst. Syst. Eng. (2012) 101–106. doi:10.1109/SYSoSE.2012.6384200.
[93] C. Chen, C. Lin, S. Huang, A fuzzy approach for supplier evaluation and selection in supply chain management, Int. J. Prod. Econ. 102 (2006) 289–301.
[94] P. Espadinha-Cruz, A. Grilo, R. Puga-Leal, V. Cruz-Machado, A model for evaluating Lean, Agile, Resilient and Green practices interoperability in supply chains, in: Ind. Eng. Eng. Manag. IEEM 2011, Singapore, 2011: pp. 1209–1213. doi:10.1109/IEEM.2011.6118107.
[95] M. Razavi, F.S. Aliee, An Approach towards Enterprise Interoperability Assessment, in: R. Poler, R and VanSinderen, M and Sanchis (Ed.), Enterp. INTEROPERABILITY, Proc., 2009: pp. 52–65.
[96] A. Zutshi, A. Grilo, R. Jardim-Goncalves, The business interoperability quotient measurement model, Comput. Ind. 63 (2012) 389–404. doi:10.1016/j.compind.2012.01.002.
[97] C. Giller, S. Matear, The termination of inter-firm relationships, J. Bus. Ind. Mark. 16 (2001) 94–112. doi:10.1108/08858620110384132.
[98] J. Guo, Business Interoperability on E-Marketplace, Res. Pract. Issues Enterp. Inf. Syst. 154 (2008) 257–267. http://link.springer.com/chapter/10.1007/978-0-387-75902-9_26 (accessed September 4, 2013).
[99] A. Tolk, Beyond technical interoperability-introducing a reference model for measures of merit for coalition interoperability, Old Dom. Univ Norfolk Va. (2003).
[100] K. Wende, C. Legner, Evolution of business interoperability in the automotive industry, in: Proceeding Conf. Exploit. Knowl. Econ. - Issues, Appl. Case Stud., 2006: pp. 239–246.
[101] D. Mensh, R. Kite, P. Darby, A methodology for quantifying interoperability, Nav. Eng. J. (1998).
[102] V. Pazos Corella, R. Chalmeta Rosaleñ, D. Martínez Simarro, SCIF-IRIS framework: a framework to facilitate interoperability in supply chains, Int. J. Comput. Integr. Manuf. 26 (2013) 67–86. doi:10.1080/0951192X.2012.681912.
[103] M. Camara, Y. Ducq, R. Dupas, Methodology for Prior Evaluation of Interoperability, in: PRO-VE 2010, Saint Etienne, 2010: pp. 697–704. doi:10.1007/978-3-642-15961-9_82.
[104] M.S. Camara, Y. Ducq, R. Dupas, A methodology for the evaluation of interoperability improvements in inter-enterprises collaboration based on causal performance measurement models, Int. J. Comput. Integr. Manuf. (2013) 1–17. doi:10.1080/0951192X.2013.800235.
[105] G. Harmel, E. Bonjour, M. Dulmet, Product, organisation and processes architectures modeling: From strategic expectations to strategic competencies, in: 12th IFAC Symp. Inf. Control Probl. Manuf. INCOM'06., Saint- Etienne Fr., 2006: pp. 1–8.
[106] S.B. Brunnermeier, S.A. Martin, Interoperability costs in the US automotive supply chain, Supply Chain Manag. An Int. J. 7 (2002) 71–82.
[107] R. Klischewski, H.J. Scholl, Information quality as a common ground for key players in e-

Government integration and interoperability, Proc. Annu. Hawaii Int. Conf. Syst. Sci. 4 (2006) 72. doi:10.1109/HICSS.2006.221.
[108] B. Lebreton, C. Legner, Interoperability Impact Assessment Model: An Overview, in: Enterp. Interoperability II, 2007: pp. 0–3. http://link.springer.com/content/pdf/10.1007/978-1-84628-858-6_79.pdf (accessed October 9, 2013).
[109] M. Kasunic, Measuring Systems Interoperability, Greensboro Drive, 2001. Carnegie Mellon University.
[110] N. Daclin, D. Chen, B. Vallespir, Enterprise interoperability measurement - Basic concepts, Proc. EMOI. (2006) 1–5. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.86.7162&rep=rep1&type=pdf.
[111] W.C. Benton, M. Maloni, The influence of power driven buyer/seller relationships on supply chain satisfaction, J. Oper. Manag. 23 (2005) 1–22. doi:10.1016/j.jom.2004.09.002.