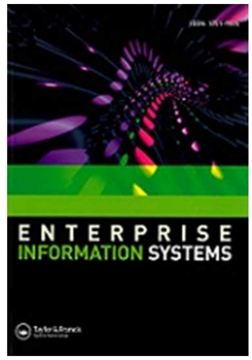

An Axiomatic Design framework to design interoperable buyer-supplier dyads

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Abstract

Cooperation arrangements as in buyer-supplier dyads are a form companies found to deal with the current competition environment. Business interoperability (BI) is an ability that makes such cooperation possible in order to achieve meaningful exchanges to create value. Nevertheless, interoperability problems have a negative impact in cooperation ranging from organisational to technical issues that rule interaction. Though, despite the contributions in interoperability literature, there is lack for a cohesive framework that allows the systematization of solutions for in interoperable problems in such cooperation, in all the scope if BI. In that sense, the present article proposes a framework to allow systematically detailing interoperability problems and provide solutions that fit the firms' conditions. Following an axiomatic design (AD) approach, a framework was proposed to support the design of buyer-supplier dyad. A case study in an automotive buyer-supplier dyad was conducted to demonstrate the application of both frameworks in practice. It was possible to achieve a better interoperable scenario by systematically addressing interoperability issues and study interoperable solutions that most comply with the AD independence axiom.

Keywords: Business interoperability, SCM, buyer-supplier dyads, axiomatic design, independence axiom

1. Introduction

Due to fierce competition, cooperative networks of value creation are established to achieve competitive advantage (Legner & Wende, 2006). Supply chains (SC) can be described as a cooperative network where supply chain management (SCM) focuses on how firms integrate and coordinate processes, use technology, and share knowledge and resources, treating all members of the value chain as an unified business entity (Choon Tan, 2001). Buyer-supplier dyads are distinguished among those kinds of cooperation as the simplest form of interaction to achieve effective management upstream SC (I. J. Chen & Paulraj, 2004). This relationship is emphasized under the concept of collaborative advantage, whereas the dyad struggles for win-win relationships with mutual benefits achieving competitive synergy (Mondini, Machado, & Scarpin, 2014). Business Interoperability (BI) is the condition that makes possible for this kind of cooperation to achieve meaningful transactions to fulfil the objectives and create value (Blanc, Ducq, & Vallespir, 2007). Legner & Wende (2006) which defined BI 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". 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 (Huhns, Stephens, & Ivezic, 2002). Nevertheless, lack of interoperability affects digital-based business relationships. As the coverage of BI ranges from organisational to technical aspects of interaction (Rezaei, Chiew, Lee, & Shams Aliee, 2013), interoperability 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 end-customer. Interoperability problems may ultimately propagate to the all SC, and can result in phenomena as unpredictable demand that may lead to the Bullwhip effect. According to Grilo, Jardim-Goncalves, & Cruz-Machado (2007), dealing with business context issues has been the greater challenge in interoperability. Existing literature on interoperability and BI provide mostly frameworks and models to help in problem identification and quantification, and few of them address the issue of design of interoperable systems and cooperation. Nonetheless, there is a lack for an integrated framework that allows one to systematically address interoperability problems and provide solutions that fit the business-context of cooperation, such in case of buyer-supplier dyads. So, the objective of this research is to propose a framework to address interoperability issues and provide solutions, keeping the structural integrity of the interactions in the dyad, in order to design solutions that fit the business interoperability requirements. Accordingly, a research question was proposed "How to systemize the design of buyer-supplier dyads to improve interoperability and keep the relationship integrity?" (RQ).

In order to accomplish the RQ, we investigated the theoretical background on BI, were we reviewed the main interoperability perspectives that rule interaction between peers. Next, our research focused on addressing interactions in buyer-supplier dyads. We aimed at reviewing supply chain management (SCM), and supply chain collaboration to identify SCM constructs that rule buyer and supplier interaction. Last, we review the subject of design in interoperability, in order to integrate the findings from BI and SCM literature into the final proposition of this article.
The article is structured in the following sections: in section 2, we review literature in interoperability definitions, buyer-supplier dyads, interoperability frameworks, interoperability design, and in axiomatic design; in section 3 we propose two frameworks two help in systemizing the detail of interoperability issues and in designing interoperable buyer-supplier dyads; in section 4, a case study is presented whereas the proposed frameworks were tested; last, in section 5 the conclusions to this research are presented.

2. Business Interoperability in buyer-supplier dyads

2.1 Inter-firm relationships: the buyer-supplier dyads

Business interoperability (BI) describes the relationships between an enterprise and its business partners, such as customers, suppliers or external service providers. In the context of SCM, interoperability is seen as a strong asset to achieve competitivity (Blanc et al., 2007). It allows to execute SC operations seamlessly, easing their alignment and information flow (Espadinha-Cruz, Grilo, Puga-Leal, & Cruz-Machado, 2011). Though, while SCM looks to internal and external perspectives of SC, BI addresses business relationships of two or more actors and, as consequence, is related to the external perspective of SC, commonly known as SC collaboration (SCC).
Collaboration in SCs is shaped in the interactions: dyadic, horizontal, lateral, market and hierarchy-oriented (Otto & Kotzab, 2003). The dyad is the simplest form of interaction in SC. Each one of them is unique characterised by a set of human resources and technical capabilities (Håkansson & Ford, 2002). The improvement of cooperation in each dyad is of paramount importance to achieve improvements in the whole SC and supply network. In SCs two dyads are distinguished: buyer-supplier and customer-seller dyads. Mondini, Machado, & Scarpin (2014) stresses the importance of strategic relationship between buyers and suppliers.
Cooperation in dyads is settled on the notion of "collaborative advantage" defended by (I. J. Chen & Paulraj, 2004; Contractor & Lorange, 1988; Dyer & Hatch, 2006; Nielsen & Nielsen, 1988). In opposition to the competitive advantage (Porter, 1998), SC suppliers and customers are viewed as partners instead of adversaries with the objective of maximizing competitiveness and profit for the individual company as well as the entire SC network (Liu, Zhang, & Hu, 2005). Mondini et al. (2014) further adds that buyer-supplier relationships must be fostered to achieve a process of competitive synergy, where both plot a horizon of opportunities.
The interaction between buyer and supplier is addressed in SCC literature through SCM constructs or practices that aim at win-win situations supported by partners collaboration and, ultimately, achieve synergies to compete with other chains. In section 3.1.3 we explore those constructs in more detail.
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 only refer 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 supports SC activities. 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 supports the interaction.

2.2 Interoperability frameworks and interoperability perspectives under BI

In interoperability literature, frameworks and models became a pillar for sustainable interoperability setting between companies. At some extent, frameworks provide the main drivers for companies' interaction and different perspectives of the subject. 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 (Vernadat, 2010). Ultimately, they allow to identify the requirements for digital-based business set up and qualify and quantify interoperability, and the means to achieve interoperable solutions, either by problem identification or modeling. In this research, we based on frameworks that fit the scope of BI, and refer to the different perspectives, criteria and requirements for business interaction.

The Levels of Information Systems Interoperability (LISI) was proposed by (DoD, 1998) combines maturity levels with the attributes of the system. Each level recommends the capabilities that should cover the enabling attributes known as PAID (D. Chen, Doumeingts, & Vernadat, 2008): procedures (P); application (A); infrastructure (I); and data (D). 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 is summed up in an interoperability profile that characterizes the level of interoperability and allows determining the interoperability setting of a system towards another. Later, the Organizational Interoperability Maturity Model (OIM) (Clark, Jones, Jones, & Pty, 1999) added five organizational maturity levels to LISI, allowing one to assess qualitatively interoperability and may contribute to trace interoperability profiles of dyads.

The Layers of coalition interoperability (LCI) (Tolk, 2003b), introduced 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 (Ford, Colombi, Graham, & Jacques, 2003). At the center of the model, the knowledge perspective joins together organizational and technical perspectives.

The IDEAS interoperability framework (IDEAS, 2003) extended the concepts of interoperability to the business perspective, proposing three main layers - Business, Knowledge and ICT - with two additional transversal dimensions - Semantics and Quality attributes (D. Chen & Daclin, 2007). This was the first model to introduce the business perspective close to the definition of BI.

The European interoperability framework (EIF) (IDABC, 2010) considers three aspects of interoperability: technical, semantic and organization interoperability (ATHENA, 2007b). EIF provides decomposition in these three factors addressing the main problems raised on public administration, through exposition of the common 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 (NEHTA, 2005).

The Enterprise Interoperability Maturity Model (EIMM) (ATHENA, 2005) is a method to scale-up interoperability using an enterprise modelling approach. The novelty of this maturity model is the three dimensional model complemented by a set of interoperability practices that establish the path to improve interoperability (ATHENA, 2007c; Berre et al., 2007). 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. EIMM proposes a procedure to apply its framework. It consists in an iterative process to identify the main problems to interoperability improvement, and model the adequate solution.

The business interoperability framework (BIF) (ATHENA, 2007a; Legner & Wende, 2006) is a business-centered framework which provides criteria that outline the key business decisions companies have to solve when establishing interoperable electronic business relationships (Legner & Wende, 2006). BIF describes the business interoperability settings that correspond to a business maturity state for a specific category, criterion and life-cycle stage.

The Enterprise Interoperability Framework (INTEROP) (D. Chen, 2006) has the underlying assumption that enterprises are not interoperable because of barriers to interoperability (D. Chen, 2006). INTEROP defines three basic dimensions concerning enterprise interoperability (Ducq & Chen, 2008): 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 different ways in which barriers can be removed (integrated, unified, and federated).

Throughout the proposed frameworks, it is remarked that despite interoperability is defined as an ability of systems and organizations, authors mostly refer to it as a problem that has to be dealt with every time a system or a business relationship needs to be set-up or improved (Cabral, Espadinha-Cruz, Grilo, Mourão, & Gonçalves-Coelho, 2013; Espadinha-Cruz et al., 2011).

Interoperability decomposition is another trend found in those frameworks. Zutshi, Grilo, & Jardim-Gonçalves (2012) argue that, with the broader user of technology, a multitude of interoperability issues have to be solver at higher levels in order to allow seamless collaboration. Hence, authors frequently propose a decomposition framework enforcing the idea that, accomplishing these smaller terms, interoperability is achieved (D. Chen & Doumeingts, 2003). That culminated in several definitions of interoperability, and derivate types. Though, as remarked by Rezaei et al. (2013), interoperability frameworks vary significantly in the way they address interoperability issues.

2.3 The state-of-play in interoperable systems design

Despite the culmination of new technologies and the awareness for interoperability problems, interoperability is not seen as a strong requirement within information systems design (Curry, 2012), or as a requirement for business set up (Pazos Corella, Chalmeta Rosaleñ, & Martínez Simarro, 2013). Most of the existing research concentrates in forms to qualify and measure interoperability, with the objective of improving existing conditions towards a more efficient system. The existing research in interoperable systems design is limited and, mostly, dedicated to technical aspects of interoperability, such as IT architectures, software design, semantics, ontologies and interfaces of communication. Few research address the design of interoperable systems approaching the multidisciplinary perspective of BI.

The work that relates the most with BI is provided by Business Interoperability Framework (BIF) (Legner & Wende, 2006). It parted from an enterprise center vision and provided the knowledge to comprehend BI, and the main decisions to accomplish in each level of interoperability. The qualitative methods provide the interoperability infrastructure and the influence map that each decision taken to achieve interoperability. Those methods constitute guidelines to accomplish interoperable systems. Nevertheless, BIF focus on improvement rather than establishing requirements to design an interoperable cooperation.

In the work from Dassisti et al. (2010), design principles are suggested to assure interoperability in cooperating companies in the SC context. Those principles were created under the concept developed on the INTEROP framework (D. Chen, 2006), defending the position that the use of design principles to design interoperability is an alternative approach compared to holistic approaches (Dassisti et al., 2010). They proposed eight design principles that encompass the interoperating companies and systems identification, the identification of reference frameworks for interacting patterns, establish a meta-model and a decisional-model, check consistency between them, aggregate various decision-makers, and avoid inconsistencies. Although this approach is provided in a comprehensive manner, encompassing the adequate interaction patterns between actors in SC, it lacks a systematic view to incorporate interoperability factors and their influence in performance. Nevertheless, this reference gives a great contribution in identifying the main needs of SCM interactions in a decisional approach. The incorporation of business-specific interacting patterns such as SCOR with the design principles and a meta-model, allows accompanying the design process ensuring consistency with objectives.

Still in the context of the INTEROP framework, the authors from (Dassisti & Chen, 2011) proposed an axiomatic approach to interoperability design. The premise for the approach is the Axiomatic Design Theory (AD) (Suh, 1990), being recognized by Dassisti & Chen (2011) that axiomatic approach was preferred to provide a structured path to design an interoperable system, allowing to approach concepts not yet fixed. Hence, the authors proposed 5 axioms to design from a low detail (high level) concept, addressing the companies' interaction and the reference framework that rules the interaction, to a high detail (low level) model, whereas modelling approaches represent the interoperability problem and present modelling solutions, both to process and data problems.

Although, the proposed model is problem-centered, leaving outside another interoperability aspects that reflect the interoperability complexity, the authors are not explicit in forms to incorporate another interoperability issues, as well as the means to deal with interoperability complexity. Also, the authors follow an axiomatic approach, providing their own axioms and systematic approach instead of implementing a design solution based on AD.

A different approach to the problem of designing interoperable systems in SCM is provided by Pazos Corella et al. (2013). The authors propose the SCIF-IRIS framework and a methodology to improve interoperability in the current SC's systems in terms of business, processes, technologies and semantics. The authors portray a different perspective to the interoperability design approach, by aiming at defining tasks, techniques and modelling languages that accompany the improvement methodology. Hence, they propose 5 phases: conceptual definition; collaborative network modelling; diagnostic and improvement; implementation; and execution and monitoring. The procedure acts as a concurrent design to define the adequate solutions for the SC, and makes use of an implementation procedure to accompany the transition from the previous to a new solution. The execution of the new system is monitored with the aid of a decision support system, which consist in a performance measurement system that acts at business, process management, knowledge, human resources, ICT and semantics perspectives.

Although SCIF-IRIS isn't a top-down design method, the guided implementation and subsequent performance measurement are some of the main contributions of this framework. Also, SCIF-IRIS acts on a multidimensional perspective of interoperability (addressing relationship management, hardware and services, human resources, knowledge management and process), instead of focusing in a specific domain.

2.3.1 Challenges in interoperable systems design

According to Suh (1990), design involves a continuous interplay between what we want to achieve and how we want to achieve it. Designing a system with objective of being interoperable in technical and organizational aspects is a difficult accomplishment due to the nature of the interoperability problem. An interoperable system should be perceived as much about technology as it is about people, organizations and strategies (Pazos Corella et al., 2013; Tolk, 2003a; Vernadat, 2007). IT acts as a strong driving force in business interactions, but technological improvement and innovation is meaningless if other core aspects of business collaborations are not interoperable (ATHENA, 2007a). Consequently, the design of interoperable systems should be made in a multidisciplinary manner and not on a single technical perspective. Every BI aspect drives the company's interactions towards different performance results (Legner & Wende, 2006). So, a design method should cope with this multidisciplinary perspective.

Complexity is another issue one as to cope with when designing a system with the objective of being interoperable. Though, conciliating a multi-perspective approach can be a challenge due to its complexity. Some issues are well documented in theoretical frameworks, but another ones lack detail to describe each interoperability problem. Pazos Corella et al. (2013) further adds that, besides some proposed frameworks make a good point concerning an interoperability issue, they fail to solve the problems found in these kinds of projects.

Another feature of interoperability issues is that they are context-dependent. Organizations and information systems are dichotomous paradigm. Both serve to achieve a certain goal in a specific purpose (Hevner, March, Park, & Ram, 2004). Thus, understanding the business context of the organizations' interactions and their supporting systems is a necessity (Dassisti & Chen, 2011; Dassisti et al., 2010). Because companies are not designed to be interoperable with one another, but to support most of their internal functions (Pazos Corella et al., 2013). Hence, the identification of specific needs for businesses, as well as the identification of reference models for each kind of interaction is crucial guidelines in the establishing effective interoperability between systems.

2.4 Axiomatic design as a solution to design interoperable systems

Axiomatic Design Theory (AD) (Suh, 1990) is the engineering design approach suggested in this research. AD makes possible to achieve a good design, keeping structural integrity of the system, allowing the systematic deepening on every functional aspect of the design.

According to AD, every design objective can be depicted in four design domains (Gonçalves-Coelho & Mourão, 2007): the customer, the functional, the physical and the process domains. The design object is described in the customer domain by the customer needs (CNs), in the functional domain by the functional requirements (FRs), in the physical domain, by the design parameters (DPs), and in the process domain by the process variables (PVs) (Suh, 2001).

The procedure of relating CNs, FRs, DPs and PVs is called mapping (Suh, 1990). Mapping from the customer to the functional domain is currently named "conceptual design"; from the functional to the physical domain, one has "product design"; and "process design" means moving from the physical to the process domain (Gonçalves-Coelho & Mourão, 2007). The design process involves interlinking

the design domains at every hierarchical level of the design process (Suh, 1990). This is developed in a top-bottom way, beginning at the system level and continuing through levels of more detail until the point that the design object is clearly represented (Gonçalves-Coelho & Mourão, 2007).
To keep the integrity of the design and aim at a better solution for a problem, designs are evaluated according to their compliance with the axioms, which inherently incorporates the degree of achieving the functional requirements (Brown, 2005). The independence axiom (axiom 1) states that the optimal design is the one who maintains the independence of FRs. Hence, the best design will be the one represented by an uncoupled matrix. The information axiom (axiom 2) states that one with the highest probability of success is the best design (Suh, 1998).
The application of the axioms fits the scope of interoperability improvement, either by providing new design solutions – independence axiom - or decide which solution provides a better result – information axiom.

3. Axiomatic design framework to address interoperability in buyer-supplier dyads

Based on literature findings, two propositions were made to answer the research questions. The first one attempts to provide a framework do detail and understand each business interoperability perspective that drive interaction between peers. The second contribution uses the first framework to assist in the design of dyads.
In our previous research, we systematized the BI body-of-knowledge (BoK) in order to reconcile the different perspectives proposed in literature (Espadinha-Cruz, 2016; Espadinha-Cruz, Grilo, Gonçalves-Coelho, & Mourão, 2018). The objective was to organize the BI BoK and provide the main interoperability perspectives to address business interaction in dyads. Hence, we proposed the business interoperability decomposition framework (BIDF) (see Figure 1).

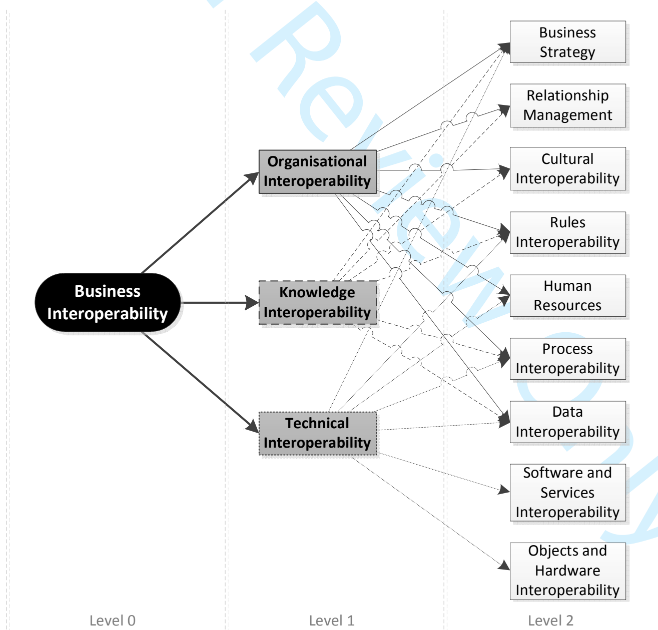


Figure 1. Business Interoperability decomposition framework (BIDF).

While BIDF allows one to understand decision-making in each of the BI perspectives, the complexity of the issues raised in business set-up or improvement makes necessary an approach that can deal with the complexity and diversity of subjects in the dyads. In that sense, the selected approach to design interoperable buyer-supplier dyads is the axiomatic design theory (AD) (Suh, 1990). AD was selected due to making possible to achieve a good design, keeping the structural integrity of the system, allowing the systematic deepening on every functional aspect of the design. AD permits to map from the conceptual design to the physical and process designs, where BI conditions are translated in physical implications for the dyad and the process variables (PVs) that enable them. In Figure 2 is presented the main framework that represents the buyer-supplier design and the respective vertical and horizontal decompositions.

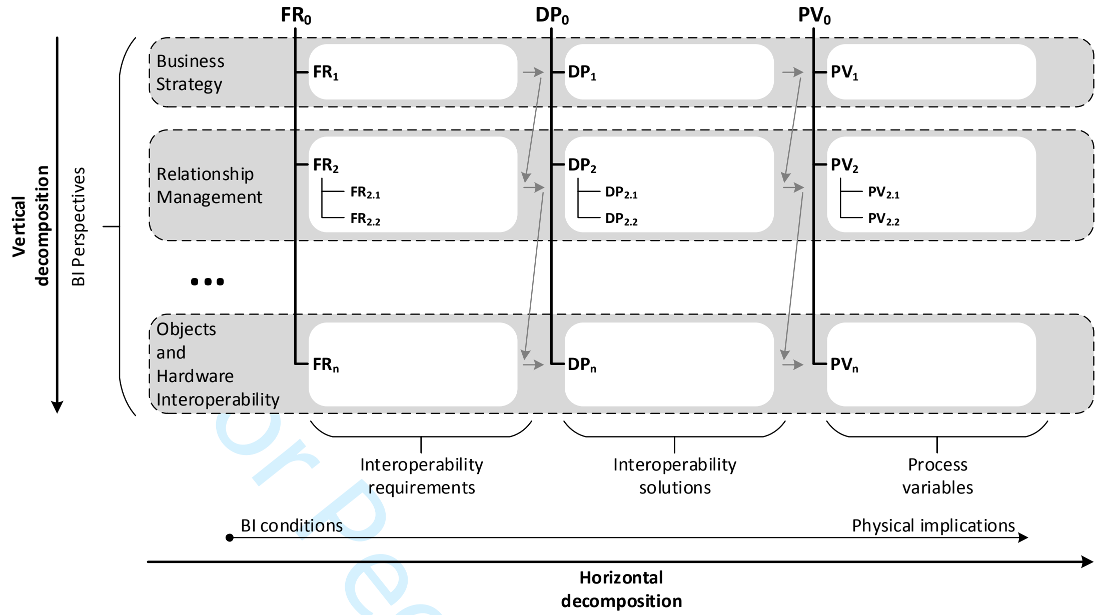


Figure 2. AD framework for interoperable buyer-supplier dyads.

To achieve the so-called good design of the interoperable buyer-supplier dyad, one has to determine the objective of the design, describe the vertical and horizontal mappings and establish the matrices for the interactions between functional requirements (FRs), design parameters (DPs) and process variables (PVs). At the utmost objective, the customer need (CN) can be stated as: "Achieve optimal interoperability in the buyer-supplier dyad". This CN can be adapted to a more specific objective, depending on the dyad's interaction context. Subsequent mapping on the functional, physical and process domains should aim at this CN to detail the requirements and physical and process implications to achieve it.

The vertical decomposition refers to the BI perspectives mapped from BS to OHI. BI conditions are mapped from strategic to technological perspectives, having processes at the core of the method. BS, RM and RI give the main business setup conditions and guidelines for processes (addressed in PI), while HR, CI, DI, SSI and OHI are addressed with respect to the process (or operation) they belong to. In this manner, only the aspects that refer to the CN are addressed subsequently in each BI perspective. Thus, the proposed sequence for the decomposition starts layering from BS to PI, and subsequent perspectives are made with regards to the operation, process or interface process they relate to. The layered decomposition should result in the enunciation of several systems and users in separate FRs, which are already considered in the processes' FRs previously addressed in PI. Having subsequent BI aspects associated to a specific process or interaction helps in dealing directly with the process and data flows, as well as, the resources implied in them.

The horizontal decomposition mappings are performed from FRs to PVs. The mapping from the conceptual to the physical design corresponds to firms' decision-making with regard to each BI aspect. For each interoperability requirement, firms' individual and joint decision-making led to a specific interoperable solution. In turn, the mapping from the physical to the process design corresponds to the actions or the required assets or resources to enable the respective interoperable solution.

3.1.1 The registering of BI conditions on the AD framework

The design process is realized by documenting the BI conditions in the vertical and horizontal decompositions following the sequence of BI perspectives of BIDF. At the highest level, the buyer-supplier dyad aims at "ensuring interoperability in dyad's interaction(s)" (FR_0), which is achieved by the "systematic design of the cooperation" (DP_0). Below FR_0 and DP_0, the BI conditions are addressed in each of the nine BI perspectives (see Table 1).

Table 1. Generic FRs, DPs and PVs to detail BI perspectives.

BI Perspective	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
Business strategy	FR_{1}: Establish the cooperation goals for the dyad.	DP_{1}: The negotiation of the conditions and ground rules for business.	
	$FR_{1.1}$: Establish business goals for cooperation.	$DP_{1.1}$: Goals negotiation.	$PV_{1.1}$: Features of the agreement.
	$FR_{1.2}$: Ensure clarity in business objectives.	$DP_{1.2}$: The communication of agreements and rules between parties.	$PV_{1.2}$: The activities to enforce the clear communication of objectives or the policy to deal with conflicts.
	$FR_{1.3}$: Reconcile actor's individual strategy with cooperation strategy.	$DP_{1.3}$: The integration of cooperation strategy into individual strategy.	$PV_{1.3}$: Methods to ensure the enforcement of the cooperation objectives.
Relationship Management	FR_{2}: Manage cooperation.	DP_{2}: Relationship measures to ensure cooperation duration and adequacy to the dyad's needs.	
	$FR_{2.1}$: Manage cooperation in its initiation.	$DP_{2.1}$: The depth of competencies analysis prior to business set-up.	$PV_{2.1}$: The sourcing approach to select the supplier.
	$FR_{2.2}$: Manage cooperation during its realization.	$DP_{2.2}$: The relationship management measures to ensure the cooperation duration and adequacy to the dyad needs.	
	$FR_{2.2.1}$: Establish business relationships that last enough time to develop trust environment and permit cooperation scale-up.	$DP_{2.2.1}$: The partnership duration and relevance of the partner to business objectives.	$PV_{2.2.1}$: Description of the partnership relevance and record.
	$FR_{2.2.2}$: Assess and review cooperation progress during cooperation.	$DP_{2.2.2}$: The depth of recurring progress and competencies revision.	$PV_{2.2.2}$: The methods to support the competencies revision: meetings, problem reporting, problem solving, etc.
	$FR_{2.3}$: Establish mechanisms to deal with premature cooperation breakdown.	$DP_{2.3}$: The approach to deal with cooperation breakdown.	$PV_{2.3}$: Description of contract conditions for failure to commitments, contingency plans to deal with supply disruption, etc.
	$FR_{2.4}$: Monitor the buyer-supplier relationship.	$DP_{2.4}$: Partnership and process monitoring policies implemented to evaluate performance.	$PV_{2.4}$: Strategic internal business, business relationships and customer service dimensions and tactical SCM and interoperability performance metrics.
	$FR_{2.5}$: Assign actors to business activities.	$DP_{2.5}$: The identification of role assignments and its level of adequacy and possible existence of responsibility gaps.	$PV_{2.5}$: Description of buyer and supplier role assignment.
	$FR_{2.6}$: Establish a risk management system.	$DP_{2.6}$: The mitigation and contingency plans for disturbances due to lack of interoperability.	$PV_{2.6}$: Procedures and processes to implement when risk conditions are fulfilled.
	$FR_{2.7}$: Distribute governance in the dyad.	$DP_{2.7}$: The definition of a governing firm, or the equal distribution of power on the dyad.	$PV_{2.7}$: Description of how decision-making process is taken place and how it affects the dyad.
	$FR_{2.8}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.8}$: The partner skills for cooperation.	$PV_{2.8}$: The competences description, implemented training programs and other measures to ensure adequate skills for cooperation and cooperation scale-up.
Rules Interoperability	FR_{3}: Reconcile applicable laws (national and cross-borders) and business rules.	DP_{3}: The harmonization of rules for business set-up.	PV_{3}: Applicable laws and business rules and the method to sustain legal cooperation.
Process Interoperability	FR_{4}: managing internal and interface processes.	DP_{4}: seamless collaborative business processes.	
	$FR_{4.1}$: Model the process sequence.	$DP_{4.1}$: The sequence approach and the business process models that choreographs the sequence.	$PV_{4.1}$: The work methods that enable process flow and resources (human and technical) that performs them.
	$FR_{4.2}$: Align internal processes with the firms' organizational structures.	$DP_{4.2}$: The organizational alignment solution BPM and DSM representations.	$PV_{4.2}$: Description of the responsibility assignment.
	$FR_{4.3}$: Select metrics to monitor internal/interface processes.	$DP_{4.3}$: Operational SCM and interoperability performance metrics.	$PV_{4.3}$: Metrics monitoring.
	$FR_{4.4}$: Align companies' internal processes.	$DP_{4.4}$: The internal processes reconciliation and the collaborative business process model.	$PV_{4.4}$: Work methods, communication procedures and resources implemented to interact with partner.
Data interoperability	FR_{5}: manage data exchange.	DP_{5}: data flows between firms.	
	$FR_{5.1}$: Manage the communication path for interface processes.	$DP_{5.1}$: The depth of communication paths definition.	$PV_{5.1}$: The communication procedure, the users and the ICT implemented for data exchange.
	$FR_{5.2}$: Assign employees to	$DP_{5.2}$: The contact points definition.	$PV_{5.2}$: If contact points were defined,

	interface processes.		identify the users and respective processes where is performed the contact between firms.
	$FR_{5.3}$: Manage compatibility between exchanged data formats.	$DP_{5.3}$: Solution for data compatibility.	$PV_{5.3}$: The procedure to enable data formats compatibility.
	$FR_{5.4}$: Manage the context of information in communications.	$DP_{5.4}$: The method to handle semantics.	$PV_{5.4}$: Procedure to handle the context of information.
	$FR_{5.5}$: Manage data exchange.	$DP_{5.5}$: The data exchange approach.	$PV_{5.5}$: The methods to handle the data exchange solution.
	$FR_{5.6}$: Ensure quality in communications.	$DP_{5.6}$: The approach to maintain data quality in communications.	$PV_{5.6}$: Semantic agreements, required data, etc.
	$FR_{5.7}$: Ensure information quality.	$DP_{5.7}$: The methods to prevent incorrect data.	$PV_{5.7}$: The data handling procedures to prevent errors (e.g. data validation tools, data insertion methods, etc.).
Software and systems interoperability	FR_6: Manage software and systems interoperability.	DP_6: Compatible systems.	
	$FR_{6.1}$: Manage compatibility between interface software.	$DP_{6.1}$: The software solution for interacting/complementary processes.	$PV_{6.1}$: The users, the procedures and conversions (software or manual) to use data from different or similar software.
	$FR_{6.3}$: Manage information systems security.	$DP_{6.3}$: The IT security approach.	$PV_{6.3}$: The procedures, agreements, protocols, etc. used to support the security approach.
	$FR_{6.4}$: Manage information systems to support the dyad interaction.	$DP_{6.4}$: The IT management solution.	$PV_{6.4}$: The activities to support interface information systems.
	$FR_{6.5}$: Maintain compatibility to required legacy systems.	$DP_{6.5}$: Solution to deal with legacy systems.	$PV_{6.5}$: The identification of legacy systems and associated hardware; and the methods to enable interaction and data flow with the legacy systems.
Objects and hardware interoperability	FR_7: Manage internal hardware used in internal processes that have influence on the dyad's interaction.	DP_7: Hardware solution for seamless data integration.	
	$FR_{7.1}$: Choose hardware to register data from/to physical processes.	$DP_{7.1}$: The selected device and the interaction type (human-machine or machine-machine).	$PV_{7.1}$: The method to use devices and users (if required).
	$FR_{7.2}$: Ensure compatibility of physical devices and internal systems.	$DP_{7.2}$: The hardware compatibility approach.	$PV_{7.2}$: The methods to enable hardware connectivity with other systems (automated or user-based).
Human Resources	FR_8: Manage users that use information systems internally and when interacting with part.	DP_8: methods to ensure motivation, efficiency and adequate competencies for cooperation.	
	$FR_{8.1}$: Ensure employees motivation.	$DP_{8.1}$: The approach to keep employees motivated.	$PV_{8.1}$: The form of implementation of the motivational programs.
	$FR_{8.2}$: Ensure adequate knowledge for SC activities.	$DP_{8.2}$: The depth of employee selection and the management of knowledge and skills.	$PV_{8.2}$: The description of the adequate knowledge skills for employees to perform activities; the implementation of training programs, etc.
	$FR_{8.3}$: Ensure adequate IT competencies.	$DP_{8.3}$: The depth of employee selection and the management of knowledge and skills.	$PV_{8.3}$: The description of adequate IT skills; implementation of training programs, etc.
Cultural Interoperability	FR_9: Manage the cultural differences on the dyad's interface.	DP_9: Methods to harmonize culture and to solve linguistic barriers.	
	$FR_{9.1}$: Harmonize cultural differences between companies and interacting employees.	$DP_{9.1}$: The methods implemented to avoid cultural differences.	$PV_{9.1}$: The description of the method and the form it is implemented.
	$FR_{9.2}$: Avoid linguistic barriers on companies' communication.	$DP_{9.2}$: The method to avoid linguistic barriers.	$PV_{9.2}$: The description of the language and identification of interfaces and employees that establish the communication.

The presented elements of the buyer-supplier dyad's design are generic examples adaptable to the interaction context. The mapping from FR to DP corresponds to the firms' decisions that will lead to more or less interoperable scenario.

3.1.2 Application of the 1st Axiom

The design matrices have the purpose of mapping the dependencies FRs-DPs and DPs-PVs in three configurations (see Table 2). A considered interoperable relationship may result on an uncoupled matrix, where for each proposed FR for the buyer-supplier dyad's design matches only one interoperable solution. Decoupled designs represent the dependencies beyond complementary FRs and

DPs or DPs and PVs. This may be a symptom of a conditioned interaction or a faulty relationship at organizational, knowledge or technical perspectives of interoperability. Solving couplings may help to achieve a more interoperable state. Coupled designs can mean a non-interoperable dyad. Being the proposed method intended for existing interoperating dyads, it means that we come from less interoperable to a more interoperable state (i.e., from "as-is" to "to-be").

Table 2. Types of design matrix couplings and their relation with interoperability.

Types of coupling	Design Equation	Interoperability result
Uncoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Interoperable
Decoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Conditioned interaction Faulty relationship
Coupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Non-interoperable

Issues are registered on the matrix according to the adequate level of interoperability. Then, on the matrix are registered existing problems in accomplishing those levels of interoperability. For example, a high interoperability scenario in BS would result on an uncoupled matrix, where there are no dependencies between BS's FRs, DPs and PVs. In counterpart, a low interoperability scenario is documented by registering dependencies on the matrix (see Table 3 and equation (3.1)).

Table 3. Example of low BS interoperability design.

$FR_{1.1}$: Establish business goals for cooperation.	$DP_{1.1}$: Written contract specifying the cooperation conditions and liabilities.
$FR_{1.2}$: Reconcile actor's individual strategy with cooperation strategy.	$DP_{1.2}$: Cooperation strategy defined but not aligned with individual strategy.
$FR_{1.3}$: Ensure clarity in business objectives.	$DP_{1.3}$: Occasional failures in cooperation.

$$\begin{bmatrix} FR_{1.1} \\ FR_{1.2} \\ FR_{1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} DP_{1.1} \\ DP_{1.2} \\ DP_{1.3} \end{bmatrix} \quad (3.1)$$

The failure to communicate clearly the objectives and the lack of reconciliation of cooperation and individual objectives are remarked on the couplings of the matrix. To ensure the enforcement of the cooperative objectives both in the clarity ($FR_{1.3}$) and business strategy alignment ($FR_{1.2}$) perspectives, the dyad is dependent on the contract specifications and liabilities ($DP_{1.1}$) applicable to failure to commitments. Also, the inability to reconcile the cooperation strategy with individual objectives ($DP_{1.2}$) sets the partnership to aim to different objectives. This, in turn, affects the form companies communicate business strategy, leading to conflict of interests.

Looking at the method globally, the AD framework serves to document the buyer-supplier dyad from the "as-is" to the "to-be" state. The framework and respective interaction matrices set main interoperability profile where all the proposed changes will be implemented. Improving interoperability, applying the 1st axiom, means that couplings will be identified, and new DPs proposed to solve them. The design matrices accompany that process by indicating what subsequent FRs and DPs will be affected, and which changes are required for the system to keep functionality. The same happens in interoperability scaling-up, whereas higher levels of interoperability DPs are suggested.

4. Case study: the re-design of a buyer-seller interaction

With the objective of testing the theoretical propositions, a single exploratory case study was conducted, in order to analyse in detail the full spectrum of BI perspectives. Hence, a buyer-supplier was analysed as characteristics presented in Table 4.

Table 4. Dyad's companies profile

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

The first supplier (FS) (buyer) in this case study is 1st tier supplier with regards to the automotive SC it belongs. Currently, this firm produces injection coils to 40 automobile manufacturers placed worldwide. Upstream, FS purchases parts from 130 raw material and component providers both worldwide and has some plants in Portugal.

The second supplier (SS) is a company located in Portugal, which produces copper wire for automotive and communications industries. SS is a long-term strategic partner of FS, providing high-specificity copper wire to produce injection coils. SS has high integration in the development and conception of its products. This high level of integration and the existence of a dedicated R&D department provide a unique strategic partner to FS work with in the development of new automotive components by permitting to develop the specifications of the wire and the enamel. All the FS's products require copper wire with different specifications, and the abrupt termination of this relationship could be detrimental for FS.

Data was collected from both companies according to the data triangulation practice, having obtained data from structured interviews, direct observation and analysis of companies' documentation.

4.1 The "as-is" design

The main CN for the FS-SS dyad is to "achieve optimal interoperability in the buyer-seller interaction". Accordingly, FR_0 and DP_0 were set. The objective of the design is to "ensure high levels of interoperability in the dyad interactions" (FR_0), through a "systematic design of the buyer-seller interaction" (DP_0).

Business set-up conditions – BS and RM

The business set-up conditions, remarked by the business strategy (BS) and relationship management (RM) interoperability perspectives, set the ground rules for FS-SS relationship and establishes what measures are put in practice to manage the cooperation duration (see Table 5). BS conditions are remarked under the FR_1, and RM conditions are remarked under FR_2.

Table 5. Dyad's business set-up conditions (BS and RM).

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
FR_1: Establishment of the cooperation goals.	*DP_1: Negotiated conditions and ground rules for business.*
$FR_{1.1}$: Establish conditions applicable to purchasing and selling.	$DP_{1.1}$: Dyad responsibilities and delivery conditions.
$FR_{1.1.1}$: Negotiate purchasing and selling conditions.	$DP_{1.1.1}$: Written contract specifying the delivery conditions set by FS.
$FR_{1.1.2}$: Reconcile the actors' individual strategy with the cooperation strategy.	$DP_{1.1.2}$: Cooperation strategy was defined, but it is not aligned with the individual objectives.
$FR_{1.1.3}$: Ensure a clear business strategy for both actors.	$DP_{1.1.3}$: Occasional failures in cooperation.
$FR_{1.2}$: Establish liabilities and contingencies for failure to commitments.	$DP_{1.2}$: Firms' conditions regarding delays and order failures.
$FR_{1.2.1}$: Negotiate the liabilities and contingencies for failure to commitments.	$DP_{1.2.1}$: Written contract specifying liabilities imposed by FS.
$FR_{1.2.2}$: Reconcile liabilities for delivery failures with the individual strategy.	$DP_{1.2.2}$: The objectives are fully aligned.
$FR_{1.2.3}$: Ensure clarity in liabilities for both actors.	$DP_{1.2.3}$: Occasional failures.

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
FR_2: Manage cooperation.	*DP_2: Measures to maintain cooperation.*
$FR_{2.1}$: Distribute governance in the dyad.	$DP_{2.1}$: Unilateral power distribution (FS is the governing firm).
$FR_{2.2}$: Assign actors to business activities.	$DP_{2.2}$: The identification of role assignments and its level of adequacy and possible existence of responsibility gaps.
$FR_{2.2.1}$: Assign responsibilities to the supplier.	$DP_{2.2.1}$: Well-defined. The responsibility and roles assignment is not an issue.
$FR_{2.2.2}$: Assign responsibilities to the focal firm.	$DP_{2.2.2}$: Well-defined. The responsibility and roles assignment is not an issue.
$FR_{2.3}$: Manage cooperation in its initiation.	$DP_{2.3}$: Selection of a certified supplier.
$FR_{2.4}$: Monitor cooperation.	$DP_{2.4}$: Record of partnership metrics and audits.
$FR_{2.5}$: Manage cooperation during its realization.	$DP_{2.5}$: The relationship management measures to ensure the cooperation duration and adequacy to the dyad needs.
$FR_{2.5.1}$: Establish business relationships that last enough time to develop a trustworthy environment and permit the cooperation scale-up.	$DP_{2.5.1}$: Strategic long-term relationship.
$FR_{2.5.2}$: Assess and review cooperation progress during the cooperation.	$DP_{2.5.2}$: Annual meetings to review partnership performance.
$FR_{2.5.3}$: Establish a mechanism to deal with premature cooperation breakdown.	$DP_{2.5.3}$: Preventive contract condition to keep the steady supply after cooperation breakdown.
$FR_{2.6}$: Establish a risk management system.	$DP_{2.6}$: The mitigation and contingency plans for disturbances due to lack of interoperability.
$FR_{2.6.1}$: Contingency plan for delays in delivery.	$DP_{2.6.1}$: Contract obligations and implementation of an alternative supplier.
$FR_{2.6.2}$: Contingency plan for delays in information transmission/communication	$DP_{2.6.2}$: Alternative procedure for communication.
$FR_{2.6.3}$: Establish preventive measures to deal with amount of orders less than ordered.	$DP_{2.6.3}$: Standard procedure to identify faulty cases and exceptional procedure to deal with missing parts and contract obligations.
$FR_{2.7}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.7}$: Appropriate skills for cooperation.

Figure 3 illustrates the relation between the interoperability requirements (FRs) , and the interoperability solutions (DPs) found by the partners to fulfil the FRs, both from Table 5 and Table 6. The last one will be explained in the next section.

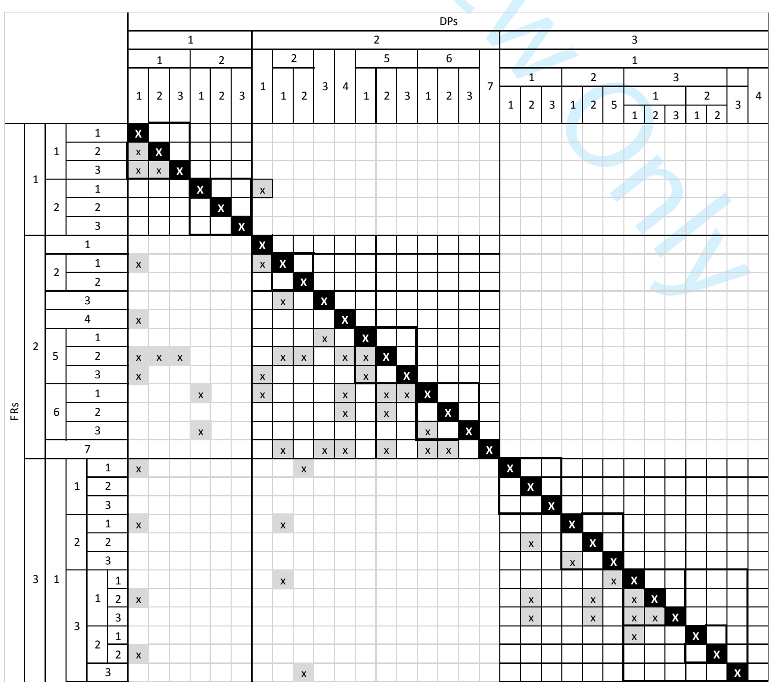


Figure 3. Design matrix for the "as-is" design of the buyer-seller interaction (mapping between FRs and DPs).

The design matrix highlights several issues in the couplings found in the lower diagonal. With regards to BS, lack of proper negotiation, alignment and clear communication of strategic objectives are remarked in the aspects beneath $FR_{1.1}$ and $DP_{1.1}$. Despite FS considers that the agreements in this setting were well-defined and communicated in a clear manner, envisioning the alignment with individual objectives, SS stressed that the objectives were strongly imposed by FS, not completely aligned with individual objectives. Instead of an objective alignment, the firms opted for the establishment of contractual liabilities and contingencies in case of failing to the agreements (see $FR_{1.2}$-$DP_{1.2}$ in Figure 3). Upon occurrence of conflicts, the strict negotiation of contract conditions occurs prior to the conflict, instead of being adequately negotiated in the dyad's set-up.
RM interoperability perspective is remarked by a dominant firm (FS), which its decisions affect the functioning of SS. This has particular influence in the responsibility assignment (see $FR_{2.2}$), and in the contingency plans to deal with particular failures in cooperation (see $FR_{2.6.1}$ and $FR_{2.6.2}$).

Processes and information systems modelling – PI, DI and SSI perspectives
The next stage in the application of the ADF, was to design the dyad's internal and interface processes. This design is presented in Table 6, and the relation between FRs and DPs is given in Figure 3.
To support the design, the dyad's processes were modelled according to the Business Process Model Notation (BPMN) (OMG, 2011).

Table 6. Dyad's internal and interface processes and supporting data and resources (PI, DI and SSI perspectives).

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
$FR_{3.1}$: Model and manage the buyer-selling relationship.	$DP_{3.1}$: Features of the FS's and SS_1's procedure to handle orders, since order placement to fulfilment.
$FR_{3.1.1}$: Model and manage FS's purchasing processes.	$DP_{3.1.1}$: FS actual business process model for purchase and reception (see "parts ordering" lane in Figure 5).
$FR_{3.1.1.1}$: Model the process sequence of FS processes.	$DP_{3.1.1.1}$: Sequential procedures with low interaction dependency.
$FR_{3.1.1.2}$: Manage the interface between the inventory management system and the ordering system.	$DP_{3.1.1.2}$: MRP data converted manually (into order and soft order data) before sending it. SAP and E-mail are not interoperable.
$FR_{3.1.1.3}$: Align purchasing and reception with FS organizational structure.	$DP_{3.1.1.3}$: Functional process distribution by matching a process to a section.
$FR_{3.1.2}$: Model and manage SS_1's sales processes.	$DP_{3.1.2}$: SS_1 actual business process model for order reception, order treatment, production and delivery (see Figure 4).
$FR_{3.1.2.1}$: Model the process sequence of SS_1 processes.	$DP_{3.1.2.1}$: Cooperative/interactive procedure between logistics planning and production planning activities. Preceding sales and succeeding production and delivery activities are independent and sequential.
$FR_{3.1.2.2}$: Manage the compatibility between the ICT for order reception and the order management system.	$DP_{3.1.2.2}$: E-mail and SAP are not interoperable. Order data must be inserted manually into SAP.
$FR_{3.1.2.3}$: Align SS_1 processes with organizational structure.	$DP_{3.1.2.3}$: Many tasks performed by one section, in the case of sales and logistics activities, and the rest are sequential (see Figure 4).
$FR_{3.1.3}$: Align companies' internal processes.	$DP_{3.1.3}$: The collaborative business process model (see Figure 5).
$FR_{3.1.3.1}$: Manage the order placement procedure.	$DP_{3.1.3.1}$: Features of the order placement.
$FR_{3.1.3.1.1}$: Assign employees to the interface for order placement/reception.	$DP_{3.1.3.1.1}$: Contact points defined.
$FR_{3.1.3.1.2}$: Manage the interface between ICT's used to place/receive orders.	$DP_{3.1.3.1.2}$: Order and soft order data is not compatible between firms. The conversion of order data to the e-mail format doesn't permit import data directly on SAP.
$FR_{3.1.3.1.3}$: Manage the communication path to place orders.	$DP_{3.1.3.1.3}$: Standard procedure defined to communicate orders.
$FR_{3.1.3.2}$: Manage the order confirmation procedure.	$DP_{3.1.3.2}$: Features of order confirmation.
$FR_{3.1.3.2.1}$: Manage the communication path to confirm orders.	$DP_{3.1.3.2.1}$: Standard procedure defined to communicate orders.
$FR_{3.1.3.2.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.1.3.2.2}$: ASN is integrated directly on SAP system.

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
$FR_{3.1.3.3}$: Establish a delivery process for material flow.	$DP_{3.1.3.3}$: 3rd party freight forwarder to retrieve components from SS and deliver them to FS.
$FR_{3.1.4}$: Select metrics to monitor interface processes.	$DP_{3.1.3}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.

On the analysis of the design matrix (see Figure 3), some issues are raised with regards to internal and external perspectives of PI. While on the internal perspective of FS there are no relevant issues that are remarked on the design matrix (relations bellow $FR_{3.1.1}$ and $DP_{3.1.1}$), an incompatibility between applications and formats ($DP_{3.1.1.2}$) – SSI and DI perspectives – produces an inadequate impact when information is exchanged with SS.

On the internal perspective of SS, issues are raised with regards to process sequence ($FR_{3.1.2.1}$) and organizational alignment ($FR_{3.1.2.3}$). The sales, logistics and production planning activities are choreographed between two departments in a dependable manner. Sales and logistics is performed in the same department, by the same employee which deals from FS's orders and corresponding materials purchasing to fulfill those orders. Although SS is set to work on make-to-stock fashion, it mostly plans production according to FS's orders. Hence, production management depends on the received orders and in the parts purchasing.

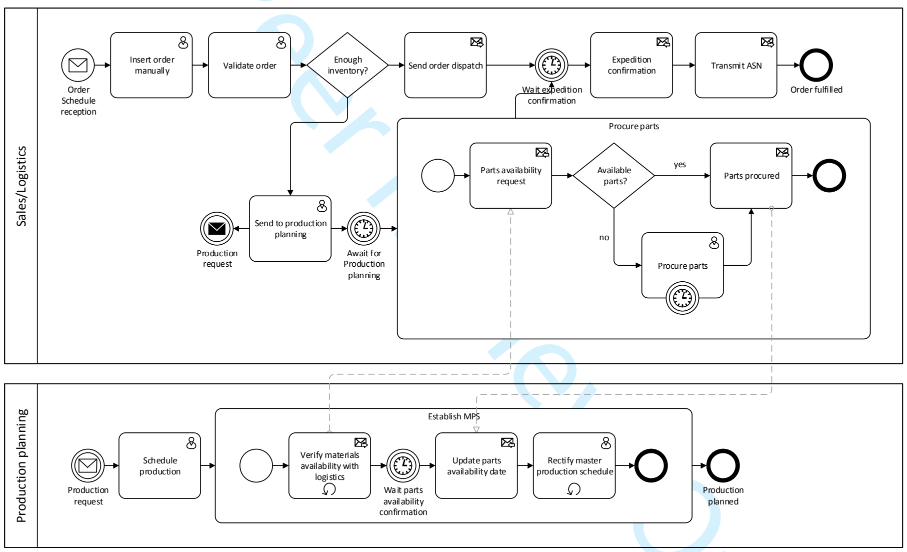


Figure 4. SS's internal processes.

The dyad's interface is remarked by several couplings in the design referring to the issues: contact points' definition; systems compatibility and the communication path. In the first one, in both companies, the contact points were defined.

In terms of systems compatibility on the interface ($FR_{3.1.3.1.2}$), like it was previously mentioned, there is a problem of compatibility between the ICT and the order management systems. That generates two conversion processes in order to be able to place orders and to introduce them on the SS's SAP system. Both companies work with similar ERP system but, by using an incompatible ICT, two non-value added (NVA) processes are necessary to convert the data.

Last, still concerning the order placement interaction, the communication path ($FR_{3.1.3.1.3}$) is accomplished by a standard procedure defined to communicate orders ($DP_{3.1.3.1.3}$). Though, the procedure only contemplates normal orders. Urgent orders managed on an ad-hoc basis.

The second interaction on the interface refers to the confirmation of the ordered components expedition. Before shipping the materials, SS_1 sends an ASN through EDI, which is incorporated in the FS SAP system. As consequence, the design matrix for this aspect is uncoupled.

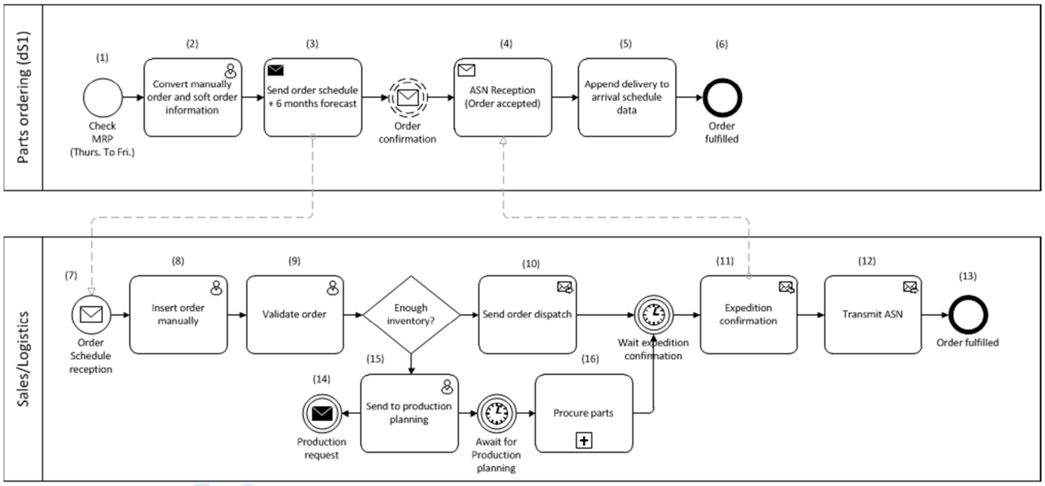


Figure 5. Interface between parts ordering and sales and logistics section.

4.2 Interoperability improvement: application of the 1st Axiom

Based on the prior characterization of the interoperability issues, the following problems were identified:

1) Lack of proper negotiation, alignment and clear communication of objectives
2) Dependencies between BS and RM, and beneath RM
3) Faulty process sequence in SS's internal processes
4) Incompatibilities in the dyad's interface

Each problem was addressed in an isolated manner and, after determining the best interoperability scenario, the final result is presented in the section 4.3.

1) Lack of proper negotiation, alignment and clear communication of objectives

The first issue is characterized by a decoupled design (see equation (1))

$$\begin{bmatrix} FR_{1.1.1} \\ FR_{1.1.2} \\ FR_{1.1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} DP_{1.1.1} \\ DP_{1.1.2} \\ DP_{1.1.3} \end{bmatrix} \tag{1}$$

An adequate definition of the first objective of this dyad could be achieved by the DPs:

- $DP_{1.1}$: All the competencies and capacities were reviewed in order to establish a mutual advantage business relationship.
- $DP_{1.2}$: The competencies were fully reviewed to avoid interest conflicts.
- $DP_{1.3}$: The strategic objectives were fully aligned. It was established a strategic partnership and both partners review constantly the competencies striving for competitive advantage.

This hypothetical scenario would deliver higher interoperability to the dyad, by keeping the FRs and DPs independent (see equation (2)).

$$\begin{bmatrix} FR_{1.1.1} \\ FR_{1.1.2} \\ FR_{1.1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{1.1.1} \\ DP_{1.1.2} \\ DP_{1.1.3} \end{bmatrix} \tag{2}$$

This scenario would have impact in subsequent liabilities set in place for conflict possibility.

2) Dependencies between BS and RM, and beneath RM

In the management of the buyer-supplier relationship (RM), there is a difficulty in maintaining a collectively exhaustive and mutually exclusive (CEME) relationship between the children FRs and DPs from the parent FR (FR_2). Ideally, the sum of children FR would give the FR_2. In opposition, several business set-up conditions set the grounds for subsequent FRs. For instance, the interoperable solutions (DPs) beneath the "establishment of the cooperation goals" (FR_1) constrain the degrees of freedom to maintain independence between FRs and DPs beneath FR_2. Also, some DPs under FR_2

have impact on subsequent FRs. Relationship governance ($FR_{2.1}$-$DP_{2.1}$) has strong impact on how the relationship is managed, how responsibility is assigned, in the establishment of mechanisms to deal with collaboration breakdown, and in contingency plans. Also, a dependency on the upper diagonal matrix exists, where the negotiation of liabilities ($FR_{1.2.1}$) is influenced by the dominating partner ($DP_{2.1}$).

Solutions to couplings between FR_1 and FR_2 matrices, and beneath FR_2 design matrices are more difficult to overcome. The RM DPs are a product of the set-up business objectives. A different partnership arrangement could result, for instance, from the correct negotiation of objectives given by equation (2). A possibility is to provide a more distributed governance in the dyad ($DP_{2.1}$), build trust between partners (impact in $DP_{2.3}$ and $DP_{2.5.1}$), a more flexible transition period for cooperation breakdown ($DP_{2.5.3}$ and $DP_{2.6.1}$).

3) Faulty process sequence in SS's internal processes

The SS's internal processes are remarked with a coupling where the organisational alignment of sales, logistics and production planning activities ($FR_{3.1.2.3}$) are constrained by the process sequence ($DP_{3.1.2.1}$) (see equation (3)).

$$\begin{bmatrix} FR_{3.1.2.1} \\ FR_{3.1.2.2} \\ FR_{3.1.2.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ x & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.1.2.1} \\ DP_{3.1.2.2} \\ DP_{3.1.2.3} \end{bmatrix} \tag{3}$$

Instead of independent processes to perform the sale to FS, production planning and materials procurement to fulfil the orders, the process occurs in a highly dependency fashion. Sales and logistics are carried on by one department and by the same employee. The sale activity triggers the production planning, which incorporates the order in the master production schedule. Though, to fulfil the master production schedule, the production planning department depends on the procurement of parts carried by the sales and logistics department, by the same user.

The solution to overcome the faulty process sequence and organisational alignment of processes is to work on a different process sequence and provide a new responsibility assignment inside SS. A possible solution could be the one provided in Figure 6.

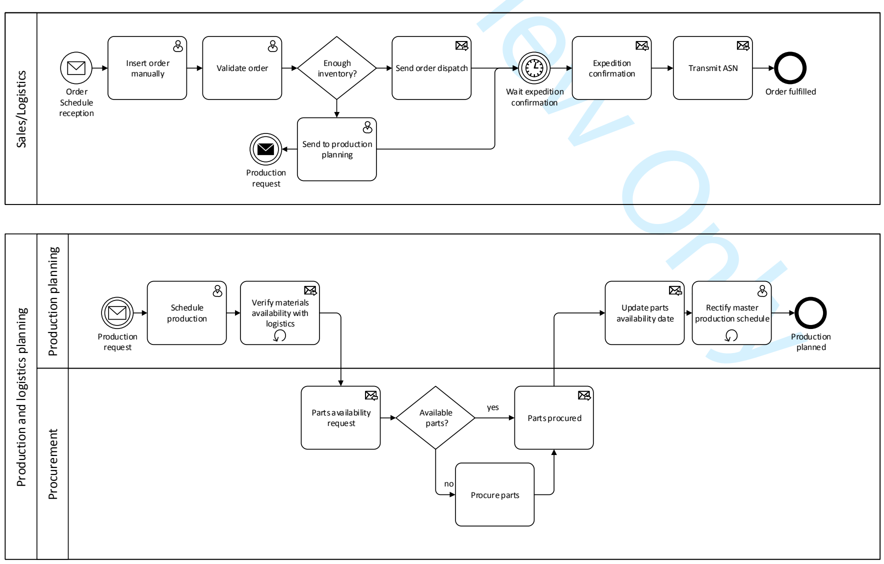


Figure 6. New process sequence and alignment for SS.

4) Incompatibilities in the dyad's process interface

Data incompatibility between order management systems and the use of a non-integrated ICT leads to several couplings in the design matrix beneath FR_3 (process interoperability perspective). To overcome this incompatibility and, thus, improve interoperability, two scenarios are suggested:

a) The implementation of a WebEDI
b) The implementation of an EDI.

The first alternative is already implemented by FS. Nevertheless, this solution still doesn't produce the expected results. Despite solving the manual conversion on the FS's side, due lack of integration of the WebEDI with the SS's SAP system, employees in the sales/logistics department still have to introduce orders manually.

In practice, the implemented WebEDI permits to generate the purchase orders which are accessible by SS, and other suppliers, via web portal. In terms of the dyad design, the produced changes affect the following DPs:

- $DP_{3.1.1}$: FS business process model for purchase and reception using WebEDI (see Figure 7).

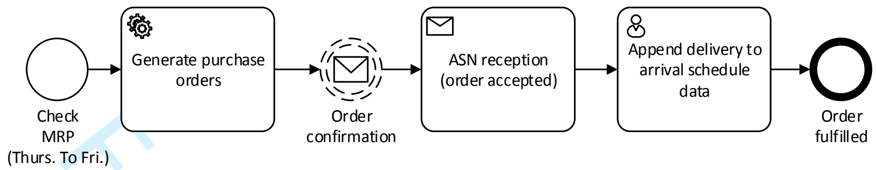


Figure 7. FS purchasing process with WebEDI implementation.

- $DP_{3.1.1.2}$: MRP data converted automatically and exported to WebEDI service.
- $DP_{3.1.2.2}$: WebEDI and SAP are not integrated. Order data must be inserted manually into SAP.

The change of DPs is still not sufficient to satisfy the first axiom and, thus, does not improve interoperability. The FS's implementation of WebEDI may improve internally the performance by eliminating an NVA activity, though the incompatibility between peers is still an issue for the dyad. The implementation of WebEDI didn't occur in a way that the design became uncoupled. In opposition, the same coupling is maintained in the design matrix, despite providing changes in interoperability solution space (DPs).

To achieve a better interoperable scenario, the new design should comply with the first axiom. In this sense, for the second scenario we proposed the implementation of the EDI to connect both companies' SAP systems (b). The objective is to interlink SAP systems through EDI, in order to enhance compatibility and avoid data conversions. Both companies have EDI implemented, but not with each other due to costs of implementation and maintenance. To implement the EDI we suggest the following DPs:

- $DP_{3.1.1}$: FS new business process model for purchase (see parts ordering pool in Figure 8).
- $DP_{3.1.1.2}$: Integrated data between SAP and EDI.
- $DP_{3.1.2}$: SS new business process model for order reception (see sales pool in Figure 8), and actual order treatment, production and delivery business process models.
- $DP_{3.1.3}$: The new collaborative business process model (see Figure 8).
- $DP_{3.1.3.1.2}$: SAP data integrated between the two firms.
- $DP_{3.1.2.2}$: Integrated data between EDI and SAP.

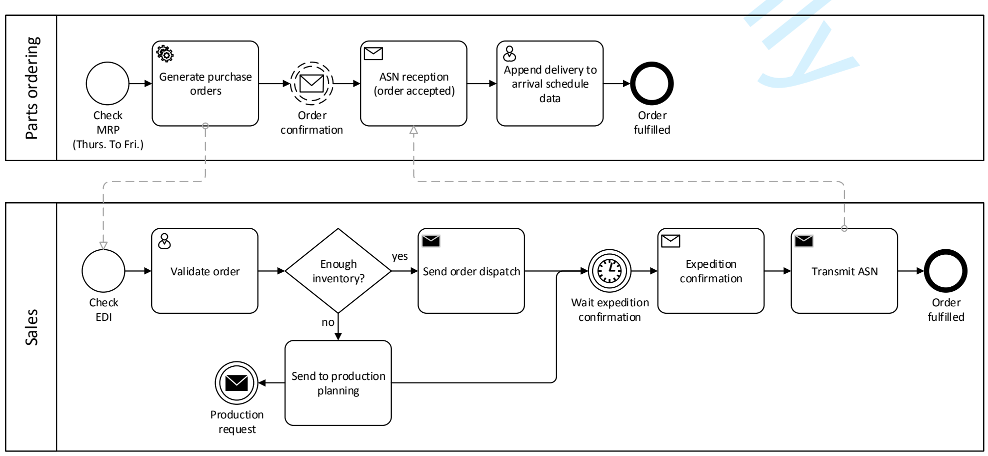
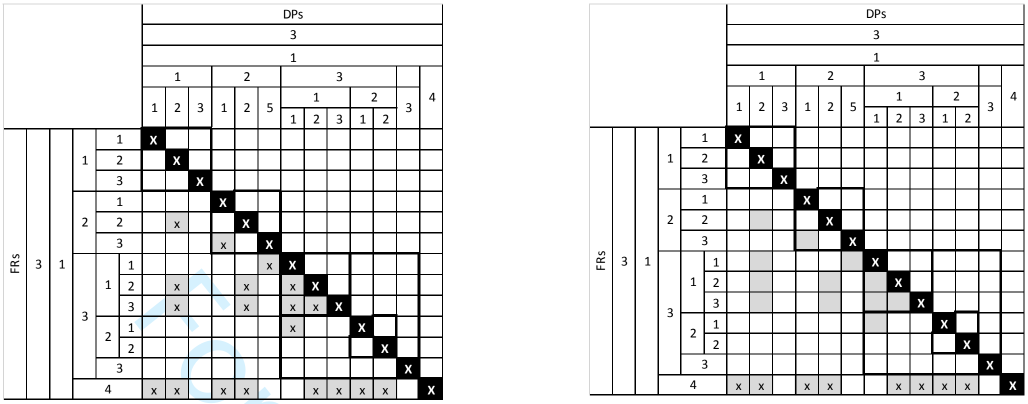


Figure 8. Interface between parts ordering and sales sections.

In Figure 9 a partial FR-DP matrix is presented. The new DPs for this scenario allow to improve interoperability by removing the dependencies between FRs and DPs in the lower triangular matrix. In this manner, the proposed DPs allow to improve interoperability by complying with the first axiom.



(a) (b)

Figure 9. Design matrices for "as-is" (a) and implementation of EDI (b).

4.3 The "to-be" design

Based on the improvements made for the four main problems, the final improved scenario should be able to reconcile different enhancements made at different perspectives of interoperability, and in different levels of the functional domain of the design. To solve interoperability problems, the following DPs were proposed:

- $DP_{1.1}$: All the competencies and capacities were reviewed in order to establish a mutual advantage business relationship.
- $DP_{1.2}$: The competencies were fully reviewed to avoid interest conflicts.
- $DP_{1.3}$: The strategic objectives were fully aligned. It was established a strategic partnership and both partners review constantly the competencies striving for competitive advantage.
- $DP_{3.1.2.1}$: Sequential procedures triggered by the order reception on sales.
- $DP_{3.1.1}$: FS new business process model for purchase (see parts ordering pool in Figure 8).
- $DP_{3.1.1.2}$: Integrated data between SAP and EDI.
- $DP_{3.1.2}$: SS new business process model for order reception (see sales pool in Figure 8), and actual order treatment, production and delivery business process models.
- $DP_{3.1.3}$: The new collaborative business process model (see Figure 8).
- $DP_{3.1.3.1.2}$: SAP data integrated between the two firms.
- $DP_{3.1.2.2}$: Integrated data between EDI and SAP.

The resulting design matrix is given in Figure 10.

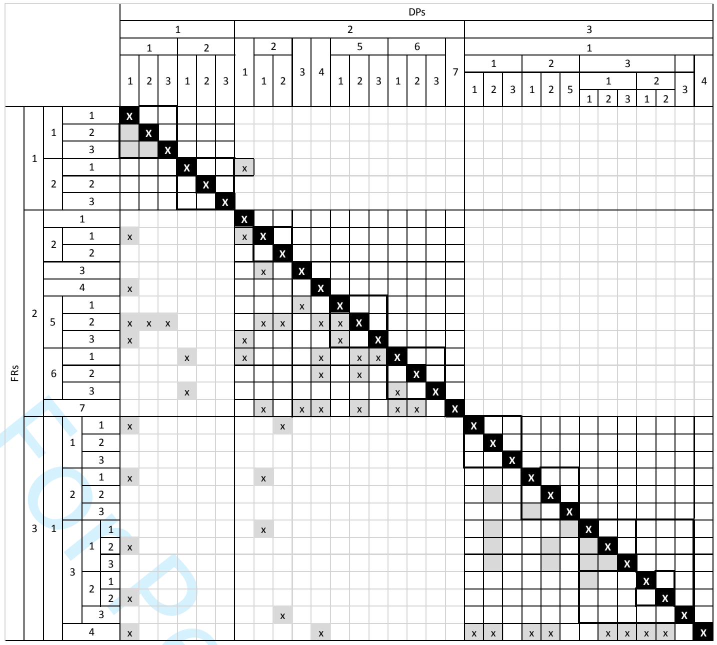


Figure 10. Design matrix for the "to-be" design of the buyer-seller interaction (mapping between FRs and DPs).

A new negotiation of objectives allows one to solve couplings beneath $FR_{1.1}$. Though, couplings between FR_1 and FR_2 are more difficult to study. A new relationship management should be made according to the new reviewed objectives and collaborative strategy. For instance, a new governance distribution ($DP_{2.1}$), responsibility assignment ($DP_{2.2}$), partnership revision ($DP_{2.5}$) and contingency measures ($DP_{2.6}$) should be established according to the new agreed objectives. Though, we do not explore this hypothesis because more validation is required to understand that, despite the existing couplings, the partnership performs adequately to expectations. In that case, less degrees of freedom in the cooperation could provide better interoperability than, for instance, a more equally distributed governance.

At the internal level of the SS, a new process sequence was proposed to avoid redundant activities and faulty work distribution. This permitted, at a functional perspective, to obtain a more fluid workflow.

Last, was proposed the implementation of the EDI to interlink SAP systems from both companies. This solution is the one that solves, at a conceptual level, more couplings in the design matrix and, thus, improve interoperability.

5. Conclusions

The present article contributes to business interoperability (BI) and supply chain management (SCM) literature, specifically related to buyer-supplier dyads. A research question (RQ) was raised and, to achieve it, a framework was proposed and demonstrated through a case study. The main articles in interoperability that propose the design of interoperable relationships and systems were revised, having accomplished that, despite the found contributions, none of them provide a systematic and comprehensive approach the design addressing the full scope of BI. The Axiomatic design theory (AD) was the proposed strategy to address such challenges, permitting an integrated and systematic approach to design, dealing with complexity and maintaining the basic systems functionality. The AD framework integrated the knowledge from BIDF to help detailing business interaction, and in the study of new interoperable scenarios that are compliant with the 1st axiom.

In the realization of the case study, was possible to demonstrate the applicability of the AD framework, being admissible that that one, jointly with AD and business process modelling (BPMN), is an adequate solution to provide the systematic detail on the dyad. The iteration procedure in the study of interoperability solutions and, subsequent re-design using the AD framework, permitted to have in consideration all the factors that rule and constrain the business relationship. The dependencies between BI perspectives represented in the AD framework allowed to verify conceptually the suggested changes. By applying the 1st axiom was possible to study each scenario, and the re-design using the AD framework led to the required changes at the different BI perspectives. To improve interoperability between the analyzed buyer and supplier, was suggested that both companies should work on a comprehensive negotiation of business objectives, rework the process sequence of supplier's logistics and sales activities, and implement EDI to integrate data form SAP systems. These solutions comply with the 1st axiom and, thus, permit achieving better interoperability.

The proposed framework is distinguished from existing interoperability contributions by providing an integrated method to analyse 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 AD framework permits to capture the essence of the buyer-supplier dyad, mimicking the business particularities guaranteeing that the studied solutions are fit for the business relationship. That is achieved by the systematic determination of BI conditions. Those allow to determine which are the conditions, and what are the dependencies between those conditions. The design matrices and the independence axiom permit to keep the integrity of the design and, when changes are made to DPs, subsequently affected conditions would require changes in order to keep the systems functionality, without problems.

Future work will concentrate in addressing the process design from the interoperable solutions (DPs) to process variables (PVs). In this one, we will explore the horizontal decomposition in the BIDF, by mapping conceptual interoperability to the physical domain. With this one, we are aiming at studying the impact of interoperability in the dyad's performance. This interoperability quantification will allow, in turn, the application of the AD's 2nd axiom, where we expect to calculate the information content of the designs and work towards interoperable solutions that deliver greater interoperability performance to buyer-supplier dyads.

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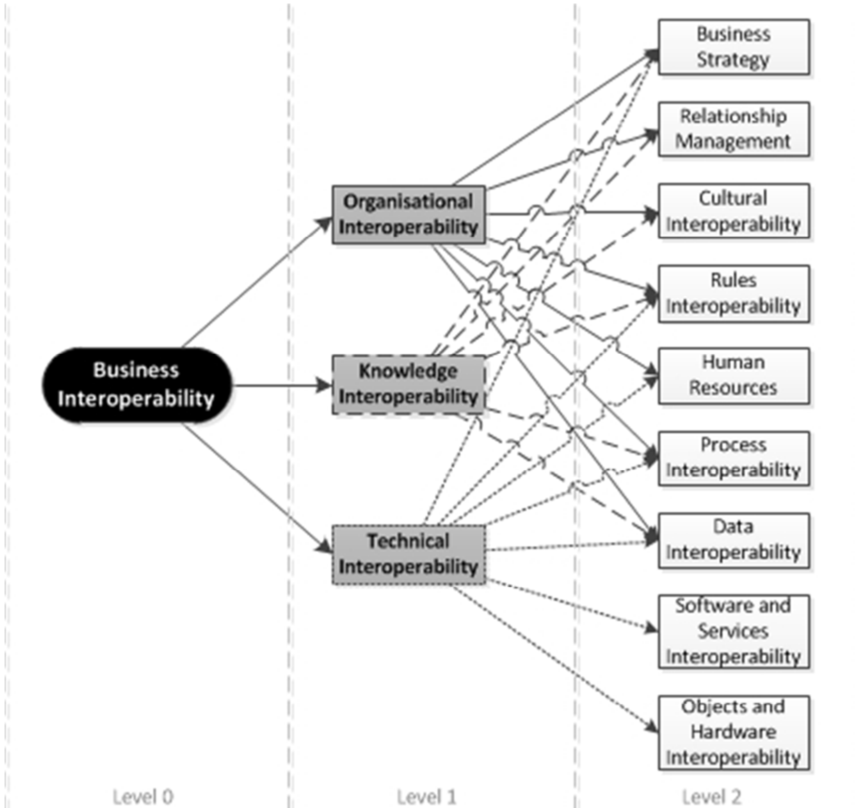

Figure 1. Business Interoperability decomposition framework (BIDF).

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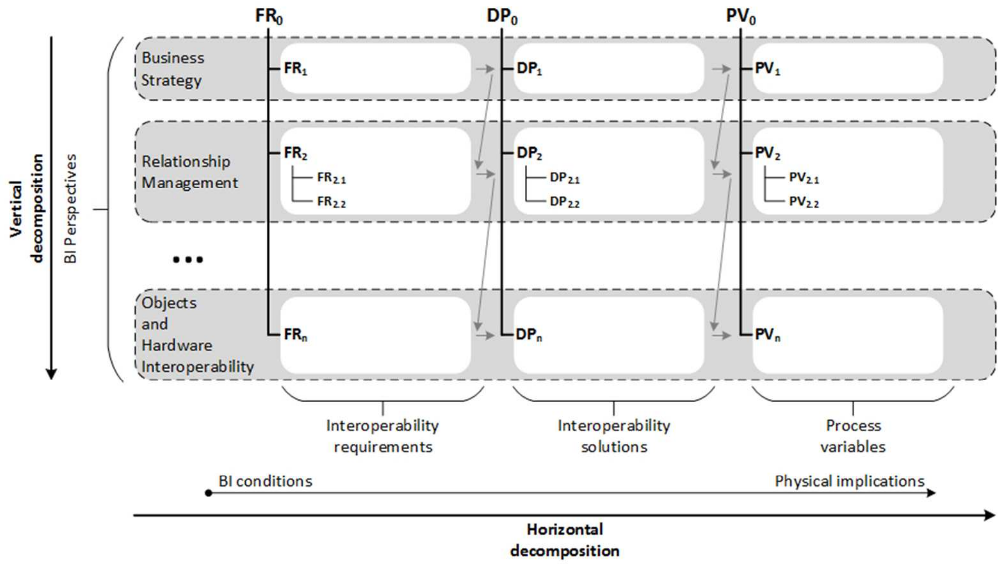

Figure 2. AD framework for interoperable buyer-supplier dyads.

Table 1. Generic FRs, DPs and PVs to detail BI perspectives.

BI Perspective	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
Business strategy	FR_{1}: Establish the cooperation goals for the dyad.	DP_{1}: The negotiation of the conditions and ground rules for business.	
	$FR_{1.1}$: Establish business goals for cooperation.	$DP_{1.1}$: Goals negotiation.	$PV_{1.1}$: Features of the agreement.
	$FR_{1.2}$: Ensure clarity in business objectives.	$DP_{1.2}$: The communication of agreements and rules between parties.	$PV_{1.2}$: The activities to enforce the clear communication of objectives or the policy to deal with conflicts.
	$FR_{1.3}$: Reconcile actor's individual strategy with cooperation strategy.	$DP_{1.3}$: The integration of cooperation strategy into individual strategy.	$PV_{1.3}$: Methods to ensure the enforcement of the cooperation objectives.
Relationship Management	FR_{2}: Manage cooperation.	DP_{2}: Relationship measures to ensure cooperation duration and adequacy to the dyad's needs.	
	$FR_{2.1}$: Manage cooperation in its initiation.	$DP_{2.1}$: The depth of competencies analysis prior to business set-up.	$PV_{2.1}$: The sourcing approach to select the supplier.
	$FR_{2.2}$: Manage cooperation during its realization.	$DP_{2.2}$: The relationship management measures to ensure the cooperation duration and adequacy to the dyad needs.	
	$FR_{2.2.1}$: Establish business relationships that last enough time to develop trust environment and permit cooperation scale-up.	$DP_{2.2.1}$: The partnership duration and relevance of the partner to business objectives.	$PV_{2.2.1}$: Description of the partnership relevance and record.
	$FR_{2.2.2}$: Assess and review cooperation progress during cooperation.	$DP_{2.2.2}$: The depth of recurring progress and competencies revision.	$PV_{2.2.2}$: The methods to support the competencies revision: meetings, problem reporting, problem solving, etc.
	$FR_{2.3}$: Establish mechanisms to deal with premature cooperation breakdown.	$DP_{2.3}$: The approach to deal with cooperation breakdown.	$PV_{2.3}$: Description of contract conditions for failure to commitments, contingency plans to deal with supply disruption, etc.
	$FR_{2.4}$: Monitor the buyer-supplier relationship.	$DP_{2.4}$: Partnership and process monitoring policies implemented to evaluate performance.	$PV_{2.4}$: Strategic internal business, business relationships and customer service dimensions and tactical SCM and interoperability performance metrics.
	$FR_{2.5}$: Assign actors to business activities.	$DP_{2.5}$: The identification of role assignments and its level of adequacy and possible existence of responsibility gaps.	$PV_{2.5}$: Description of buyer and supplier role assignment.
	$FR_{2.6}$: Establish a risk management system.	$DP_{2.6}$: The mitigation and contingency plans for disturbances due to lack of interoperability.	$PV_{2.6}$: Procedures and processes to implement when risk conditions are fulfilled.
	$FR_{2.7}$: Distribute governance in the dyad.	$DP_{2.7}$: The definition of a governing firm, or the equal distribution of power on the dyad.	$PV_{2.7}$: Description of how decision-making process is taken place and how it affects the dyad.
	$FR_{2.8}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.8}$: The partner skills for cooperation.	$PV_{2.8}$: The competences description, implemented training programs and other measures to ensure adequate skills for cooperation and cooperation scale-up.
Rules Interoperability	FR_{3}: Reconcile applicable laws (national and cross-borders) and business rules.	DP_{3}: The harmonization of rules for business set-up.	PV_{3}: Applicable laws and business rules and the method to sustain legal cooperation.
Process Interoperability	FR_{4}: managing internal and interface processes.	DP_{4}: seamless collaborative business processes.	
	$FR_{4.1}$: Model the process sequence.	$DP_{4.1}$: The sequence approach and the business process models that choreographs the sequence.	$PV_{4.1}$: The work methods that enable process flow and resources (human and technical) that performs them.
	$FR_{4.2}$: Align internal processes with the firms' organizational structures.	$DP_{4.2}$: The organizational alignment solution BPM and DSM representations.	$PV_{4.2}$: Description of the responsibility assignment.
	$FR_{4.3}$: Select metrics to monitor internal/interface processes.	$DP_{4.3}$: Operational SCM and interoperability performance metrics.	$PV_{4.3}$: Metrics monitoring.
	$FR_{4.4}$: Align companies' internal processes.	$DP_{4.4}$: The internal processes reconciliation and the collaborative business process	$PV_{4.4}$: Work methods, communication procedures and resources implemented to interact with partner.

		model.	
Data interoperability	FR_5: manage data exchange.	DP_5: data flows between firms.	
	$FR_{5.1}$: Manage the communication path for interface processes.	$DP_{5.1}$: The depth of communication paths definition.	$PV_{5.1}$: The communication procedure, the users and the ICT implemented for data exchange.
	$FR_{5.2}$: Assign employees to interface processes.	$DP_{5.2}$: The contact points definition.	$PV_{5.2}$: If contact points were defined, identify the users and respective processes where is performed the contact between firms.
	$FR_{5.3}$: Manage compatibility between exchanged data formats.	$DP_{5.3}$: Solution for data compatibility.	$PV_{5.3}$: The procedure to enable data formats compatibility.
	$FR_{5.4}$: Manage the context of information in communications.	$DP_{5.4}$: The method to handle semantics.	$PV_{5.4}$: Procedure to handle the context of information.
	$FR_{5.5}$: Manage data exchange.	$DP_{5.5}$: The data exchange approach.	$PV_{5.5}$: The methods to handle the data exchange solution.
	$FR_{5.6}$: Ensure quality in communications.	$DP_{5.6}$: The approach to maintain data quality in communications.	$PV_{5.6}$: Semantic agreements, required data, etc.
	$FR_{5.7}$: Ensure information quality.	$DP_{5.7}$: The methods to prevent incorrect data.	$PV_{5.7}$: The data handling procedures to prevent errors (e.g. data validation tools, data insertion methods, etc.).
Software and systems interoperability	FR_6: Manage software and systems interoperability.	DP_6: Compatible systems.	
	$FR_{6.1}$: Manage compatibility between interface software.	$DP_{6.1}$: The software solution for interacting/complementary processes.	$PV_{6.1}$: The users, the procedures and conversions (software or manual) to use data from different or similar software.
	$FR_{6.3}$: Manage information systems security.	$DP_{6.3}$: The IT security approach.	$PV_{6.3}$: The procedures, agreements, protocols, etc. used to support the security approach.
	$FR_{6.4}$: Manage information systems to support the dyad interaction.	$DP_{6.4}$: The IT management solution.	$PV_{6.4}$: The activities to support interface information systems.
	$FR_{6.5}$: Maintain compatibility to required legacy systems.	$DP_{6.5}$: Solution to deal with legacy systems.	$PV_{6.5}$: The identification of legacy systems and associated hardware; and the methods to enable interaction and data flow with the legacy systems.
Objects and hardware interoperability	FR_7: Manage internal hardware used in internal processes that have influence on the dyad's interaction.	DP_7: Hardware solution for seamless data integration.	
	$FR_{7.1}$: Choose hardware to register data from/to physical processes.	$DP_{7.1}$: The selected device and the interaction type (human-machine or machine-machine).	$PV_{7.1}$: The method to use devices and users (if required).
	$FR_{7.2}$: Ensure compatibility of physical devices and internal systems.	$DP_{7.2}$: The hardware compatibility approach.	$PV_{7.2}$: The methods to enable hardware connectivity with other systems (automated or user-based).
Human Resources	FR_8: Manage users that use information systems internally and when interacting with part.	DP_8: methods to ensure motivation, efficiency and adequate competencies for cooperation.	
	$FR_{8.1}$: Ensure employees motivation.	$DP_{8.1}$: The approach to keep employees motivated.	$PV_{8.1}$: The form of implementation of the motivational programs.
	$FR_{8.2}$: Ensure adequate knowledge for SC activities.	$DP_{8.2}$: The depth of employee selection and the management of knowledge and skills.	$PV_{8.2}$: The description of the adequate knowledge skills for employees to perform activities; the implementation of training programs, etc.
	$FR_{8.3}$: Ensure adequate IT competencies.	$DP_{8.3}$: The depth of employee selection and the management of knowledge and skills.	$PV_{8.3}$: The description of adequate IT skills; implementation of training programs, etc.
Cultural Interoperability	FR_9: Manage the cultural differences on the dyad's interface.	DP_9: Methods to harmonize culture and to solve linguistic barriers.	
	$FR_{9.1}$: Harmonize cultural differences between companies and interacting employees.	$DP_{9.1}$: The methods implemented to avoid cultural differences.	$PV_{9.1}$: The description of the method and the form it is implemented.
	$FR_{9.2}$: Avoid linguistic barriers on companies' communication.	$DP_{9.2}$: The method to avoid linguistic barriers.	$PV_{9.2}$: The description of the language and identification of interfaces and employees that establish the communication.

Table 1. Types of design matrix couplings and their relation with interoperability.

Types of coupling	Design Equation	Interoperability result
Uncoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Interoperable
Decoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Conditioned interaction Faulty relationship
Coupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$	Non-interoperable

Table 1. Example of low BS interoperability design.

$FR_{1.1}$: Establish business goals for cooperation.	$DP_{1.1}$: Written contract specifying the cooperation conditions and liabilities.
$FR_{1.2}$: Reconcile actor's individual strategy with cooperation strategy.	$DP_{1.2}$: Cooperation strategy defined but not aligned with individual strategy.
$FR_{1.3}$: Ensure clarity in business objectives.	$DP_{1.3}$: Occasional failures in cooperation.

Table 1. Dyad's companies profile

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

Table 1. Dyad's business set-up conditions (BS and RM).

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
FR_{1}: Establishment of the cooperation goals.	*DP_{1}: Negotiated conditions and ground rules for business.*
$FR_{1.1}$: Establish conditions applicable to purchasing and selling.	$DP_{1.1}$: Dyad responsibilities and delivery conditions.
$FR_{1.1.1}$: Negotiate purchasing and selling conditions.	$DP_{1.1.1}$: Written contract specifying the delivery conditions set by FS.
$FR_{1.1.2}$: Reconcile the actors' individual strategy with the cooperation strategy.	$DP_{1.1.2}$: Cooperation strategy was defined, but it is not aligned with the individual objectives.
$FR_{1.1.3}$: Ensure a clear business strategy for both actors.	$DP_{1.1.3}$: Occasional failures in cooperation.
$FR_{1.2}$: Establish liabilities and contingencies for failure to commitments.	$DP_{1.2}$: Firms' conditions regarding delays and order failures.
$FR_{1.2.1}$: Negotiate the liabilities and contingencies for failure to commitments.	$DP_{1.2.1}$: Written contract specifying liabilities imposed by FS.
$FR_{1.2.2}$: Reconcile liabilities for delivery failures with the individual strategy.	$DP_{1.2.2}$: The objectives are fully aligned.
$FR_{1.2.3}$: Ensure clarity in liabilities for both actors.	$DP_{1.2.3}$: Occasional failures.
FR_{2}: Manage cooperation.	*DP_{2}: Measures to maintain cooperation.*
$FR_{2.1}$: Distribute governance in the dyad.	$DP_{2.1}$: Unilateral power distribution (FS is the governing firm).
$FR_{2.2}$: Assign actors to business activities.	$DP_{2.2}$: The identification of role assignments and its level of adequacy and possible existence of responsibility gaps.
$FR_{2.2.1}$: Assign responsibilities to the supplier.	$DP_{2.2.1}$: Well-defined. The responsibility and roles assignment is not an issue.
$FR_{2.2.2}$: Assign responsibilities to the focal firm.	$DP_{2.2.2}$: Well-defined. The responsibility and roles assignment is not an issue.
$FR_{2.3}$: Manage cooperation in its initiation.	$DP_{2.3}$: Selection of a certified supplier.
$FR_{2.4}$: Monitor cooperation.	$DP_{2.4}$: Record of partnership metrics and audits.
$FR_{2.5}$: Manage cooperation during its realization.	$DP_{2.5}$: The relationship management measures to ensure the cooperation duration and adequacy to the dyad needs.
$FR_{2.5.1}$: Establish business relationships that last enough time to develop a trustworthy environment and permit the cooperation scale-up.	$DP_{2.5.1}$: Strategic long-term relationship.
$FR_{2.5.2}$: Assess and review cooperation progress during the cooperation.	$DP_{2.5.2}$: Annual meetings to review partnership performance.
$FR_{2.5.3}$: Establish a mechanism to deal with premature cooperation breakdown.	$DP_{2.5.3}$: Preventive contract condition to keep the steady supply after cooperation breakdown.
$FR_{2.6}$: Establish a risk management system.	$DP_{2.6}$: The mitigation and contingency plans for disturbances due to lack of interoperability.
$FR_{2.6.1}$: Contingency plan for delays in delivery.	$DP_{2.6.1}$: Contract obligations and implementation of an alternative supplier.
$FR_{2.6.2}$: Contingency plan for delays in information transmission/communication	$DP_{2.6.2}$: Alternative procedure for communication.
$FR_{2.6.3}$: Establish preventive measures to deal with amount of orders less than ordered.	$DP_{2.6.3}$: Standard procedure to identify faulty cases and exceptional procedure to deal with missing parts and contract obligations.
$FR_{2.7}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.7}$: Appropriate skills for cooperation.

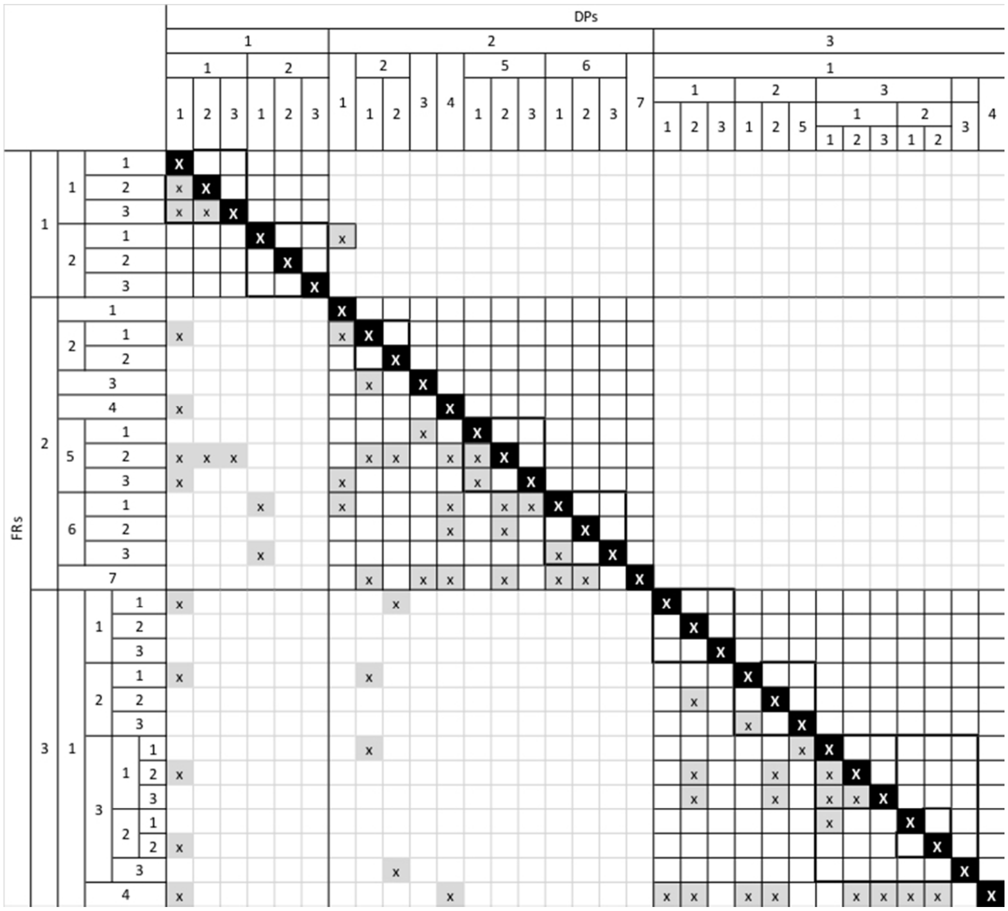

Figure 3. Design matrix for the "as-is" design of the buyer-seller interaction (mapping between FRs and DPs).

132x119mm (150 x 150 DPI)

Table 1. Dyad's internal and interface processes and supporting data and resources (PI, DI and SSI perspectives).

Interoperability Requirements (FRs)	Interoperability solutions (DPs)
$FR_{3.1}$: Model and manage the buyer-selling relationship.	$DP_{3.1}$: Features of the FS's and SS_1's procedure to handle orders, since order placement to fulfilment.
$FR_{3.1.1}$: Model and manage FS's purchasing processes.	$DP_{3.1.1}$: FS actual business process model for purchase and reception (see "parts ordering" lane in **Error! Reference source not found.**).
$FR_{3.1.1.1}$: Model the process sequence of FS processes.	$DP_{3.1.1.1}$: Sequential procedures with low interaction dependency.
$FR_{3.1.1.2}$: Manage the interface between the inventory management system and the ordering system.	$DP_{3.1.1.2}$: MRP data converted manually (into order and soft order data) before sending it. SAP and E-mail are not interoperable.
$FR_{3.1.1.3}$: Align purchasing and reception with FS organizational structure.	$DP_{3.1.1.3}$: Functional process distribution by matching a process to a section.
$FR_{3.1.2}$: Model and manage SS_1's sales processes.	$DP_{3.1.2}$: SS_1 actual business process model for order reception, order treatment, production and delivery (see **Error! Reference source not found.**).
$FR_{3.1.2.1}$: Model the process sequence of SS_1 processes.	$DP_{3.1.2.1}$: Cooperative/interactive procedure between logistics planning and production planning activities. Preceding sales and succeeding production and delivery activities are independent and sequential.
$FR_{3.1.2.2}$: Manage the compatibility between the ICT for order reception and the order management system.	$DP_{3.1.2.2}$: E-mail and SAP are not interoperable. Order data must be inserted manually into SAP.
$FR_{3.1.2.3}$: Align SS_1 processes with organizational structure.	$DP_{3.1.2.3}$: Many tasks performed by one section, in the case of sales and logistics activities, and the rest are sequential (see **Error! Reference source not found.**).
$FR_{3.1.3}$: Align companies' internal processes.	$DP_{3.1.3}$: The collaborative business process model (see **Error! Reference source not found.**).
$FR_{3.1.3.1}$: Manage the order placement procedure.	$DP_{3.1.3.1}$: Features of the order placement.
$FR_{3.1.3.1.1}$: Assign employees to the interface for order placement/reception.	$DP_{3.1.3.1.1}$: Contact points defined.
$FR_{3.1.3.1.2}$: Manage the interface between ICT's used to place/receive orders.	$DP_{3.1.3.1.2}$: Order and soft order data is not compatible between firms. The conversion of order data to the e-mail format doesn't permit import data directly on SAP.
$FR_{3.1.3.1.3}$: Manage the communication path to place orders.	$DP_{3.1.3.1.3}$: Standard procedure defined to communicate orders.
$FR_{3.1.3.2}$: Manage the order confirmation procedure.	$DP_{3.1.3.2}$: Features of order confirmation.
$FR_{3.1.3.2.1}$: Manage the communication path to confirm orders.	$DP_{3.1.3.2.1}$: Standard procedure defined to communicate orders.
$FR_{3.1.3.2.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.1.3.2.2}$: ASN is integrated directly on SAP system.
$FR_{3.1.3.3}$: Establish a delivery process for material flow.	$DP_{3.1.3.3}$: 3rd party freight forwarder to retrieve components from SS and deliver them to FS.
$FR_{3.1.4}$: Select metrics to monitor interface processes.	$DP_{3.1.3}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.

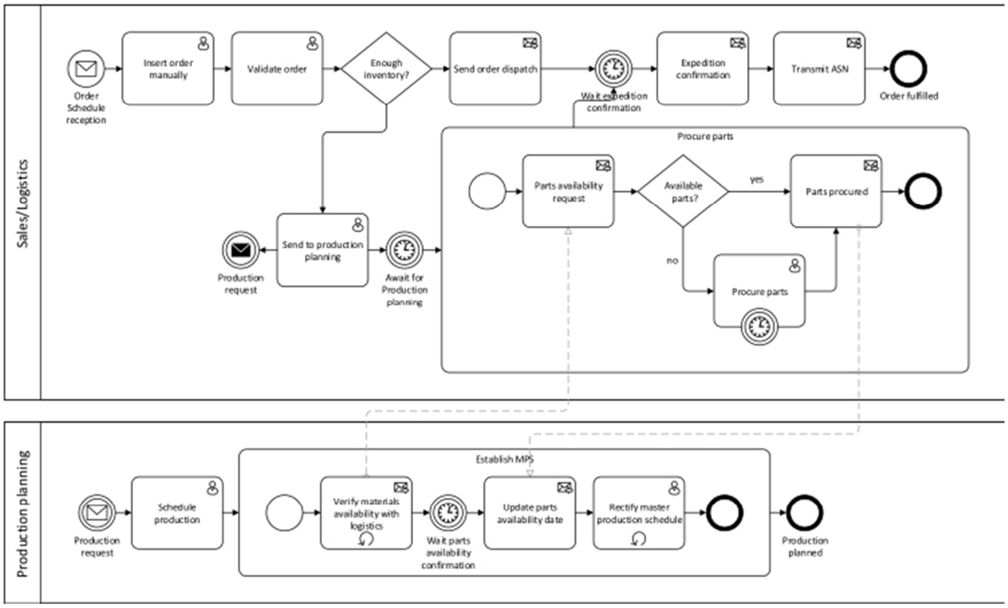

Figure 4. SS's internal processes.

126x76mm (150 x 150 DPI)

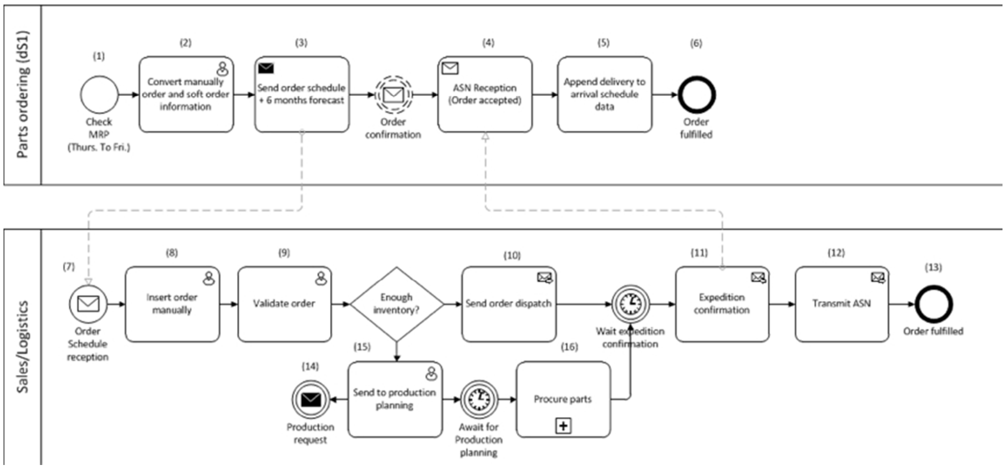

Figure 5. Interface between parts ordering and sales and logistics section.

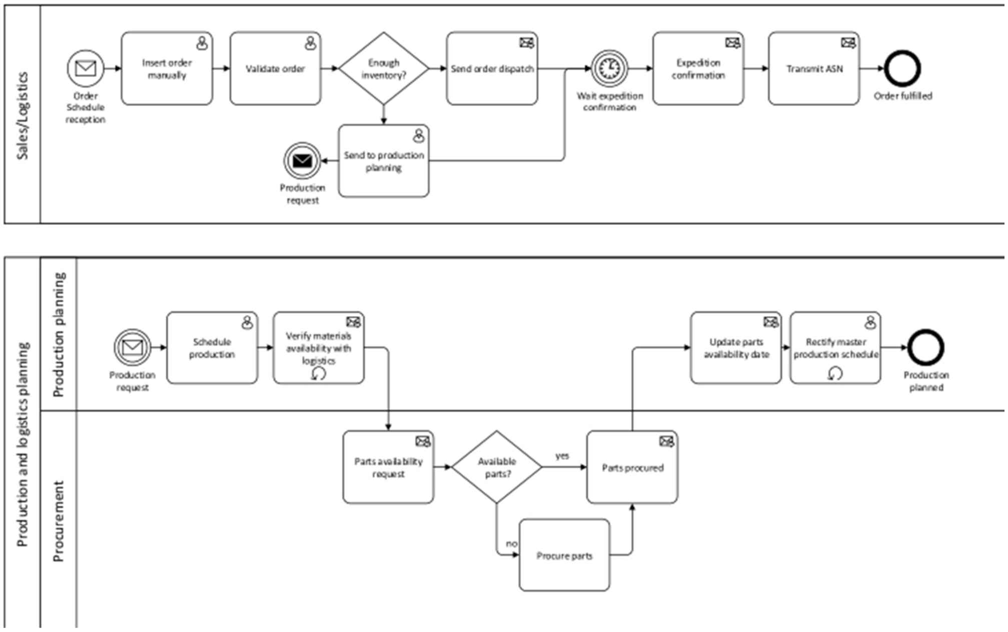

Figure 6. New process sequence and alignment for SS.

123x76mm (150 x 150 DPI)

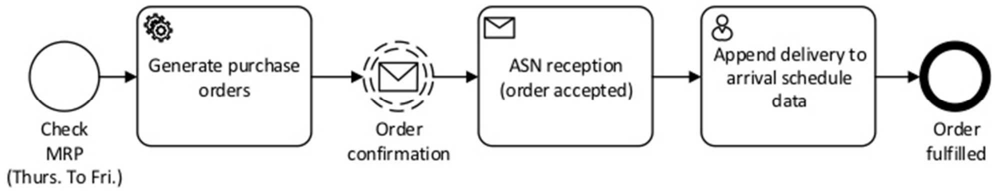

Figure 7. FS purchasing process with WebEDI implementation.

123x23mm (150 x 150 DPI)

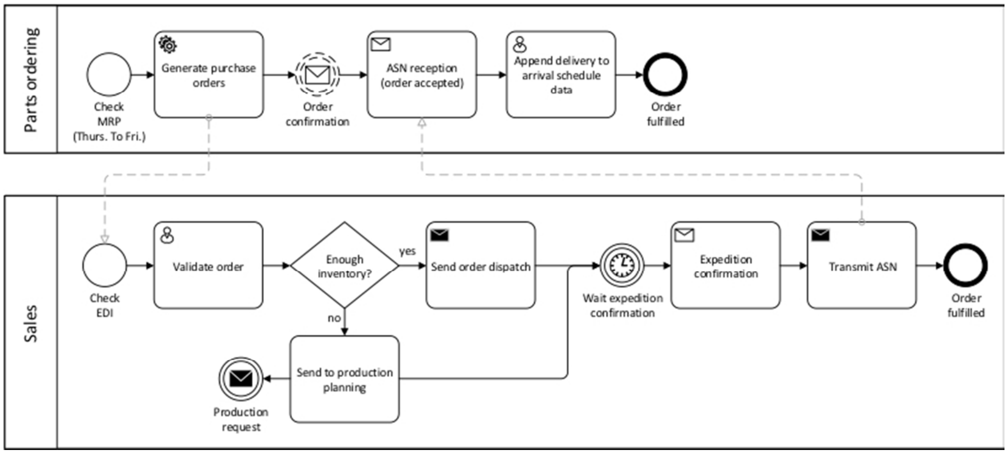

Figure 8. Interface between parts ordering and sales sections.

137x61mm (150 x 150 DPI)

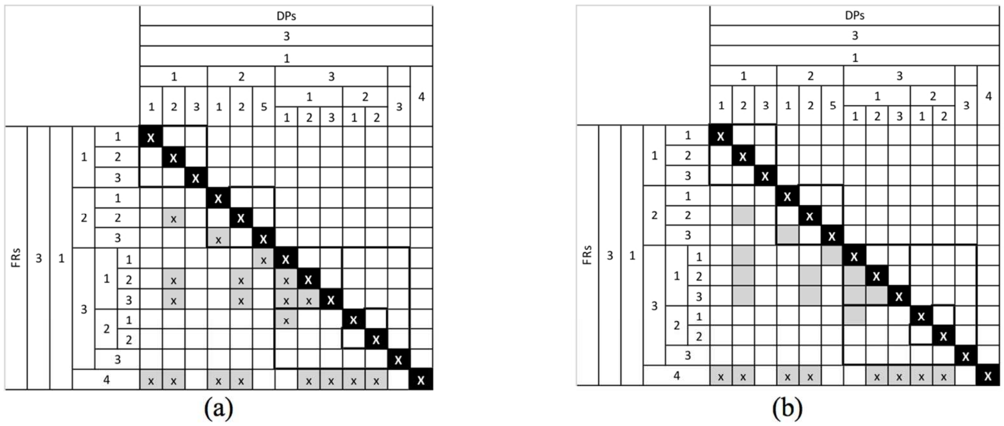

Figure 9. Design matrices for "as-is" (a) and implementation of EDI (b).

507x213mm (72 x 72 DPI)

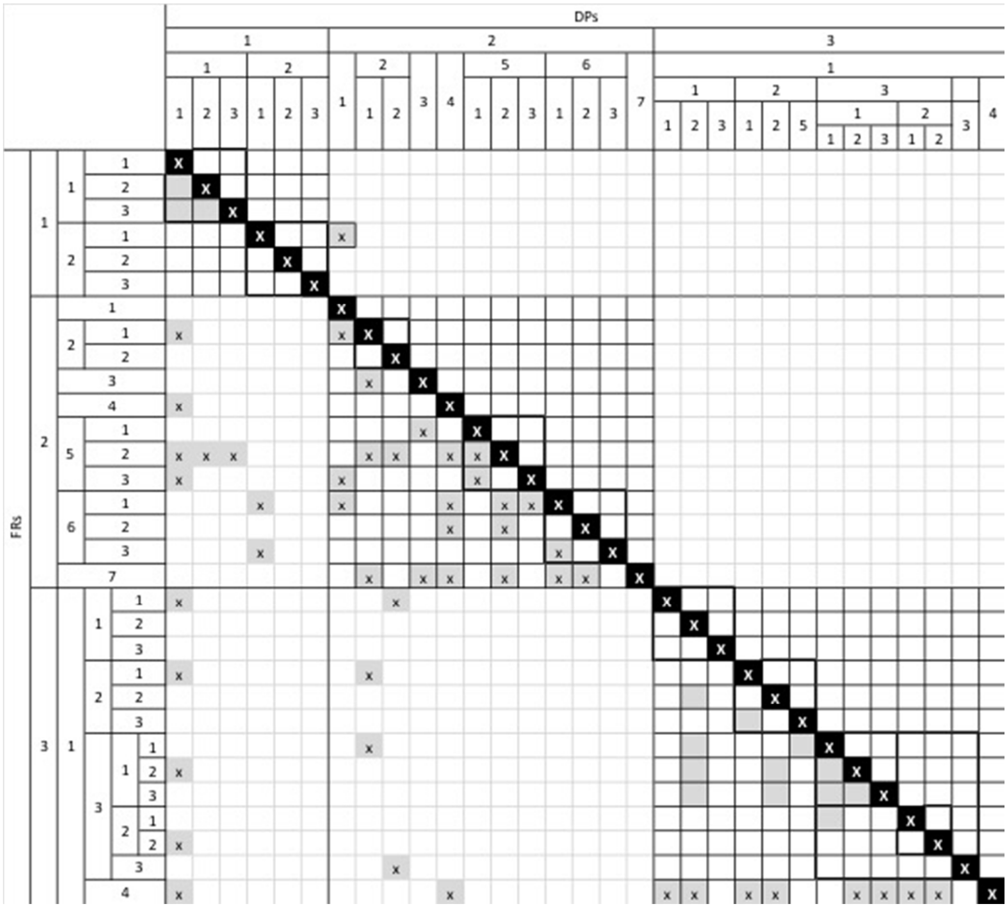

Figure 10. Design matrix for the "to-be" design of the buyer-seller interaction (mapping between FRs and DPs).

99x89mm (150 x 150 DPI)