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Mestre em Engenharia e Gestão Industrial

Licenciado em Engenharia Química

Business Interoperability: a methodology to analyse and re-design interoperable buyer-supplier dyads

Dissertação para obtenção de grau de Doutor em Engenharia Industrial (DEI)

Orientador: António Grilo, Professor Auxiliar com Agregação, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

Júri:

Presidente:	Prof. Doutor Virgílio António Cruz Machado
Arguente(s):	Prof. Doutora Susana Maria Palavra Garrido Azevedo
	Prof. Doutor Luís Miguel Domingues Fernandes Ferreira
Vogais:	Prof. Doutor Henrique José da Rocha O'Neill
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FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Dezembro 2016

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I wish you were all here...

Pedro Espadinha da Cruz

Abstract

Cooperation between firms is an increasing strategy for firms that wish to achieve competitive advantage. Buyer-supplier dyads are distinguished among other relationships of the supply chains as the simplest form of interaction, which allows achieving competitive synergy to compete with other dyads, networks or the entire supply chain. Business interoperability has become an indisputable reality for firms to achieve successful cooperation in electronic-based business, being considered as an enabler that makes possible to execute the supply chain operations seamlessly, easing their alignment and the information flow, guaranteeing high performance and competitiveness. However, lack of interoperability affects business interactions at organisational, knowledge and technical levels. In supply chains, and in the specific case of the buyer-supplier dyad, that problem may result in incoordination of processes, inefficiencies, and redundant operations that subtract the value-added to costumer and, ultimately, its effect may propagate to all the supply chain. This thesis aims to study the interoperability of business in the context of buyer-supplier dyads and develop a methodology that allows the identification and resolution of interoperability problems. Acting on existing interoperability limitations, the ADADOP method was proposed with the aim of analysing and re-design the buyer-supplier dyads, with the ultimate objective of achieving optimal interoperability, reflected in the performance and value added to the final customer. The method was tested in the automotive industry in four case studies. The main findings in the practical applications was that Axiomatic Design theory is fit to design interoperable buyer-supplier dyads, allowing the representation of interoperability problems and the improvement through the application of the 1st axiom (independence) and re-design by studying other interoperability solutions. The integration of Axiomatic Design with modelling techniques allowed to study the physical implications of the design on the business processes performed by the firms and, using simulation, was possible to study the impact of interoperability problems and solutions on the dyad's performance. With regards to practical implications, the ADADOP method allows to assist managers in making decisions, allowing to study the impact of these decisions physically and performance of the dyad. This, ultimately, contributes to recognize interoperability not as a problem but as a utility or service that provides improved performance for buyer-supplier dyads, and increased value to the final customer.

Keywords: business interoperability, SCM, buyer-supplier dyads, axiomatic design, BPMN, DSM

Resumo

A cooperação entre empresas é uma estratégia cada vez mais comum para empresas que pretendem alcançar vantagem competitiva. As díades comprador-fornecedor são distinguidas de outras relações da cadeia de abastecimento como a forma mais simples de interação, que permite uma sinergia competitiva para competir com outras díades, redes ou toda a cadeia de abastecimento. A interoperabilidade negócio tornou-se uma realidade indiscutível para as empresas alcançarem uma cooperação de sucesso em negócios baseados em tecnologias de informação, sendo considerado como um elemento que torna possível executar as operações da cadeia de abastecimento, facilitando seu alinhamento e do fluxo de informações, garantindo alto desempenho e competitividade. Contudo, a falta de interoperabilidade afeta as interações de negócios a nível organizacional, do conhecimento e técnico. Nas cadeias de abastecimento e, no caso específico da díade comprador-fornecedor, este problema pode resultar em falta de coordenação dos processos, ineficiências e operações redundantes que subtraem o valor acrescentado ao cliente e, em última instância, o seu efeito pode-se propagar a toda a cadeia de abastecimento. A presente tese tem como objetivo estudar a interoperabilidade de negócio no contexto de díades comprador-fornecedor e desenvolver uma metodologia que permita a identificação e resolução de problemas de interoperabilidade. Atuando sob limitações da literatura existente, foi proposto o método ADADOP com o intuito de analisar e redesenhar díades comprador-fornecedor, com o objectivo ultimo de atingir interoperabilidade ótima, reflectida na performance e no valor acrescentado ao cliente final. O método proposto foi testado na indústria automóvel em quatro casos de estudo. As principais conclusões nas aplicações práticas foram que a teoria do Projeto Axiomático está apta para projetar díades comprador-fornecedor interoperáveis, permitindo a representação de problemas de interoperabilidade e para a melhoria através da aplicação do primeiro axioma (axioma de independência) e redesenho, estudando novas soluções de interoperabilidade. A integração desta teoria com técnicas de modelação, permitiu estudar as implicações físicas do desenho nos processos de negócio realizados pelas empresas e, usando simulação, foi possível estudar o impacto da interoperabilidade no desempenho da díade. Sob o ponto de vista prático, o método ADADOP permite assistir os gestores na tomada de decisão, possibilitando estudar o impacto dessas decisões fisicamente e no desempenho da díade. Isto, em última instância, contribui para reconhecer a interoperabilidade não como um problema, mas como uma utilidade ou serviço que proporciona maior desempenho para díades comprador-fornecedor, e o aumento do valor para o cliente final.

Palavras-chave: interoperabilidade de negócio, GCA, díades comprador-fornecedor, teoria axiomática de projeto, modelação de processos de negócio, matriz de estrutura de projeto

Publications

This thesis is based on the following papers, published by the author during its PhD research and in the project “Business Interoperability for Collaborative Platforms with Axiomatic Design Theory for Lean, Agile, Resilient and Green Industrial Ecosystems” (BIXLARGIE).

Paper A Espadinha-Cruz P, Grilo A, Cruz-Machado V. Fuzzy evaluation model to assess interoperability in LARG Supply Chains. 9th International Conference Fuzzy Systems Knowledge Discovery (FSKD 2012), Chongqing, China: 2012, p. 75–9.

Paper B Espadinha-Cruz P, Cabral I, Grilo A, Cruz-Machado V. Information Model for LARGeSCM Interoperable Practices. 34th International Conference Information Technology Interfaces, 2012.

Paper C Espadinha-Cruz P, Cabral I, Grilo A. LARG Interoperable Supply Chains: from Cooperation Analysis to Design. 5th International Conference Intelligent Decision Technology, 26-28 June, Sesimbra, Portugal: 2013.

Paper D Espadinha-Cruz P, Gonçalves-Coelho A, Mourão AJF, Grilo A. The Design of an Interoperable Self-Supported Reverse Logistics Management System. 7th International Conference of Axiomatic Design (ICAD 2013), 27-28 June, Worcester, USA: 2013.

Paper E Cabral I, Espadinha-Cruz P, Grilo A, Mourão AJF, Gonçalves-Coelho A. A Methodology for Designing an Interoperable Industrial Ecosystems, using the Axiomatic Design Theory. Industrial Engineering and Engineering Management (IEEM 2013), 10-13 December, Bangkok, Thailand: 2013.

Paper F Espadinha-Cruz P, Grilo A. Methodology to analyse and re-design dyadic industrial cooperation. 21st International Annual EurOMA Conference (EurOMA 2014), 20-25 June, Palermo, Italy: 2014, p. 1–10.

Paper G Espadinha-Cruz P, Mourão AJF, Gonçalves-Coelho A, Grilo A. Business Interoperability: Dyadic Supply Chain Process Decomposition Using Axiomatic Design. 8th International Conference of Axiomatic Design (ICAD 2014), 24-26 September, Caparica, Portugal: 2014, p. 93–9.

Paper H Espadinha-Cruz P, Grilo A. A simulation approach to select interoperable solutions in supply chain dyads. 7th Int. KES Conference Intelligent Decision Technology (KES-IDT 2015), 17-19 June, Sorrento, Italy: 2015, p. 10.

Paper I Espadinha-Cruz P, Gonçalves-Coelho A, Mourão A, Grilo A. Re-design of an Interoperable Buyer-seller Automotive Relationship Aided by Computer Simulation. 9th International Conference of Axiomatic Design (ICAD 2015), 16-18 September, Florence, Italy: 2015, p. 98–105. doi:10.1016/j.procir.2015.07.011.

Paper J Espadinha-Cruz P, Grilo A, Cruz-Machado V. Business Interoperability: the re-design and modelling of interoperable buyer-supplier dyads, Proceedings in International Conference on Computers & Industrial Engineering CIE 46, Tianjin, China, 29-31 October: 2016.

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Abbreviations

AA	Analysis axiom
AD	Axiomatic design theory
ADADOP	A+D stages, AD framework and Optimisation Procedure
AHP	Analytical hierarchy process
AIDC	Automatic identification and data capture
AIF	ATHENA interoperability framework
ANOM	Analysis of means
ANP	Analytical network process
APL	Action-profit linkage
BI	Business interoperability
BIF	Business interoperability framework
BIQMM	Business interoperability quotient measurement model
BPM	Business process modelling
BPMN	Business process modelling notation
BS	Business strategy
BSA	Business strategy analysis
CBP	Collaborative business processes
CI	Cultural interoperability
CIA	Cultural interoperability analysis
CNs	Customer needs
CPM	Collaborative performance measurement
CPMM	Causal performance measurement model
Cv	Conversion time
DI	Data interoperability
DIA	Data interoperability analysis
DID	Data interoperability decomposition
DoD	United States department of defense
DOE	Design of experiments
DPs	Design parameters
DSM	Design structure matrix
DSS	Decision support system
EA	Enterprise architectures
EDI	Electronic data interchange
EE	Extended enterprise
EI	Enterprise interoperability
EIF	European interoperability framework
EIMM	Enterprise interoperability maturity model
EM	Enterprise modelling

ERP	Enterprise resource planning
FIFO	First in first out
FRs	Functional requirements
FS	First supplier
GRAI	Graphs with results and actions inter-related
HLA-RTI	High-level architecture run-time infrastructure
HR	Human resources
HRA	Human resources analysis
HRD	Human resources decomposition
HVAC	Heating, ventilating, and air conditioning
IA	Interfacing axiom
IAM	Interoperability assessment methodology
ICT	Information and communication technology
IIAM	Interoperability impact analysis model
IPM	Interoperability performance measurement
IT	Information technology
KI	Knowledge interoperability
KPI	Key performance indicator
LCI	Layers of coalition interoperability
LISI	Levels of information systems interoperability
MA	Modelling axiom
MCDM	Multi-criteria decision-making
MMA	Meta-modelling axiom
MPI-ASP	Extended asynchronous simulation protocol using message passing interface
NC3TA	NATO C3 technical architecture
NVA	Non-value added
OEM	Original equipment manufacturer
OHI	Objects and hardware interoperability
OHIA	Objects and hardware interoperability analysis
OHID	Objects and hardware interoperability decomposition
OI	Organisational interoperability
OIAM	Organisational interoperability agility model
OIM	Organisational interoperability maturity model
OLT	Order lead-time
PI	Process interoperability
PIA	Process interoperability analysis
PID	Process interoperability decomposition
PM	Performance measurement
PMS	Performance measurement system

PVs	Process variables
RI	Rules interoperability
RIA	Rules interoperability assessment
RM	Relationship management
RMA	Relationship management analysis
RMD	Relationship management decomposition
ROI	Return of investment
RQ	Research question
R&D	Research and development
SA	Systemic axiom
SC	Supply chain
SCC	Supply chain collaboration
SCI	Supply chain integration
SCM	Supply chain management
SCOR	Supply chain operations reference
SCPM	Supply chain performance measurement
SLA	Service level agreements
SMEs	Small and medium scale enterprises
SOA	Service oriented architecture
SoSI	System of systems interoperability
SSI	Software and systems interoperability
SSIA	Software and systems interoperability analysis
SSID	Software and systems interoperability decomposition
SS_1	Second supplier
TIP	Time of interoperation in purchasing
TOPSIS	Technique for order preference by similarity to ideal solution
TUP	Time of use to plan orders
UEML	Unified enterprise modelling language
UML	Unified modelling language
VA	Value added
VE	Virtual enterprise
WebEDI	Web-electronic data interchange

Symbols

I	Information content
p	Probability of satisfying a given FR
cr	Common range
dr	Design range
sr	System range
Δ	Range of factor

Equations

Chapter 1 - Introduction and research method

Considering business interoperability as a scientific research area presupposes the possibility of expanding the existing knowledge and dive into newer possibilities. Researching in this field allows contributing with new methods that will aid in mitigating problems that affect business activities that rely on information technology. Problem description and consequent identification of challenges and constrains will contribute to identify the main difficulties to deal in research. After establishing what and why business interoperability needs to be researched, the definition of the research questions will club the research methodology that will guide this thesis until the end.

Cooperation between firms is an increasing strategy in the current industrial context. 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). In turn, the condition that makes such activities possible is that companies are interoperable (Blanc, Ducq, & Vallespir, 2007). Rooted in information technology (IT), the concept of business interoperability (BI) is regarded as an 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 of creating value (Legner & Wende, 2006). In the context of SCM, 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). Then, in turn, is reflected in the effective management of strategic alliances, extensive data management capabilities, and advanced inter-organisational information systems to enable better information exchange (Liu, Zhang, & Hu, 2005).
Despite the acknowledgement of the advantages of cooperating, interoperability problems hinder the IT-supported interaction. As the coverage of BI ranges from organisational to technical issues of firms' interaction (Rezaei, Chiew, Lee, & Shams Aliee, 2013), interoperability problems may be reflected in all this areas. For instance, at strategic level, problems are reflected in misaligned objectives and in conflicts; at operational level, those problems may result in process incoordination; and, in IT perspective, miscommunications or incompatibility may occur in data exchange. In SCs, the impact of lack of interoperability is pronounced. Problems in business partnering and in IT that supports such relationships may result in incoordination of processes, inefficiencies, redundant operations that subtract the value-added for end-customer. Interoperability may ultimately propagate to the all SC, and can result in phenomena as unpredictable demand that may lead to the Bullwhip effect.

This thesis aims to study the BI in buyer-supplier dyads. This SC relationship is of great importance for all the SC and the value chain, defended as a kind of relationship that should be fostered in all SC to achieve competitive synergies (Mondini, Machado, & Scarpin, 2014). Being the buyer-supplier dyad the simplest form of interaction in upstream of SC, improving interoperability in this smaller link in the chain allows dealing with interoperability as a service or utility that delivers value and increased performance to the dyad, propagated to all the SC.

In the next sections, a brief overview on BI is presented, stressing on the main achievements and limitations that delineate the research. Subsequently, the research objectives and questions are exposed and the research methodology is defined.

1.1. Existing research in BI

To get a clear picture of the current research, a quantitative analysis was made referring to academic articles mentioning to "business interoperability" or "interoperability" or "interoperation" on the title or keywords (see Table 1.1). The growth in the published articles overtime is remarked, having the majority published since 2004, constituting 76% of the total publications since 1980. With regards to subject areas, most articles are addressed in technical perspectives of interoperability and few are addressed under the scope of information systems, where BI fits.

Table 1.1. Academic publications until September 2013.

Total number of publications	**14202**	**Percentage**
Year of publication		
1980-1992	112	1%
1993-1996	347	2%
1997-2000	1321	9%
2001-2003	1536	11%
2004-2007	4289	30%
2008-2013	6597	46%
Subject areas		
Computer Science Information Systems	4461	31%
Engineering Electrical Electronic	3806	26%
Computer Science Theory Methods	3569	25%
Telecommunications	2715	19%
Computer Science Interdisciplinary Applications	2302	16%
Computer Science Software Engineering	2298	16%
Computer Science Artificial Intelligence	2167	15%
Computer Science Hardware Architecture	1450	10%
Information Science Library Science	580	4%
Medical Informatics	574	4%

Source: Web of Science academic articles that contained "interoperability" or "interoperation" or "business interoperability" in keywords or title.

Research trends

The inherent technologic evolution is remarked in the interoperability and BI literature through its dimension and diversity. While early work focused on technical aspects as IT architectures and interfaces, more recent publications address the systems, but also business areas as organizational and knowledge issues (Legner & Lebreton, 2007). The inclusion of organisational and knowledge assets in interoperability was an achievement to the field. This allowed rethinking the way firms interact, and electronic data exchange become not only a necessity, but re-shaped the way business and people connect. As consequence, interoperability fields focused on organisational aspects emerged, where BI and Enterprise interoperability (EI) are distinguished.

One of the cornerstones in interoperability literature is the interoperability frameworks proposed by several research institutions. Each one attempts to characterize interoperability and provide requirements for systems and for companies interaction. Fitting the specific needs of each research, the existing frameworks address different issues considered under the scope of interoperability (Rezaei et al., 2013). Those frameworks influenced subsequent research where the guidelines are considered crucial to achieve effective interoperation.

Another trend found in literature is the attempt to decompose interoperability in perspectives. According to each author, a decomposition framework is provided enforcing the idea that, accomplishing these smaller terms, interoperability is achieved (Chen & Doumeingts, 2003). That culminated in several interoperability types, or perspectives, and different models applied with different levels of detail.

A more paradigmatic view of interoperability is emphasized in the way researchers look at interoperability. Interoperability is often remarked as a problem (or lack of interoperability) rather than being considered as ability. As consequence, frameworks and subsequent research provide levels, maturity levels, assessment models, criteria, and performance metrics that attempt to qualify and to quantify interoperability. With these assets, those frameworks and models intend to identify problems and barriers that inhibit interoperation in order to devise means to remove them (Espadinha-Cruz & Grilo, 2014). In turn, this led to the concept of optimal interoperability, whereas interoperating firms and systems strive to achieve the adequate levels of interoperability that fits the business requirements (ATHENA, 2007).

Challenges and needs in BI

Since the first contributions in interoperability, the subject has grown from IT perspective into a more comprehensive vision that incorporates BI. During this growth, interoperability became a multidimensional concept featuring different perspectives and levels of detail (Rezaei et al., 2013). Nevertheless, despite the growth in awareness for the subject, the BoK is considered disperse and disorganized. Contributions are either single subject focused or approach interoperability in a generic manner. Different designations, interoperability types, criteria and performance metrics are enounced from different authors, but interoperability problems are addressed in different manner, resulting in overlapping and problem fragmentation (Ford, 2008; Razavi & Aliee, 2009).

The diversity in interoperability contributed to a broad and complex BoK, having provided several frameworks and solutions for interoperability. However, an integrated method to address BI in an integrated perspective is still missing. The need for a comprehensive framework and methodology is well recognized in different perspectives of literature. Regarding enterprise interoperability (EI), Chen, Doumeingts, & Vernadat (2008) defend that an interoperability domain framework is needed to precisely identify and structure interoperability research issues. That would help guide through interoperability BoK and determine the adequate solutions to implement. In the BI perspective, Legner & Wende (2006) defend the need for a systematic analysis of strategic, organisational and operational issues associated with interoperability. Camara, Ducq, & Dupas (2013) look at the limitations in the existing frameworks and approaches, emphasizing the need to establish links between interoperability measurements and objectives defined by a company taken individually or as a part of collaboration. These last two visions highlight the organisational and operational perspectives that characterize BI. However, as is remarked by Westerheim & Baalsrud Hauge (2015) in present frameworks there is still missing links between the technical and the business-level interoperability.

Existing research treat the interoperability concept as a problem rather than an ability or requirement. As so, 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). As consequence, business relationships, and supporting IT, are set-up regardless of providing a well-tuned synergy between companies' structures and systems. The need, herein, is to consider what requirements are necessary to ensure that both companies and respective systems are interoperable. Though, at the beginning of a project, very little is known about interoperability requirements (Morris, Levine, Myers, Place, & Plakosh, 2004). Current frameworks and models look at on-going interactions and attempt to devise means to solve interoperability problems. To successfully achieve interoperability, one has to anticipate the needs and set good practices that, effectively, ensure interoperability. The problem here is that interoperability research is considered to be at an early stage (Ducq & Chen, 2008; Kotzé & Neaga, 2010; Legner & Wende, 2006). Although many frameworks and models provide valuable empirical insights from interoperability at different perspectives and areas of application, there is lack of documented cases from designed or improved systems that makes possible to conclude about what are the adequate interoperability requirements (Pazos Corella et al., 2013).

1.2. Aim and objectives

Although it is acknowledged that the existing literature is a valuable asset for future developments in BI, the identified shortcomings leave open a cohesive method to address BI in business relationships, and specifically in the case of the buyer-supplier dyads. In this sense, the present thesis aims at studying the impact BI has on these relationships, and determining how interoperability can be used to improve them. More specifically, the following objectives are propositioned:

- To propose a framework for interoperability perspectives and types under the concept of BI;
- To study the influence of BI in buyer-supplier dyads;

- To develop a method to assist problem identification and re-design of the interoperable buyer-supplier dyad.

To tackle those objectives, it is necessary to understand how the buyer-supplier dyads can be addressed in the different perspectives of BI. Further, one should study how interoperability is affecting the business interaction, and how to solve problems in a systematic manner.

To address the objectives, seven research questions (RQs) were set addressing two main areas: the interoperability problem identification and characterization (A); and the integration of design, modelling and performance measuring (B). In the first, it is necessary to review how existing frameworks and methods deal with the interoperability problem identification and solving, in order to understand how the buyer-supplier dyad can be decomposed in the different drivers that rule firms' interaction, and determine to what extent firms are interoperable. On the second area (B), it is necessary to study the influence of BI in the dyad, and devise practical implications for the dyad to be improved. The aim is to develop a method that supports the assessments of the impact of BI in the dyad, assisted by design and modelling methods.

The success of this research depended on the author's previous experience and the participation on research projects. In the participation on the project "Lean, agile, resilient and green supply chain management" (MIT-Pt/EDAM-IASC/0033/2008), the author developed BI models applied in automotive industry to assess interoperability in the implementation of SCM practices. The BI approach herein was of a conceptual nature, and settled on subjective assessment of interoperability. The present work was part of the project "Business interoperability for collaborative platforms with axiomatic design for lean, agile, resilient and green industrial ecosystems" (PTDC/EME-GIN/115617/2009). Herein, the author extended from the conceptual to physical implications of interoperability in SCs. This integrated vision characterized the present research in the fulfilment of the objectives, where a top-down integrated method is intended.

Considering the objectives and the enounced success factors, the value proposition of this thesis is stated as follows:

"Provide an integrated methodology that systematizes the analysis and re-design of the interoperable buyer-supplier dyads to improve their performance and value-added to end-customer."

In the next section, the RQs are defined based on the research objectives, and the research methodology is described to support subsequent research.

1.3. Research approach

1.3.1. Research questions

Based on previously exposed fundament and objectives, the main research question (RQ) of this thesis is stated as follows:

Main RQ:	*"How does the business interoperability problem identification and solving may be systematized in order to re-design buyer-supplier dyads, improving their performance and value?"*

The higher objective is to study the influence BI has on buyer-supplier dyad in order to determine which factors require improvement, and determine solutions that aid in improving dyad's performance and enhancing value. The main RQ was subdivided in two main functional parts: the interoperability problem identification and characterization (A), and the integration of design, modelling and performance measuring of buyer-supplier dyads (B).

A. Interoperability problem identification and characterization

Problem identification and analysis is the interoperability area which most of literature focused since their early contributions. Like was observed in section 1.1, earlier contributions focused on providing frameworks and means to identify and classify interoperability problems. Complying with those, two sub-RQs are suggested:

RQ A.1:	*"In what perspectives may the buyer-supplier dyad be decomposed to reflect the business interoperability requirements and problems that have impact on their performance?"*

RQ A.2:	*"What are the criteria and methods that characterize the influence of BI in buyer-supplier dyad's performance?"*

RQ A.1 has the objective of systemizing the existing body-of-knowledge to allow the decomposition of buyer-supplier dyads into the interoperability and SCM areas. Those areas rule the companies' interaction and it is where the interoperability problems are reflected, which affect their performance and value creation.

Concerning RQ A.2, the objective is to study different methods and criteria used in the proposed frameworks to determine how interoperable systems and firms are. This aspect is related to the previous question, in the form that is classifies how far companies are from being perfectly interoperable. Though, RQ A.1 has a higher purpose in this thesis. Not only has the objective of decomposing interoperable dyads into lesser interoperability subjects, but also to assist in interaction decomposition that has the objective of maintaining an interaction framework to correlate the interoperability conditions with the practical implications, and how these conditions will impact the buyer-supplier dyad's performance.

B. The integration of design, modelling and performance measurement

The second part of the Main RQ was decomposed in one sub-RQ that addresses three different aspects of interoperability: design, modelling and performance measurement. RQ B is stated as:

RQ B:	*"How to systemize the design of buyer-supplier dyad's in the improvement of their performance and value?"*

In this RQ is addressed the need for a comprehensive method to systematically analyse interoperability, looking at the main problems and studying the impact in the buyer-supplier dyad's performance. The areas of design, modelling and measuring performance pursue different objectives in the interoperability scope. Design attempts to establish requirements and guided principles that aid in building interoperable systems. Modelling allows representing the operation between companies in functional, decisional, information system, and business process points of view (Blanc et al., 2007). Performance measurement permits to determine how interoperability impacts the system and the business relationship as a whole. Conciliating design, modelling and performance measurement allows one to go further in the interoperability problem identification and assessment, permitting to study the impact the interoperability conditions has on the dyad's performance and how they produce value. The systematic approach allows the manipulation of variables to determine which is the adequate configuration for interoperability drivers and requirements, and map which conditions are affecting interoperability towards the achievement of optimal interoperability performance. Hence, RQ B was subdivided into three sub-RQs:

RQ B.1:	*"How to integrate design and modelling in the improvement of the buyer-supplier dyad's performance and value?"*

RQ B.2:	*"What methods allow representing the interoperability problems reflected in dyad's processes that affect performance and decrease value?"*

RQ B.3:	*"How to measure the impact of business interoperability in buyer-supplier dyad's performance?"*

RQ B.1 aims at design methods that allow incorporating the existing interoperability knowledge with regards to interoperability frameworks and models, and attempt to set requirements and design principles that guide through the conception of an interoperable system. Integrating the modelling perspective with design allows converting the conceptual design into a representation of a specific function of companies' interaction. RQ B.1 aims at the need to set interoperability as a requirement, and to convert to physical implications aided by modelling.

In turn, RQ B.2 looks in depth to interoperability modelling function to discover the appropriate methods that are fit to address buyer-supplier dyads, which allow representing interoperability problems that have impact in performance and value. Frameworks and models assess interoperability in specific perspectives or problems. Physical representation goes further allowing to illustrate the company in terms of its organisation and functions (activities, information, resources, organisation units, and system infrastructure and architecture). Modelling languages may allow mapping and representing interoperability problems in these different functions, and in the different interoperability perspectives.

RQ B.3 is the final raised question that attempts to link interoperability problems and conditions with the performance. Performance measuring is distinguished from existing methods of interoperability that qualify or quantify subjectively interoperability. These second ones allow determining how interoperable companies are in terms of maturity levels. However, being more interoperable or perfectly interoperable may have a different meaning than optimal interoperability (Legner & Wende, 2006). The interactions in a dyad are dynamic, and improving interoperability in one of each interoperability perspectives may allow higher interoperability on a conceptual basis. Nevertheless, being a dyad a dynamic system, in practice another improvements may be required to achieve the adequate synergy between interoperability levels that allow companies, not only to be interoperable, but to be effective and efficient being it traduced in the dyad's performance and the value generated to customers.

1.3.2. Adopted Research Method

Research approach

Based on the characterization of the BI BoK, the research methodology was defined according to the adequate methods that fit to the exposed research problem and the existing knowledge on the subject. According to Hill & Hill (2009), there exist two general approaches for knowledge acquisition (see Figure 1.1): the deductive and inductive processes.

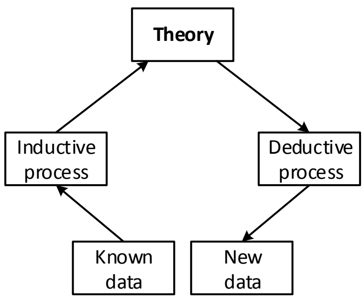


Figure 1.1. Deductive and inductive methods (adapted from (Hill & Hill, 2009)).

While in deductive process existing theories are used to formulate new hypothesis (or propositions) to obtain empirical results, the inductive process uses empirical data to formulate new theories (Hill & Hill, 2009). The deductive process starts with the literature revision to identify existing theories to develop, through the deductive process, new theories or hypothesis or propositions, which will be tested empirically to confirm or refute the theory (Golicic, Davis, & McCarthy, 2005). In opposition, the inductive process results from observations and established generalisations on the researched phenomenon (Bradford, 2015).

The present research was performed according to the deductive process. This method was selected because it is adequate to test formal theories, while the inductive process serves to generate new theories about a new or complex phenomena (Golicic et al., 2005). In practice, the identification of theories during the literature review allowed establishing RQs that are associated with underlying hypotheses or propositions that needs to be tested. With regards to BI BoK, the formulation of propositions was made considering existing knowledge, gaps in literature and similarities with another research areas that fit the scope of BI. Due to BI's multidimensional attribute, in some issues where BI BoK fails to provide theories to comprehend the buyer-supplier interaction, another fields (e.g. SCM, social sciences, computer sciences, industrial design, etc.) already have formulated theories to support the proposition formulation. This process follows a similar approach to hypotheses formulated by deduction and analogy (Hill & Hill, 2009). The first, like the deductive process, reports on existing theories to postulate new hypotheses. The second looks at the research problem in related or complementary knowledge areas that permit to understand the problem, and devise new hypothesis. That, ultimately, led to the creation of a method to analyse and re-design buyer-supplier dyads.

Research design: the case study approach

The selected research design strategy was the case study approach. Yin (2009) defines case studies "as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used". Their aim is to provide an analysis of the context and processes which illuminate the theoretical issues being studied (Cassell & Symon, 2004). Case studies involve investigation of a specific, unique system with patterned behaviour, dynamic properties, and defined features (L. A. Curry, Nembhard, & Bradley, 2009; Yin, 2003), enabling the researcher to develop a better insight into a complex and relatively unexplored phenomenon (Yin, 2003). Regarding its aim, a case study may be exploratory (to define questions or hypotheses), descriptive (to depict a phenomenon within its context), or explanatory (to identify cause-and-effect relationships) in nature (L. A. Curry et al., 2009; Yin, 1993).

The exploratory case study approach is used in this thesis because it allows dealing with qualitative data (Easton, 1995), and serves to investigate the phenomenon (the BI) in its natural context (the buyer-supplier dyads in a specific industrial context), addressing research questions and propositions defined to widen the examination of BI. According to Cassell & Symon (2004), the case study is particularly fit to RQs that require detailed understanding of organisational processes because of the rich data collected in context. Being BI a multidimensional and complex research area, the case studies are an adequate manner to provide a detailed understanding of buyer-supplier dyads' interactions, and cope with multiple sources of evidence.

Furthermore, the development of conceptual frameworks containing the relationship between key factors, construct and variables is advised for the implementation of case studies (Voss, Tsikriktsis, & Frohlich, 2002). Eisenhardt & Graebner (1989) supports this idea, arguing that a priori specifications of constructs permits researchers to measure constructs more accurately and, if they prove important, researchers have a firmer empirical grounding for the emerging theory. Voss et al. (2002) adds that, during the case-based research, the RQs may evolve over time, and the constructs can, consequently, be modified, developed or abandoned. Parallel, conceptual frameworks also evolve as the study progresses (Miles & Huberman, 1994).

The application of case study approach in BI, allowed setting initial RQs that were adjusted narrowing the research problem, and adapting to the knowledge that exists to support that problem. The constructs and variables considered in the frameworks delimit the research by establishing relationship between those ones and the objectives in study. This, in turn, aids in maintaining the focus on the problem during the execution of the case study (Voss et al., 2002).

With regards to number of cases performed, Flynn et al. (1990) distinguish two approaches: the single case study and the multiple case studies. Voss et al. (2002) defends that the fewer the case studies, the greater the opportunity for depth of observation. This principle is followed in this thesis. Due to the complexity of interactions between actors on the buyer-supplier dyad, in-depth case studies were preferred to address the full scope of interoperability in an integrated top-down approach to BI perspectives. In addition, the proposed method also captures the main SC operations and inherent interactions. Hence, instead of a replication approach of the same method in another dyads, the implemented case study focused on addressing different perspectives on a same dyad. Though, as is referred by Voss et al. (2002), although single cases haver greater depth than multiple cases, their application limits on the generalisation of conclusions drawn. The validity of the case may be restricted to the single case, due to the possibility of biasing the representativeness of observed events.

Data collection method

Associated to the execution of a case study, there is the inherent need of gathering data that will permit to test the method, and operationalize the case study in practice. Several different data-gathering techniques may be used in case studies (Gummesson, 2000; Yin, 1993). An underlying principle in collection of data in case research is that of triangulation, where a combination of different methods is used to study the same phenomenon (Voss et al., 2002). The quality of a case study is enhanced by the use of diverse data sources, including documentation, archival records, interviews, direct observation, participant-observation notes, and physical artefacts (L. A. Curry et al., 2009; Yin, 1993) (see Table 1.2).

Table 1.2. Qualitative data collection methods (L. A. Curry et al., 2009).

Approach	Application/Purpose
In-depth interview (discussion between researchers and participant, driven by participant)	Explore individual experiences and perceptions in rich detail
Focus group (guided discussions among a group of people who share a common characteristic of interest)	Generate unique insights into shared experiences and social norms
Observation (systematic, detailed, observation of people and events to learn about behaviours and interactions in natural settings)	Learn about behaviours and interations in natural settings; examine situations or processes typically hidden from the public; study cultural aspects of a setting or phenomenon
Document review (objective and systematic analysis of written communication to categorize and classify essential concepts)	Identify patterns of communication; analyse traits of individuals; describe characteristics of organisations or processes; make inferences about antecedents and effects of communication

For an in-depth exploration of BI in buyer-supplier dyads, the use of different data collection methods (i.e. data triangulation) was implemented. Due to the multidisciplinary nature of BI, data was collected through the use of interviews, questionnaires, firms' documentation and direct observation. That approach allowed a different observation angle of the different subjects, providing the required richness to the case to understand the nature and the context of interoperability issues raised in the interaction between buyers and suppliers.

Data analysis

The case study application ends with the analysis of data, where the gathered data and obtained results through implementation of the method are analysed and the propositions are verified with the theory that supports them. Data analysis has the objective of obtaining conclusions eliminating alternative justifications (Miles & Huberman, 1994). Data analysis in this thesis accompanies the full procedure since the application of data collection methods, until completion of the proposed method application. This process avoided the gathering of unnecessary data, and permitted to verify its quality for the method application.

Once data is collected, it should be properly documented and coded (Voss et al., 2002). This procedure translates raw data into manageable data, useful for the method testing. Miles & Huberman (1994) (cited by (Voss et al., 2002)) suggests that data is refined through three stages: data reduction, data display and conclusions. In the first, data is restructured or simplified. In data display, the collected data is presented and communicated. Last, the conclusions are drawn based on the displayed data, avoiding alternative explanations refined through data reduction and display stages.

Coding and reduction procedures are used on this thesis. Depending on each BI perspective and the related criteria, a rationale is provided to understand how a certain perspective is represented on the real context of the buyer-supplier dyad, and how that data is used in frameworks and process models. This procedure narrows down other subjective interpretations.

Eisenhardt & Graebner (1989) suggests two analysis perspectives for case studies: analysis within case data, and searching for cross-case patterns. In within-case analysis, the researcher gains familiarity with data and preliminary theory generation. In cross-case pattern search using divergent techniques, investigators are forced to look beyond initial impressions and see evidence thru multiple lenses (Eisenhardt & Graebner, 1989). To draw the final conclusions for the implemented case studies, both within-case and cross-case analyses were implemented.

Case study validity and reliability

During the case study implementation procedure, validity and reliability should be maintained. Those have the following dimensions (Voss et al., 2002; Yin, 1993):

- Construct validity – means that the operational measures used to measure construct actually measure the concepts it intends to measure.
- Internal validity – means that the study measures what is supposed to measure, establishing a causal relationship where certain conditions lead to other conditions, distinguishing them from erroneous data.
- External validity – means that the results can be generalized beyond the immediate case study.
- Reliability – means that the case study operations can be repeated to obtain the same results.

Tactics to ensure validity and reliability are presented in Table 1.3.

Table 1.3. Validity and reliability in case research (Voss et al., 2002; Yin, 1993).

Test	Case study tactic	Phase of research
Construct validity	Use multiple sources of evidence	Data collection
	Establish chain of evidence	Data collection
Internal validity	Do pattern matching or explanation building or time-series analysis	Data analysis
External validity	Use replication logic in multiple case studies	Research design
Reliability	Use case study protocol	Data collection
	Develop case study database	Data collection

To maintain the case studies valid and reliable, in the present thesis were used during the collection phase: multiple data collection methods (interviews, questionnaires, firms' documentation and direct observation), multiple sources, multiple cases using replication logic, a case study protocol explained in the proposed method, and a data recording procedure and database to store collected data.

Research process

Based on the selected research approach, research design, data collection method and data analysis, the research process occurred in the following steps:

1. **Selection of the topic and background research** – The first stage consisted in selecting the key topic of research (the business interoperability field) and performing a thorough literature revision on the subject. Through research in BI, was possible to identify frameworks and models that attempt to identify interoperability problems and solve them. The adequacy of those assets to

address buyer-supplier dyads was verified and, in areas where the BI BoK was insufficient or inadequate to address these dyads (i.e. research gaps), another complementary or analogous areas were selected to permit to understand, model and measure performance of interoperability problems in those dyads.

2. **Formulation of objectives and research questions** – During the research procedure in BI, and in the identified complementary areas, objectives and research questions were established. Those ones were reformulated along the literature revision in order to convey properly the research problem, dealing with the main literature findings and with the research gaps.
3. **Development of the integrated method to analyse and re-design buyer-supplier dyads** – In this stage a method do analyse and re-design buyer-supplier dyads was developed. The method consists in two stages (the determination of interoperability conditions and the optimization procedure) that attempt to answer the RQs.
4. **Design a proof-of-concept** – Prior to the application of the methodology, several application scenarios were designed until obtaining the final method to apply in the industrial environment. The several prototypes (or proofs-of-concept) were produced, representing different stages of development of the final method. Each one was reviewed theoretically with BIXLARGIE project's experts on AD, and through the revision process of submitting publications and oral presentation in conferences. In section 7.1 these application scenarios are briefly described and, in annexes A, B, C and D a copy of each publications referring to each application scenario is provided.
5. **Formulation of case studies** – After the tuning process of developing the proof-of concept, the final method was accomplished and applied on the automotive industry. Four case studies were conducted between a 1st tier and 2nd tier suppliers. Their application was made through a series of interviews, analysis of companies' documentation, direct observation and record of processes and procedures and data retrieval. The case studies are presented in sections 7.3, 7.4, 7.5, 7.6 and 7.7.
6. **Analysis of results** – After obtaining and treating the required data in the proposed method, a result analysis was carried out in individual perspective and in cross-case comparison. Based on the application of these cases, results were discussed with regards to the previously established RQs.
7. **Publish findings** – The several cycles between theoretical researches, practical application and validation generated several outputs in the form of application scenarios and the final method application (case studies). In the accomplishment of each cycle, the different scenarios and case studies have been published.

1.4. Thesis outline

This thesis is divided into eight chapters. Chapter 1 refers to the research setting, chapters 2 to 5 present the literature review on the key topics of research, chapter 6 presents the proposed method and the theoretical propositions, chapters 7 to 8 present the case study application, results, discussion, and conclusions. These are explained further:

- **Chapter 1: Introduction and research method -** describes the research problem, by characterizing existing literature and defining the aim, the objectives and the research approach. This last one comprises the definition of research questions and the methodological approach, where the research approach and research design are defined, as well as the methods to ensure the research validity.
- Literature review is performed in chapters 2 to 5:
  - **Chapter 2: Business interoperability overview –** sets the main theoretical and scientific foundation for this research, addressing the business interoperability topic and the inter-firm relationship where it is addressed (the SCM context and the buyer-supplier dyads). The chapter contains the review of interoperability frameworks, types and criteria and also provides the main SC constructs that govern the buyer-supplier dyad's interaction. Taxonomy of interoperability types and perspectives and a framework is also proposed in this chapter.
  - **Chapter 3: The design of interoperable systems –** presents theory related to industrial design, and how the main topic (BI) is addressed in this setting. The chapter details the existing methods applied in interoperability, and refers to the industrial design methods adequate for the research problem.
  - **Chapter 4: Modelling interoperability –** addresses the methods to model processes in the context of interoperability and supply chains. In this one are reviewed the modelling techniques used to address interoperability problems, the good practices in modelling and modelling of SC operations.
  - **Chapter 5: Measuring interoperability performance –** reviews performance measurement in interoperability and in SCM. In this one, interoperability performance measurement methods are reviewed, providing practices applicable to technical interoperability. Moreover, performance measurement is reviewed in SCM in the context of SC collaboration and buyer-supplier dyads, identifying the good practices in measurement and performance metrics.
- **Chapter 6: The ADADOP method –** presents the proposed method to fulfil the research objectives described in Chapter 1. The chapter presents the theoretical framework that represents the scope of the proposed method to solve the research problem. Then, the method is described in detail, addressing the relevant interoperability perspectives, the SCM constructs and the interoperability criteria required to understand the interoperable buyer-supplier dyads, and the relationship between those constructs. Next, the design, modelling and optimisation procedures are described.
- **Chapter 7: Case studies –** demonstrates the method proposed in the previous chapter through the application scenarios and case studies. Four case studies were conducted in a buyer-supplier dyad operating in the automotive industry, where was possible to test the proposed method in four

different perspectives of the interaction. The chapter ends with the analysis and discussion of results, addressing the main practical findings that will be explored in the conclusions chapter.

- **Chapter 8: Conclusions –** last, Chapter 8 summarizes the main findings in the research, addressing how the research questions were answered, and what were the main contributions. Practical findings are herein put in scope with the research, and some considerations are provided regarding theoretical and managerial implications. The recommendations for future research close the chapter and the thesis.

Chapter 2 - Business Interoperability Overview

Interoperability is a concept rooted in IT, recognized as an ability of systems to interchange data and use it. But, besides being considered as ability, interoperability itself is also considered a problem. This paradigmatic perspective paved way for several interpretations of the subject in different areas of knowledge, from the computer sciences to knowledge and organizational perspectives. Interoperability is a necessity for companies to cooperate in order to establish business relations generating value, but is also seen as a barrier that inhibits them and systems to achieve higher goals, decreasing the value generated. This duality and diversity of the interoperability concept contributed to a very complex, but somewhat unstructured, knowledge area.

The first documented event (of lack) of interoperability is dated 1965, when the US Department of Defence (DoD) detected a "communication fiasco", regarding an incompatibility between air force and army radios (T. C. Ford, Colombi, Graham, & Jacques, 2003). Still, only 25 years later this concept was first defined by (IEEE, 1990) as an ability of systems or components to exchange information and to use the information that has been exchanged. In the beginning, interoperability was merely viewed as technical ability of systems, contributing to the development of the first frameworks and maturity models that ruled interoperability between systems throughout military, governmental, corporate and academic institutions. In early research, provided mostly by the US DoD, Spectrum of Interoperability Model (SoIM) (LaVean, 1980), Quantification of Interoperability Methodology (QoIM) (Mensh, Kite, & Darby, 1998) and Levels of Information Systems Interoperability (LISI) (DoD, 1998) are some of the highlighted references that established the ground for many research and models to come.

Though, first achievements concerned mostly with IT architectures and communication interfaces, contributing for the now known definition of "technical interoperability". The technical perspective is one of many different angles of interoperability. Since its IT origins, interoperability has grown to a wider concept, incorporating knowledge and organisational perspectives. The current vision of interoperability applied to networked organizations is called “business interoperability”, and was defined by (Legner & Wende, 2006) as “an organisational 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”.

Nevertheless, although interoperability is referred as a systems and organizations ability to interoperate, we usually refer to it as a problem or, more commonly, lack of interoperability. On the systems perspective, problems like incompatibility between systems or software, and data formats (syntax and semantics) are some of the examples that are addressed in the technical perspective of interoperability. But if, in one hand, interoperability problems occur when systems fail to properly exchange information and use it, on the other hand, organizational interoperability problems have a different impact. In organizations, interoperability issues arise whenever organisations need to exchange information and work together to achieve common goals. According to (F. B. Vernadat, 2007) modern organizations business must have interoperable business processes and human resources to face the current business challenges. Lack of interoperability at the organizational level is reflected at different levels. In terms of business strategy, lack of goals alignment results in detrimental business relationships. To accomplish that, one must strive to establish win-to-win relationships providing a reciprocal benefit between peers. At relationship management perspective, gap in responsibility generate divergences between partners businesses, leading to independent operating companies working in a networked environment. Process misalignment may result in process incompatibility, needing for an adequate business process modelling and the establishment of adequate collaborative business processes in order to fulfil the partnership goals. All these perspectives are, by definition, supported by IT. IT is the common denominator for every business activity, and interoperability acts as a driving-force, but also, as a barrier to every business interaction. Non symmetric relationships and the Bullwhip effect are some of the consequences of lack of interoperability in organizations (Dassisti, Chen, & Scorziello, 2010).

In the next sections the interoperability definitions, the business context, the existing frameworks and related research, interoperability types and the efforts made to characterize and measure interoperability are approached.

2.1. Defining Interoperability and Business Interoperability

Interoperability has been addressed in different contexts and by different kinds of institutions. For almost every new publication, being it a scientific article or a technical report, a new definition of interoperability is given that conveys the actual vision of the person of the group that performed new research on the subject (Razavi & Aliee, 2009). Throughout literature we can find dozens of definitions, each one of them giving a different perspective on the matter and, also, a different level of detail. In this thesis it isn't presented an exhaustive list and analysis of all the existing definitions. A collection of the relevant definitions was retrieved, according to the objectives and scope of the thesis, and an analysis conveyed the chronologic evolution and the main trends reflected along the time.

As stated in the previous section, the first known definition was given by IEEE, which is stated as follows:

"The ability of two or more systems or components to exchange information and to use the information that has been exchanged" (IEEE, 1990).

This first formal conception of interoperability reflects upon the fact of interoperability being an inherent feature of computer systems when they try to communicate with each other. Since the conception of networks that conveyed information between computer systems or, early on, computer mainframes, interoperability became a concern regarding communication standards and system architectures. The first successful connection between systems were established through the ARPAnet[1] in 1969, used to connect computers between military and research facilities in the United States. This concept of computer networking was later explored, contributing to enterprise networks and, later, the Internet as we know it. Though, the first issues arose regarding systems compatibility. Computer networking was only possible between computer systems of the same OEM[2]. The first discussion to achieve successful interoperation occurred by creating compatible standards of communication, and addressing systems architecture. So, in the early stages of research, interoperability was addressed in this perspective to make possible for computer systems to communicate with each other.

Subsequent issues arose when systems tried to function between them. The definition from (David Chen, Doumeingts, & Vernadat, 2008; F. Vernadat, 1996) extends the earlier definition from a data exchange point of view, to the use of another systems functions. Or, as stated:

"The ability of a system to communicate with peer systems and access their functionality".

Chen et al. (2008) reinforces the idea conveyed by this definition, stating that semantics and application should be so well defined that, when replacing systems with a different manufacturer, all the applications should be able to operate as before the replacement.

Several lines of research are grounded on the technical perspective of interoperability portrayed in earlier definitions. Inside them, the following interoperability types are addressed: syntactic, semantic, pragmatic, services, software and systems, objects, electronic identity, applications, programmatic, cloud, constructive interoperability, etc. These are some of the found examples in literature. In section 2.4 the relevant types are detailed.

During the research performed by (DoD, 1998) that led to the "Levels of Information System Interoperability (LISI)", an interoperability definition was proposed:

"The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together."

Although this one was stated on a military perspective, the message it transmits is relevant due to incorporating not only the technical perspective ("systems"), but also organizational ("forces") and human ("units") perspectives. These were pillars for subsequent research in interoperability. Although the work from (DoD, 1998) was seen from a technical perspective, the presence of this factors in this vision inspired the Organisational Interoperability Maturity Model (OIM) (Clark, Jones, Jones, & Pty,

[1] ARPAnet - Advanced Research Projects Agency Network created by the US DoD.

[2] OEM – Original Equipment Manufacturer.

1999), that complemented LISI with organisational aspects of interoperability. The organisational and knowledge became a trend for researchers that approached interoperability beyond the technical perspective. In the works Organisational Interoperability Maturity Model (OIM) (Clark et al., 1999), IDEAS interoperability framework (IDEAS, 2003), enterprise interoperability maturity model (ATHENA, 2005), Business Interoperability Framework (ATHENA, 2007a) and INTEROP framework (David Chen, Doumeingts, et al., 2008), the non-technical interoperability aspects were the basis for achievements that contributed to the vision of business interoperability (BI), in its current perspective. The definition that fits the complete scope of BI is one of the earliest given by (Legner & Wende, 2006):

"The organisational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business with the objective to create value."

This is the vision that is comprised in this thesis. BI is present in every electronic-based business, in the context of direct interactions and in the context of complexly integrated networked environments. On the same way IT is what enables and, in part, constrains IT businesses, BI refers to organizational and knowledge assets that rule, and may also constrain, business relationships. Cooperation goals alignment by establishment of contracts, service level agreements, business process alignment, semantic agreements and message content and structure are some of the aspects that BI as to deal (Legner & Lebreton, 2007). These ones will be addressed lately in sections 2.4 and 2.6.

BI is closely related to integration (Guo, 2008). Integration technology can be defined as any type of IT technologies that enable business information exchange between businesses (Guo, 2008). They connect interfaces between heterogeneous systems using interconnection technologies (NEHTA, 2005). Though, integration refers more to provide better business information exchange systems (Guo, 2008). In counterpart, BI is a state of readiness for organisational and technical compatibility leading to integration outcomes (Guo, 2008). One can affirm that two integrated systems are interoperable, but two interoperable systems are not necessarily integrated (David Chen, Doumeingts, et al., 2008).

Like in the case of the concept of interoperability itself, BI can be view in two different perspectives. One can look at BI from a technical perspective and from a business perspective. The referred definition by (Legner & Wende, 2006) stresses on an unified perspective of BI referring to technical and business levels of interoperability. Still, a purely business level perspective is given by (Guo, 2007):

"The business interoperability that can be defined as the capability of business collaboration between business partners for the fulfilment of certain business functions at certain cost and efficiency".

This definition almost strips the inherent use of IT for electronic businesses, and looks forward the achievement of business functions at a cost and efficiency, though these ones depend on IT, but focuses on organisational issues that is given priority to solve BI problems at business levels. Looking at this perspective, two different approaches to BI could be admissible: integrated and focused. The integrated perspective of BI, should deal with every aspect that may compose BI. For instance, to achieve successful business interoperation, one should solve the technical aspects, then the subsequent aspects regarding knowledge and organisation in order to achieve BI. In counterpart, in a focused perspective, one can look only to the organisational perspective of interoperability and assume that the technical part is interoperable or, at least, functional to support the main business processes. This thesis aims at an integrated perspective of BI, like is defined by (Legner & Wende, 2006). Still, being a thesis on Industrial Engineering and not on Computer Sciences, some limitations exist approaching technical aspects of interoperability. Some assumptions and qualitative assessments will be presented on the next sections that serve to compliment the integrated approach of BI.

Another subject close to BI, is Enterprise Interoperability (EI). Enterprise interoperability is concerned with interoperability between organisational units or business processes either within a large (distributed) enterprise or within an enterprise network (F. B. Vernadat, 2007). It is a concept close to integration or enterprise integration (Kotzé & Neaga, 2010), which can be either vertical or horizontal, and full, loose or tightly coupled. Enterprise interoperability aims at tying loose integration, providing two or more business entities (of the same organization or from different organizations and irrespective of their location) with the ability of exchanging or sharing information (wherever it is and at any time) and using functionality of one another in a distributed and heterogeneous environment (F. B. Vernadat, 2010). The main distinction between EI and BI is the focus of each discipline. Although both act beneath an organisational perspective, EI focus technical aspects of the organisations, and BI goes beyond that vision, and addresses also non-technical issues (Kotzé & Neaga, 2010).

2.2. Inter-firm relationships

Business interoperability (BI) describes the relationships between an enterprise and its business partners, such as customers, suppliers or external service providers (ATHENA, 2007a). The focus of this thesis is the buyer-supplier relationships operating in the context of supply chain management (SCM) – buyer-supplier dyad. Though, to study BI one must understand the nature and the context of the business itself where a dyad may belong. Österle, Fleisch, & Alt (2001) distinguish four main operative coordination areas (see Figure 2.1): SCM, innovation, relationship management and infrastructure.

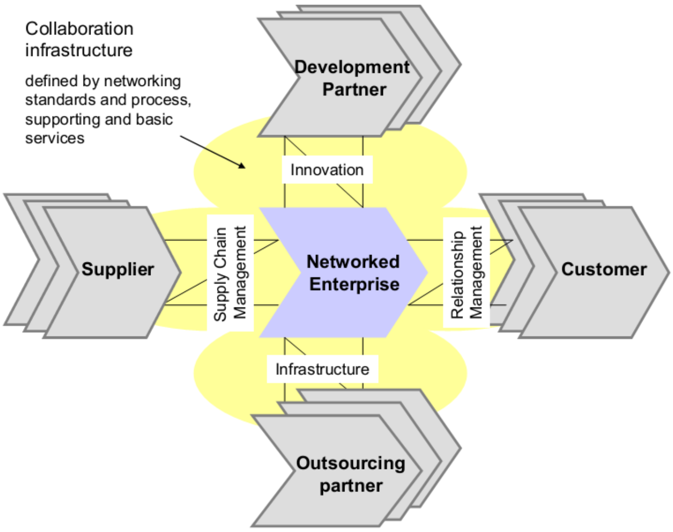


Figure 2.1. The networked enterprise (ATHENA, 2007a).

Networked companies may fall in most of these four coordination areas, depending on the relationship one company has to another. For each relationship context, the features that compose a business relationship are different, and so are the main objectives towards the partner:

- SCM relies on deep integration of suppliers and customers, to ease the flow of materials, components and products depending on operative planning and processes executed as efficiently as possible.
- Relationship management aims at getting customers and/or suppliers, and maintain relationships.
- The coordination area innovation aims at the rapid creation of new products, which requires a dynamic environment in the early phases. This coordination mechanism is often coordinated with SCM. Early phases of development of a new product, a customer (OEM or focal firm) needs to interact in a dynamic environment with a supplier or development partner to achieve initial prototypes and first versions of a finished product or component. As a project matures, the need for interaction for the innovation collaboration is reduced and triggers new coordination area phases from the types established above.
- The infrastructure coordination area is related to the 3rd party services, logistics and infrastructures providers. For instance, the use of datacentres to process financial data from a company, the outsourcing of freight forwarding logistics or IT, and the renting of infrastructures or subcontract of employees, are some of the examples of the aspects dealt with in this coordination area. Depending on the contracted service, the interaction and integration may be low or high, representing a challenge to address interoperability in this matter.

Chen & Doumeingts (2003) affirm that one of the trends in the global market is the increasing collaboration among enterprises during the entire product life cycle. Approaching SCM in a BI context means that one may be dealing with different stages of a collaboration life-cycle (Wulan & Petrovic, 2012a): pre-creation, creation, operation and termination. The four coordination areas provide a useful manner to break down business relationships, without neglecting the interdependencies of the delimited areas (ATHENA, 2007a), keeping also the context of relationship duration and the service or product life-cycle.

In this thesis SCM relationships are addressed in current daily operation conditions. SCM and relationship management are the two main featured coordination areas, although references may be made to innovation and infrastructure contexts. The addressed product or service exchange between partners is considered on the operation stage of development, flowing in a steady state on the SC. Also, termination phase of relationship is not approached, though will be addressed in dealing with relationship management measures.

2.2.1. Business networks and dyads

The concepts of business networks and dyads were introduced in 1970's as a marketing area of inter-firm relationships. Emerson (1981) defines business network as a set of two or more connected business relationships, in which, each exchange relation is between business firms that are conceptualized as collective actors. A complex business market can be seen as a network where the nodes are business units — manufacturing and service companies and the relationships between them are the threads. Each node or business unit, with its unique technical and human resources is bound together with many others in a variety of different ways through its relationships (Håkansson & Ford, 2002).

Though, dyadic relationships can be both directly and indirectly connected with other relationships that have some bearing on them, as part of a larger business network (D. Ford, 2002). If company A is a supplier and B and C are two customers, then any development between company A and customer B will have a negative or positive effect on its relationship with the other customer C (Håkansson & Ford, 2002). Anderson, Håkansson, & Johanson (1994) distinguishes two primary functions of the dyad interaction: primary and secondary. The primary function is related with positive and negative effects of their interaction in a focal dyadic relationship. Activities, actors and resources are the three main components that characterize the function of business relationships (D. Ford, 2002). The primary function states that these three components are efficiency through interconnecting activities, creative leveraging of resource heterogeneity and mutuality based on self-interest of actors. This may result in improved combined efficiency, in terms of activities (Frazier, Spekman, & O'neal, 1988; Håkansson, Havila, & Pedersen, 1999) and resource use (Lundvall, 1985 cited by (Anderson, Håkansson, & Johanson, 1994)), and increased benefits for both actors ((Axelrod, 1984; Kelley and Thibaut, 1978) cited by (Anderson, Håkansson, & Johanson, 1994)).

Secondary functions - or network functions - comprehend the indirect positive and negative effects of a relationship because it is directly or indirectly connected to other relationships. They are caused by the existence of connections between relationships (see Figure 2.2). The network functions concern chains of activities involving more than two firms, constellations of resources controlled by more than two firms, and shared network perceptions by more than two firms.

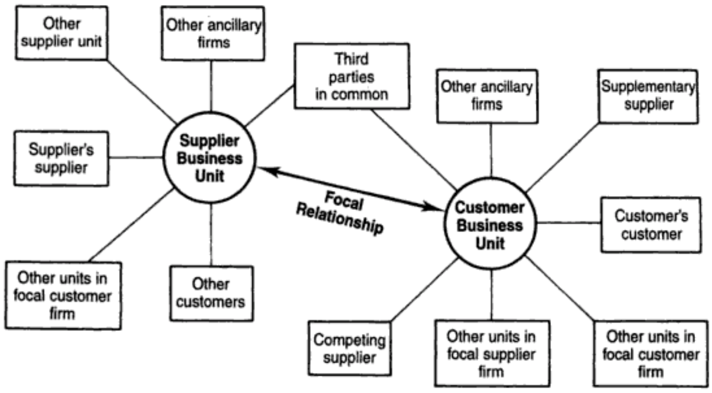


Figure 2.2. Relationships above and below a focal dyadic relationship (Anderson et al., 1994).

Networked organizations are characterized by distributed control, inter-organizational business processes, various producer–consumer supply chains, and shared information and knowledge (F. B. Vernadat, 2007). The basic unit of a business relationship is always a dyad, but the existence of the secondary functions means that a dyad is also part of a network (Anderson et al., 1994). A dyad shares the same functions of a network, but its affected by the primary and secondary functions of the relationship. In this thesis business relationships are addressed on its simplest form: dyad. It was built on the notion of the primary functions of business relationships, considering direct impact of actors on one another. The network effect is not studied, though it is accepted the actors on the case studies (Chapter 8) to share some of the principles that rule the network they're inserted on.

2.2.2. Supply chain management and buyer-supplier dyads

In the context of SCs and SCM, interoperability is being seen as a strong asset to achieve competitivity (Blanc, Ducq, & Vallespir, 2007). The particular case of BI looks at different perspectives, which comply with SCM. As so, SCM has been approached in several perspectives (Tan, 2001). At a wide scope, SCM focuses on how a firm uses processes, technology and capability to enhance competitive advantage (Choon Tan, 2001; Farley, 1997). More specifically, it relies on a precise allocation of resources that manage economies of scale, reduce redundant and duplicate operations, and increases the customer loyalty through a personalized service (Bowersox, Closs, & Stank, 2003). In this sense, SCM may be seen in two perspectives: internal and external. Accordingly, Harland (1996) defends that, internally, SCM focuses in assets within an organisation, and externally, in establishing relationships with first and second-tier suppliers, customers and the entire SC. On the internal perspective, Gunasekaran (2004) emphasizes the integration of all activities that add value to customers, since product development to design. Internal integration is thus defended as a measure to enhance the flow of goods from immediate strategic suppliers through manufacturing and distribution chain to the end user (Houlihan, 1988; Tan, 2001). In counterpart, the collaborative perspective of SCM looks at a set of approaches to efficiently integrate suppliers, manufacturers, warehouse, and stores, so that merchandise is produced and distributed at right quantities, to right locations, and at the right time, in order to minimize system wide cost while satisfying the service level requirements (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008). In this vision, SC's activities include forward flows, such as planning, product design and development, sourcing, manufacturing, fabrication, assembly, transportation, warehousing, distribution, post delivery customer support, as well as reverse flows, through recycling or re-use (see Figure 2.3).

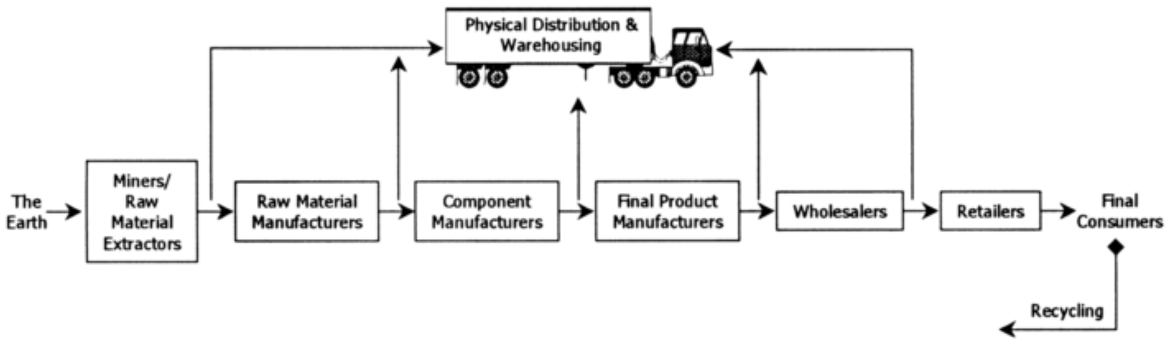


Figure 2.3. Activities and firms in supply chains (New & Payne, 1995; Tan, 2001).

Cooperation in SC's firms is also approached in two different visions: SC collaboration (SCC) and SC integration (SCI). SCI relies on central control, ownership, or process integration governed by contract means, while SCC puts more emphasis on governance through relational means (Cao & Zhang, 2011; Nyaga, Whipple, & Lynch, 2010). The interoperability and BI perspectives act according to the collaborative perspective of SC. Mutual benefits and win-win mechanisms are the main driving force for SCC and interoperability, which allow cooperating companies to be competitive as a whole.

Collaboration in SCs is shaped in the interactions: dyadic, horizontal, lateral, market and hierarchy-oriented (Otto & Kotzab, 2003). The simplest form of interaction in SC is a dyad. A dyad is one of many possible links in the chain (Cordon & Vollmann, 2005; Cordon, Vollmann, & Hald, 2005), and each one of them is unique characterized by a set of human resources and technical capabilities (Håkansson & Ford, 2002). In SCs two dyads are distinguished (see Figure 2.4): buyer-supplier and customer-seller dyads. Mondini, Machado, & Scarpin (2014) stresses the importance of strategic relationship between buyers and suppliers. Buyer-supplier dyads are, hence, distinguished as one of the utmost importance to effective management of SC (I. J. Chen & Paulraj, 2004).

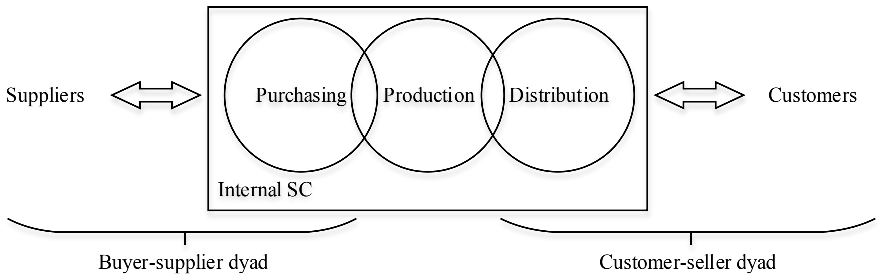


Figure 2.4. Dyads in a supply chain (adapted from (I. J. Chen & Paulraj, 2004)).

The dyadic and network approaches are advocated by the relational view theory (Dyer & Singh, 1998). These collaborative relationships are seen as unit of analysis in opposition to another relational theories such as resource-based view (RBV) (Wernerfelt, 1984) and industry structure view (Porter, 1980). RBV (Wernerfelt, 1984), transaction cost economics (TCE) (Williamson, 1989), relational view (Dyer & Singh, 1998), extended resource-based view (Lavie, 2006), relational governance theory (Zaheer & Venkatraman, 1995) and social exchange theory (Emerson, 1981) are the main theories in which SC collaboration is built towards the vision of "collaborative advantage" defended by (I. J. Chen & Paulraj, 2004; Contractor & Lorange, 1988; Dyer & Hatch, 2006; Nielsen & Nielsen, 1988). This one, in turn, comes in opposition to competitive advantage, defined by Porter (1998) as the extent to which organisations are able to create a defensible position over its competitors. Contrasting this vision, 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). Forrester (1958) defends that confrontation in links of SC without alignment, synchronization and cooperation, often results in inefficiencies, redundant operations without value added for end-customer that, in turn, can lead to unpredictable demand and the Bullwhip effect. Shang, Li, & Tadikamalla (2004) reinforce the idea that members in the chain have to team up and define clearly how to cooperate to maximize the overall SC performance. 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 notion of collaborative advantage establishes common grounds between SCC and BI literature. More specifically, literature in buyer-supplier dyads set the strategic aim of these relationships towards win-win situations supported by partners collaboration and, ultimately, achieve synergies to compete with other chains (Paulraj, Chen, & Flynn, 2006). Authors in this area focus on SCM constructs or practices that allow achieving better performance individually, on buyer and supplier perspective, and on the dyad. Table 2.1 presents the collected practices from buyer-supplier literature.

At a strategic level, buyer-supplier literature refers to mutual benefits, strategy alignment, contractual clauses, incentive alignment and buyer-supplier financing alignment as practices for effective collaboration (Cao & Zhang, 2011; I. J. Chen & Paulraj, 2004; Paulraj et al., 2008; Wandfluh et al., 2015). Aligned with those, strategic sourcing is addressed by authors (Carr & Pearson, 2002; De Toni, 1999; Mondini et al., 2014; Yeung et al., 2015). This practice comes in orientation with the need to achieve beneficial relationships, promoting open communication between suppliers and buyers (I. J. Chen & Paulraj, 2004; Yeung et al., 2015).

On the relationship management perspective, I. J. Chen & Paulraj (2004) refer to reduction of supplier-base, supplier involvement and the creation of cross-functional teams. These ones make part of the management of long-term relationships between buyer and suppliers, where a larger volume of business is placed in limited number of strategic suppliers (Hahn, Pinto, & Brag, 1983; Shin et al., 2000). Still, additionally, strategic sourcing leads to the need for supplier evaluations systems (Yeung et al., 2015). Strategic alliances are a result of the articulation of effective supplier selection as well as adequate power distribution to go beyond contractual issues, setting an environment of cooperation (Mondini et al., 2014). Resources of effective collaboration include monitoring, supplier involvement, cross-functional teams, joint relationship effort, trust and resource sharing (see references in Table 2.1). Those refer to activities that promote interaction between buyer and supplier. Cannon et al. (2010) also includes cultural issues as a conditioning factor that has impact in buyer's long-term orientation.

Table 2.1. SCM practices and constructs that support buyer-supplier relationships.

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

References: [1] - (Cao & Zhang, 2011); [2] - (Wandfluh, Hofmann, & Schoensleben, 2015); [3] - (Terpend, Tyler, Krause, & Handfield, 2008); [4] - (Nyaga et al., 2010); [5] - (Paulraj, Lado, & Chen, 2008); [6] - (I. J. Chen & Paulraj, 2004); [7] - (Mondini et al., 2014); [8] - (Yeung, Cheng, & Lee, 2015); [9] - (Carr & Pearson, 2002); [10] - (De Toni, 1999); [11] - (Prahinski & Benton, 2004); [12] - (Shin, Collier, & Wilson, 2000); [13] - (Cannon, Doney, Mullen, & Petersen, 2010); [14] - (Benton & Maloni, 2005); [15] - (Villena, H., Revilla, & Choi, 2011); [16] - (Hald, Cordón, & Vollmann, 2009); [17] - (Cheung, Myers, & Mentzer, 2008).

Knowledge in cooperation is addressed in terms of joint knowledge creation (Cao & Zhang, 2011) and knowledge sharing (Cheung et al., 2008; Terpend et al., 2008).

The information perspective of buyer-supplier interaction is promoted by the collaborative communication and information sharing practices (see references in Table 2.1).

The presented collaborative practices share similarities with the interoperability types and criteria, addressed in sections 2.4 and 2.6. Though, the literature regarding buyer-supplier dyads only refer to the perspective of collaboration and practices that allow achieving higher performance, in terms of dyad and individual performance, as well as financial, operational, quality perspectives and in terms of value creation. Formal approaches regarding processes, material and information flows between buyer-suppliers are missing, together with the IT that supports SC activities. 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.

2.3. Interoperability frameworks and related work

Interoperability frameworks and models became a pillar for sustainable interoperability setting between companies. They provide means to characterize problems and solutions (M. S. Camara, Ducq, & Dupas, 2013). At some extent, these frameworks provide the main drivers for companies' interaction and different perspectives of the subject. These ones allow to identify the main requirements for electronic-based business set up, qualify and quantify interoperability and means to achieve interoperable solutions, either by problem identification or modelling. Also, 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 (F. B. Vernadat, 2010). As a result, the interoperability frameworks vary significantly in the way they address interoperability issues (Rezaei, Chiew, Lee, & Shams Aliee, 2013). This occurs, mostly, due to technological evolution and also the awareness to interoperability problems affecting subsequent structures of business interaction. That is remarked in earlier frameworks that address IT architectures and interfaces of communication (Legner & Lebreton, 2007), and subsequent framework begun to incorporate business areas such as organisational and knowledge issues (e.g. (ATHENA, 2007a; IDEAS, 2003)), as well as recent tendencies in IT like cloud interoperability, social networks interoperability and ecosystems interoperability (Rezaei et al., 2013). These are some of the examples that demarcate the earlier and recent scientific publications in interoperability and business interoperability.

In this section the frameworks and relevant models that support BI, as well as the ones that provide means to analyse, model, assess and re-design SC dyads are portrayed. In order to contextualize them, they are presented in an evolutionary context, reflecting the main features and contributions, and where a new framework complemented the prior vision, but also, when a new approach was provided.

2.3.1. Levels of Information Systems Interoperability (LISI)

The Levels of Information Systems Interoperability (LISI) (DoD, 1998) is a procedure developed by the US DoD applied in the US military. Strongly based on the prior frameworks Spectrum of Interoperability Model (SoIM) (LaVean, 1980) and Quantification of Interoperability Methodology (QoIM) (Mensh et al., 1998), LISI makes use of the following attributes of these frameworks: the representation of interoperability in levels (T. Ford, 2008); the measurement of interoperability; and necessary components as languages, standards, environment, procedures, requirements, human factors, and media (Rezaei et al., 2013).

LISI focuses on the increasing levels of sophistication of systems (Morris, Levine, Myers, Place, & Plakosh, 2004), through the LISI "Maturity Model". Each level recommends the capabilities that should cover the enabling attributes known as PAID (David Chen, Doumeingts, et al., 2008): procedures (P); application (A); infrastructure (I); and data (D). The LISI Reference Model (see Figure 2.5) describes, in broad terms, the intersections of the levels defined in the interoperability maturity model and the PAID attributes that define the composition and makeup of each level (DoD, 1998). The identification of PAID capabilities, using the "capabilities model", permits to generate an "interoperability profile" assessed in three metrics: generic, expected and specific.

Description	*Computing Environment*	*Level*	**P**	**A**	**I**	**D**
Enterprise	Universal	4	Enterprise Level	Interactive	Multi-Dimensional Topologies	Enterprise Model
Domain	Integrated	3	Domain Level	Groupware	World-wide Networks	Domain Model
Functional	Distributed	2	Program Level	Desktop Automatior	Local Networks	Program Model
Connected	Peer-to-Peer	1	Local/Site Level	Standard System Drivers	Simple Connection	Local
Isolated	Manual	0	Access Control	N/A	Independen	Private

Figure 2.5. LISI reference model (David Chen, Doumeingts, et al., 2008; DoD, 1998).

All sums up in a procedure for defining, measuring, assessing, and certifying the degree of interoperability required or achieved by and between organizations or systems (Rezaei et al., 2013). It allows defining the set of characteristics required for exchanging information and services at each level, and defines a process that leads to interoperability profiles and other products (Morris et al., 2004). Also provides the common vocabulary and structure needed to discuss interoperability between systems (David Chen, Doumeingts, et al., 2008). In addition, as stated by (DoD, 1998), the model can be used "as a guide to develop and improve a system's general capability to interoperate with other systems without predefined or formal sets of requirements necessarily established between them".

The main feature to retain from this framework is the assessment philosophy of combining maturity levels with the attributes of the system. Addressing interoperability can be a complex and time-consuming task, and a combined model such as LISI reference model permits to put in scale the maturity of the system and the scenario on which the first one was valid. Interoperability depends of several factors and contexts, and crossing different perspectives of interoperability may contribute to scoping the interoperability problem and to identify the interoperability needs.

The establishment of an "interoperability profile" is another characteristic of LISI. It allows determining the interoperability setting of a system towards another.

Last, the assessment process in the metrics generic, expected and special, allows mapping the system evolution between the existing and the ideal scenario, which maybe the optimal interoperability or the sufficient degree of interoperability for the system. This vision contributed to the "as-is" to "to-be" benchmarking portrayed in subsequent frameworks and models (e.g. (ATHENA, 2007a; M. S. Camara et al., 2013)).

2.3.2. Organisational Interoperability Maturity Model (OIM)

Although LISI provides a framework focusing on technical interoperability and the complexity of interoperations between systems, it does not address the environmental and organizational issues (Morris et al., 2004). Having this in consideration, Clark et al. (1999) developed the Organisational Interoperability Maturity Model (OIM) that complements LISI (see Figure 2.6) with layers of command and control support, proposing five levels of organisational maturity: level 0 – independent; level 1 – ad hoc; level 2 – collaborative ; level 3 – integrated (or combined); and level 4 – unified. They establish the range between independent companies, whereas no framework for interaction has taken place and without objectives alignment; to unified, where the organisational goals, values, command structure/style, and knowledge bases are shared across the system (Clark et al., 1999).

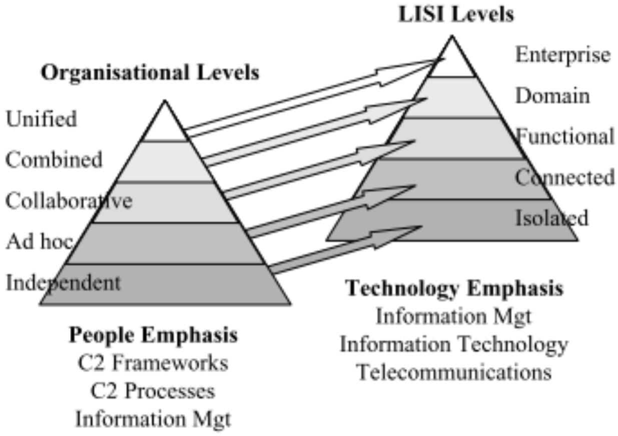


Figure 2.6. Alignment between Organisational Model and LISI (Clark et al., 1999).

The vision portrayed in the (DoD, 1998) interoperability definition (see section 2.1) is that interoperability regards the technical ("systems"), organizational ("forces") and human ("units") perspectives. Though, this is not completely achieved by LISI. LISI approaches the technical aspect of interoperability and, in counterpart, OIM addresses the human and organizational aspects of interoperability in military operations (Rezaei et al., 2013). Just as LISI provided PAID attributes (see section 2.3.1) for systems interoperability, OIM provides four attributes of organisational interoperability (T. C. Ford et al., 2003): preparedness (training, experience, and doctrine); understanding (measurement of the amount of communication and sharing of information and knowledge in the organization and how information is used); command and coordination (management and command style of the organization, decisions, roles and responsibilities assignment), and ethos (goals and aspiration of the organization, value systems of the organization, level of trust). These reflect upon key areas in BI: preparedness contributes to organisational and human resources knowledge, training, experience and responsibility; understanding regards data and knowledge interoperability, regarding knowledge and information sharing and data utility (or use); command and coordination reflects on strategic assets of organisations; and ethos, acts as the socio-cultural characteristics of organisations and from the external environment. The organisational interoperability reference model correlates these attributes with the levels of organisational interoperability (see Figure 2.7).

	Preparedness	Understanding	Command Style	Ethos
Unified	Complete - normal day-to-day working	Shared	Homogeneous	Uniform
Combined	Detailed doctrine and experience in using it	Shared comms and shared knowledge	One chain of command and interaction with home org	Shared ethos but with influence from home org
Collaborative	General doctrine in place and some experience	Shared comms and shared knowledge about specific topics	Separate reporting lines of responsibility overlaid with a single command chain	Shared purpose; goals, value system significantly influenced by home org
Ad hoc	General guidelines	Electronic comms and shared information	Separate reporting lines of responsibility	Shared purpose
Independent	No preparedness	Communication via phone etc	No interaction	Limited shared purpose

Figure 2.7. Organizational interoperability reference model (Clark et al., 1999).

In sum, LISI combined with OIM, provide a high level (low detail) vision of interoperability problems regarding organisational, knowledge and technical interoperability perspectives. Being built on the same perspective as LISI, correlating two different factors, OIM allows one to assess qualitatively interoperability and may contribute to trace interoperability profiles of dyads. Though, the model lacks the study of a cause-effect analysis, gauging organisational interoperability is just one start to provide solutions for the problem. But, although a detailed plan can be obtained to improve interoperability, the model does not provide the means to study the effect of interoperability, and if, in fact, higher levels of maturity are better or worse for a specific dyad setting. Though, it aids in establishing requirements for business scale-up.

2.3.3. Interoperability Assessment Methodology (IAM)

Concurrently to the development of LISI, Leite (1998) introduced the interoperability assessment methodology (IAM) that provided a methodology to assess qualitative and quantitatively interoperability in systems (see Figure 2.8).

IAM proposes seven qualitative measures as "degrees of interconnection", which are connectivity, availability, interpretation, understanding, utility, execution, and feedback (T. C. Ford et al., 2003). These measures are presented as levels, which intend to achieve interoperability as a progression of steps in a ladder (Leite, 1998). They provide some valuable insights at technical and data interoperability perspectives. Connectivity, availability, execution and feedback address the ability to communicate between systems (and users), admitting that they are available to receive information and give the due feedback. Interpretation and understanding reflect the quality and compatibility of the exchanged data.

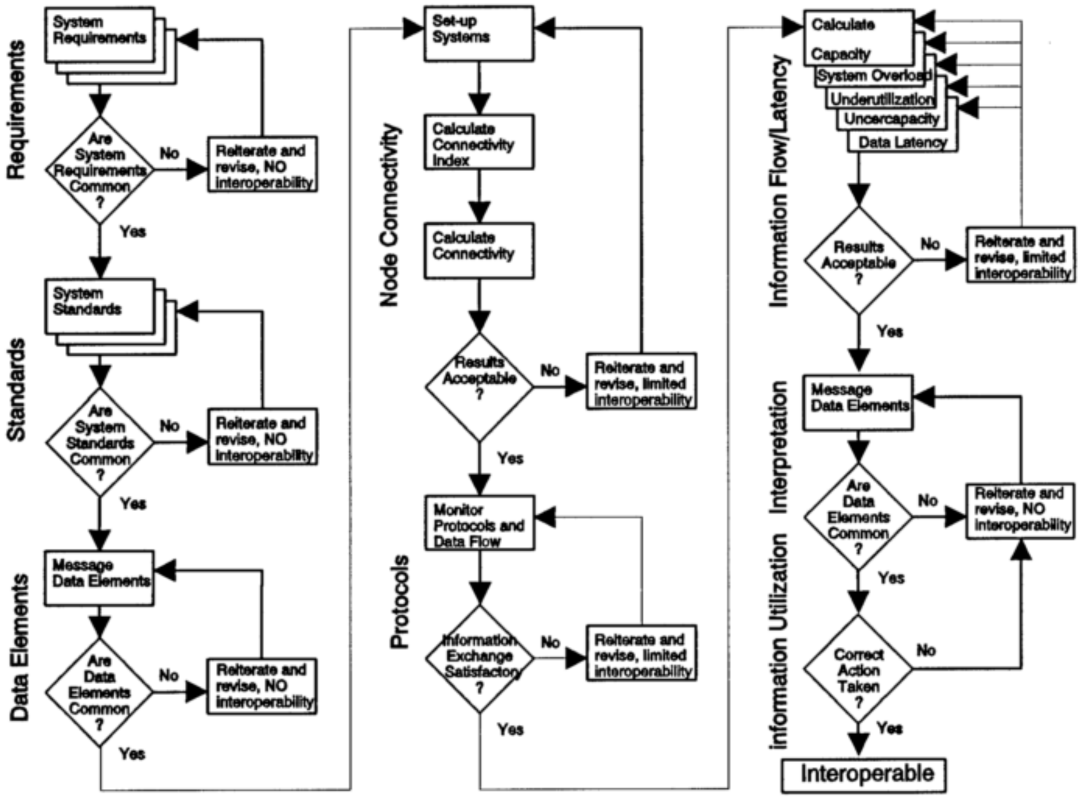


Figure 2.8. Interoperability assessment process (Leite, 1998).

IAM also proposes nine components, which feature the main assets of a system, and should be common between two interacting systems. The "interoperability components" are provided in a sequence of checklists to verify requirements, standards, data elements, protocols, information utilization and interpretation; and quantitative measures that reflect the performance of the system and the ability to communicate and the data quality:

- Node connectivity is a function that quantifies the ability to send and receive data at any time (Leite, 1998). Two measures are proposed to evaluate the connectivity between nodes: connectivity index and node connectivity.
- Information flow is a proposed measurement that (Leite, 1998) sub-divides in: capacity, system overload, underutilization and undercapacity. The capacity of a system is the rate at which data may be passed over time (Kasunic, 2001).
- A system overload occurs when more data must be exchanged than the system is able to transmit (Kasunic, 2001).
- System underutilization occurs when the system data rate/message load is less than its full capacity but messages are waiting in queues to be transmitted (Kasunic, 2001).
- System undercapacity occurs when messages remain in queues and the system data rate is at the maximum (Kasunic, 2001).

- Data latency is the elapsed time from the time of the event to the time of receipt by the user (tactical data processor) (Kasunic, 2001).

IAM has the novelty of proposing actual tangible metrics that permit to infer about the systems interoperability. Also, the proposed qualitative attributes and checklists provide requirements for systems. Though, like in case of LISI, this portrays only a technical part in interoperability, while contributed to earliest performance measures for interoperability.

2.3.4. Layers of coalition interoperability (LCI)

The Layers of coalition interoperability (LCI), developed by (Tolk, 2003b), introduced a low level (high detail) framework when compared with LISI and OIM. Nine layers of interoperability are proposed by LCI, and shows through his reference model that there is a continuum between technical interoperability and operational interoperability rather than a distinct breakpoint between the two (T. C. Ford et al., 2003) (see Figure 2.9). The four levels from the bottom (physical, protocol, data/object model and information interoperability) reflect a more detailed vision of the technical aspects of interoperability. The top four levels (political objectives, harmonized strategy/doctrines, aligned operations and aligned procedures) reflect the organisational interoperability aspects, related with strategy and process interoperability. In the middle, the knowledge/awareness level provides a transition between technical interoperability and organizational interoperability (Morris et al., 2004).

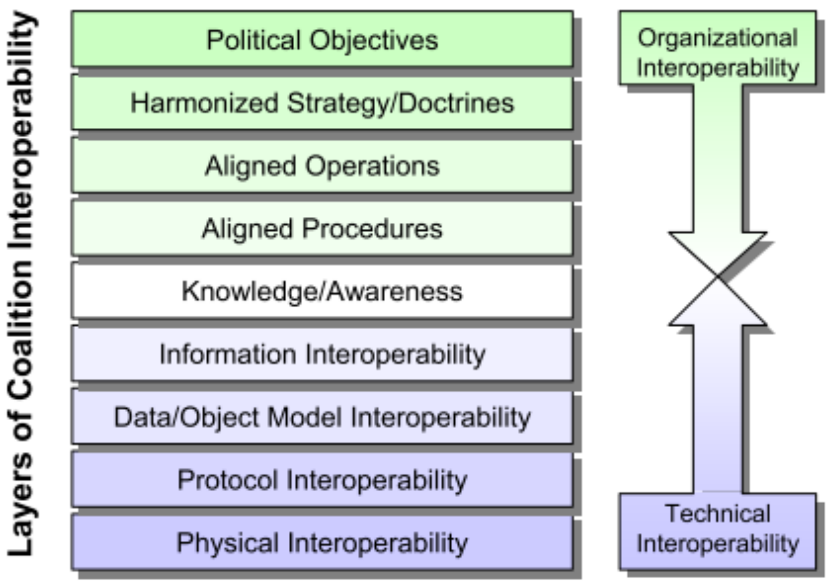


Figure 2.9. Layers of coalition interoperability (Tolk, 2003b).

Though this model was presented in its earliest stages of development, like was stated by Morris et al. (2004), it gave valuable insights to facilitate discussion on technical and organizational (political and military) support required for interoperable solutions.

2.3.5. The IDEAS framework

The IDEAS interoperability framework (IDEAS, 2003) extended the concepts of interoperability to the business perspective. They defend that, in order to achieve meaningful interoperation between enterprises, interoperability must be achieved on all layers of an enterprise (David Chen & Doumeingts, 2003). Hence, IDEAS (2003) defines three main layers (Business, Knowledge and ICT) with two additional vertical dimensions (Semantics and Quality attributes) (David Chen & Daclin, 2007) (see Figure 2.10).

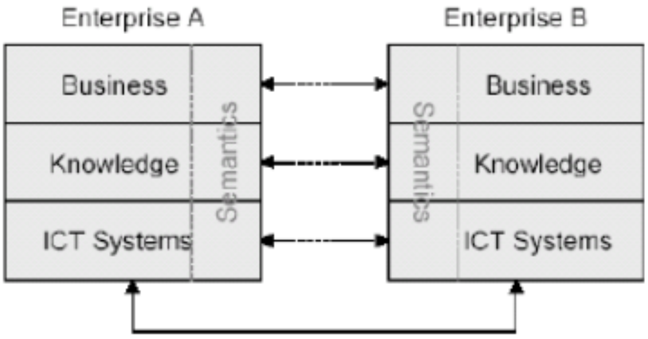


Figure 2.10. IDEAS interoperability framework (ATHENA, 2007a; Blanc et al., 2007; IDEAS, 2003).

On a business-centred perspective, interoperability should be seen as the organizational and operation ability of enterprises to cooperate with other enterprises (David Chen, Doumeingts, et al., 2008). Though this cooperation is inherently supported by IT, (IDEAS, 2003) layered perspective allows one to look at each perspective independently. On the top business layer, companies environment issues are addressed: decisional model, business model and business processes (ATHENA, 2007a). The decisional model of an enterprise defines the taken decisions and the degree of responsibility of each operating unit, role and position. The business model is the description of the commercial relationships between an enterprise and the way it offers products or services to the market. Business processes are the set of activities that deliver value to one's customers (David Chen, Doumeingts, et al., 2008).

On the knowledge layer, (IDEAS, 2003) distinguishes internal and external knowledge, and the compatibility of knowledge as the main attributes. Internal knowledge is perceived as the companies' knowledge assets such as products (e.g. IPR[3]) and employees (e.g. roles, skills/competencies, experience, etc.) and its ability to gather, structure and represent the collective and individual knowledge of an enterprise. External knowledge relates with how companies manage the relationship with suppliers/partners, and also the laws and regulations, legal obligations and relationships with public institutions. The compatibility of knowledge occurs when internal companies' knowledge is

[3] IPR – Intellectual property rights

confronted. Companies need to struggle towards compatibility of skills, competencies and knowledge assets with business partners (David Chen, Doumeingts, et al., 2008).

Interoperability at ICT systems level should be seen as the ability of an enterprise's ICT systems to cooperate with those of other external organizations (David Chen, Doumeingts, et al., 2008). ICT supports every business activities taken place inside and outside companies' boundaries. This layer includes various areas such as solution management (tools and procedures required to administer an enterprise system), workplace interaction (user interaction with the system), application logic (computation carried out by an enterprise system to achieve a business result), process logic (steps in which an application is carried out) and data logic (required data by an enterprise system during its lifecycle) (David Chen, Doumeingts, et al., 2008).

Transversal to the three enounced layers, the sematic dimension of IDEAS framework is concerned with capturing and representing the actual meaning of concepts towards a mutual understanding (ATHENA, 2007a).

Last, the quality attributes are inherent to the ICT systems, but may be transversal to all the layers of IDEAS framework. They include: security (data storage, transfer and protection etc.); scalability; portability (both data and applications); performance; availability and evolution (David Chen, Doumeingts, et al., 2008).

Though one could look at each layer as an individual perspective of interoperability, there are always areas that will depend, reciprocally, on each other. D. Chen et al. (2008) conveys this idea, stating that the execution of the enterprise application is orchestrated by the business process model identified in the top layer and formally represented and stored in the knowledge layer. This idea is also portrayed in LCI, where the knowledge layer is where organizational (business layer) and technical (ICT systems) issues meet. Some attributes may be executively from a specific type of interoperability, but there may be some interface between layers and transversal aspects that cross every layer. The IDEAS framework portrays this notion adequately by addressing semantics and quality attributes as shared assets between layers.

2.3.6. European Interoperability Framework (EIF)

The European interoperability framework (EIF) (IDABC, 2010) was developed to support the EU[4] member states in providing user-centred e-Government services by facilitating the interoperability of services and systems between public administrations, as well as between administrations and the public (citizens and businesses) (David Chen, Doumeingts, et al., 2008). The EIF considers three aspects of interoperability: technical, semantic and organisation interoperability (ATHENA, 2007b) (see Figure 2.11).

[4] EU – European Union

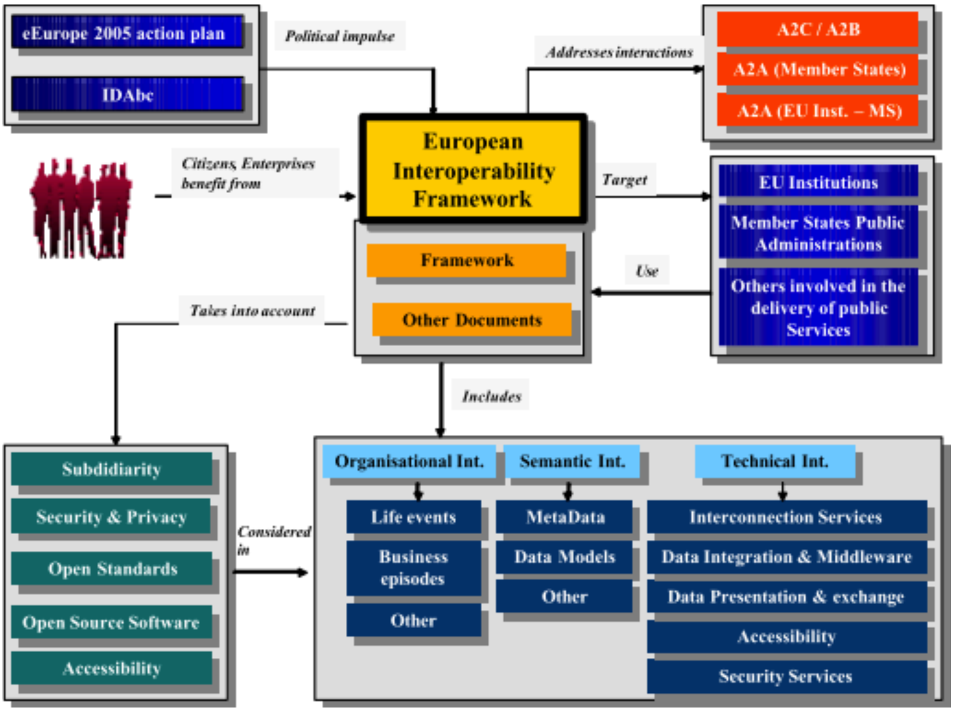


Figure 2.11. The European Interoperability framework (IDABC, 2010).

The three considered aspects are similar to earlier frameworks. Though, 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). These interoperability aspects take into account what (IDABC, 2010) defines as "underlying principles". Accessibility, security, privacy and multilingualism, are some of the relevant contributions of this framework. Technical aspects (accessibility, security and privacy) cover the main requirements for access of users to systems guaranteeing security and privacy. Cultural aspects are ensured having the notion that EU is a fusion of different countries and countries, where the individuality must be respected, but the underlying information architectures should be linguistically neutral so that multilingualism is not a blocking issue for the delivery of e-Government services (IDABC, 2010).

The EIF takes into account the influence of the "underlying principles" on the interoperability perspectives and, consequently, on the framework itself. One of the idiosyncrasies of this model is that an interoperability framework is not a static document, being adapted over time to technologies, standards and administrative requirements change (David Chen, Doumeingts, et al., 2008). That portrays an important notion that a framework should not be static and should consider external factors.

2.3.7. Enterprise Interoperability Maturity Model (EIMM)

The Enterprise Interoperability Maturity Model (EIMM), developed by (ATHENA, 2005), is a method to scale-up interoperability using an enterprise modelling approach. Using a maturity approach in the same philosophy as LISI or OIM, EIMM uses a more grounded approach to interoperability in the technical, knowledge and organisational perspectives of interoperability. The novelty of this maturity model is the three dimensional model (see Figure 2.12) complemented by a set of interoperability practices that establish the path to improve interoperability (ATHENA, 2007c; Berre et al., 2007).

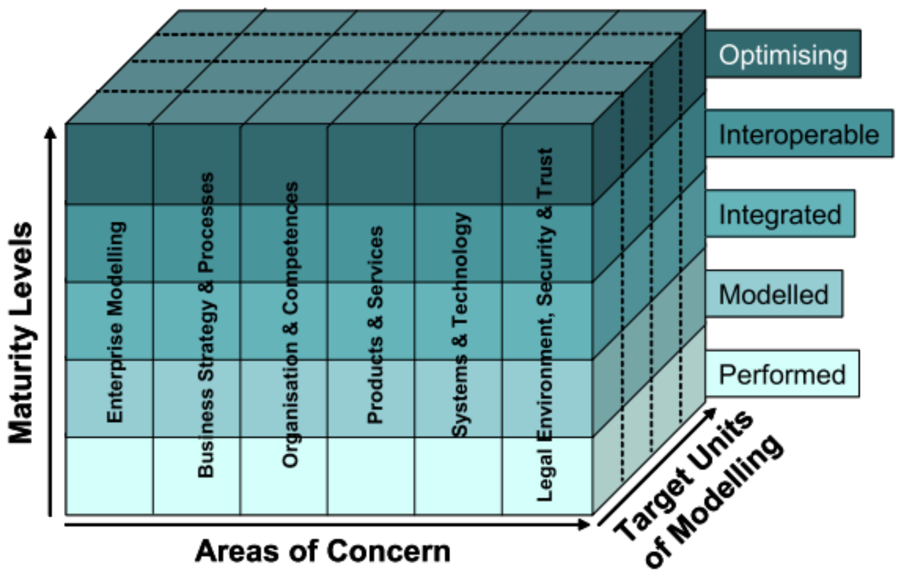


Figure 2.12. The three dimensions of EIMM (ATHENA, 2005).

Defining the EIMM involves two tasks: identifying the main areas of concern on which an enterprise need to work in order to achieve interoperability both internally and externally, and defining the maturity levels that describe the improvement path for each area of concern (David Chen & Daclin, 2007). The areas of concern involve (ATHENA, 2005, 2007c; Rezaei et al., 2013): the alignment of business strategy (strategy perspective); pursuing and improving collaborative processes inside and outside companies (process perspective); identifying the external entities to collaborate with each other, specifying the networked organization topology, and its improvement and deployment (organisational perspective); identify players skills and knowledge (knowledge perspective); identification of new opportunities and specification of the same aspects for new products and services that make use of networked technologies for its delivery (product/service life-cycle perspective); research and evolution of enterprise systems to apply innovative technologies that foster interoperability (technical perspective); and the identification of legal, trust and security requirements (legal rules and external environment perspectives).

The EIMM maturity levels rank interoperability from level 1 (enterprise modelling is performed, but in an ad-hoc and chaotic manner) to 5 (optimising, i.e. Enterprise models allow the organisation to react and adapt to changes in the business environment in an agile, flexible and responsive manner) (ATHENA, 2005). For each maturity level, in a specific area of concern, EIMM provides the adequate objectives and best practices that permit achieve better interoperability between companies. That is particularly useful if one intends to improve interoperability in the existing conditions, or scale-up to higher levels of interoperability (in terms of maturity) allowing mapping each evolution step and planning the implementation procedure. Hence, EIMM proposes a procedure to apply its framework (see Figure 2.13). It consists in an iterative process to identify the main problems to interoperability improvement, and model the adequate solution.

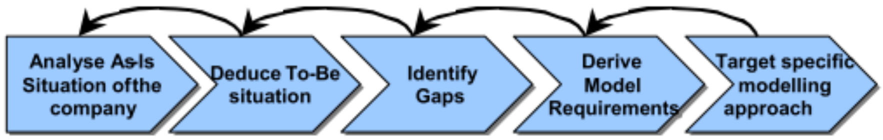


Figure 2.13. Procedure to apply EIMM (ATHENA, 2005).

2.3.8. The Business Interoperability Framework (BIF)

The business interoperability framework (BIF) (ATHENA, 2007a; Legner & Wende, 2006) is a framework dedicated to organisational and management layers of interoperability. Although information systems are an integrated sector on this framework, the approach is business-centred in opposition to earlier frameworks. BIF was created in the scope of ATHENA project (ATHENA, 2006) and, in opposition to ATHENA interoperability framework (AIF) which focuses on the IT solution approaches (Berre et al., 2007) and EIMM that introduces an enterprise modelling approach to interoperability (see section 2.3.7), BIF proposes a qualitative assessment model to verify interoperability in dyads (see Figure 2.14), emphasizing on non-technical issues by identifying four main categories of interoperability (information systems, collaborative business process interoperability, employees and culture interoperability, and management of external relationships) (Kotzé & Neaga, 2010), and contingencies (internal and external) (ATHENA, 2007a).

Business Interoperability (= organisational design of business relationships)		
Category	***Perspective***	***Description***
Management of External Relationships	"How do we manage and control business relationships?" **(Governance Perspective)**	Interoperable organisations manage and monitor their business relationships.
Employees & Culture	"How do we behave towards our business partners?" **(Behavioural Perspective)**	Interoperable organisations promote relationships with business partners at an individual, team-based and organisational level.
Collaborative Business Processes	"How do we collaborate with business partners?" **(Operational Perspective)**	Interoperable organisations can quickly and inexpensively establish and conduct electronic collaboration with business partners.
Information Systems	"How do we connect with business partners?" **(Technical Perspective)**	Interoperable ICT systems can be linked up to other ICT systems quickly and inexpensively and support the cooperation strategy of the organisation.
Contingencies (= factors which impact the organisational design)		
Category	***Perspective***	***Description***
Internal Contingencies	"What are the characteristics of the business relationship?"	Cooperation targets and transactional characteristics impact the optimum level of business interoperability.
External Contingencies	"Which environmental factors affect the business relationships?"	E-Business maturity, legislation and industry dynamics determine preconditions in the specific context.

Figure 2.14. Business Interoperability Framework (ATHENA, 2007a; Legner & Wende, 2006).

Besides the main business interoperability categories and contingencies, BIF provides criteria that outline the key business decisions companies have to solve when establishing interoperable electronic business relationships (Legner & Wende, 2006). Each criterion is addressed in the scope of the product or service life-cycle (approach, deploy and assess & review) and in five levels of interoperability (from none to fully interoperable) (see Figure 2.15). For each of these variables, BIF describes the business interoperability settings that correspond to a business maturity state for a specific category, criterion and life-cycle stage. That not only serves the purpose of assessing business interoperability, but also to determine what decisions one must implement to scale-up interoperability. Though, Legner & Wende (2006) affirm that the maximum level of interoperability is not necessarily the optimal one. The organizational and environmental contingencies serve to scope the interoperability conditions having into account the strategic objectives, the cooperation environment and what external conditions affect the businesses. In sum, it is affirmed by the authors that lower interoperability conditions could be sufficient to fulfil cooperation objectives.

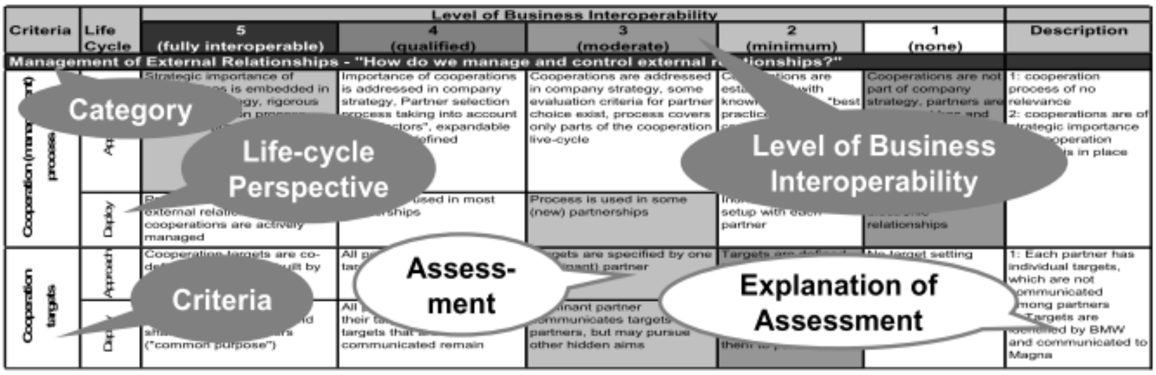


Figure 2.15. Structure and Application of BIF (Wende & Legner, 2006).

2.3.9. Interoperability impact analysis model (IIAM)

The Interoperability impact assessment model (IIAM) (ATHENA, 2007b) is an ATHENA's contribution that complements BIF, establishing together the Excellence model of business interoperability (see Figure 2.16). The objective of this model is to assess how interoperability creates value and quantify the benefits resulting from interoperability improvements, due to significant investment (ATHENA, 2007b).

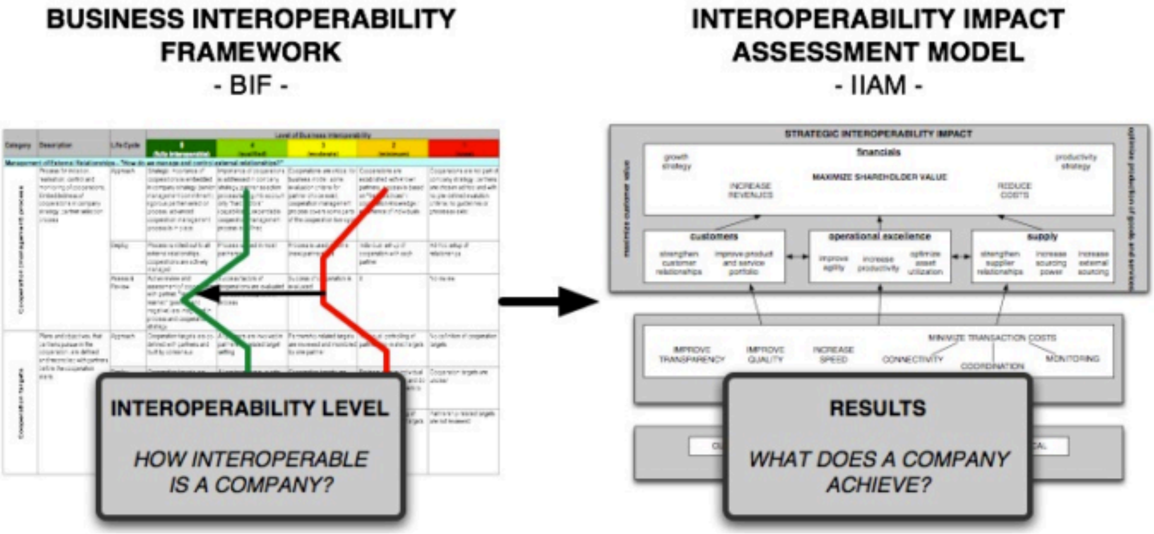


Figure 2.16. Excellence Model of Business Interoperability (ATHENA, 2007b).

Hence, in a cost-based approach, authors track the effect of cultural, organisational and technical investments, on the performance of the organisation or the entire value chain (see Figure 2.17). IIAM measures two kinds of impacts: direct and indirect.

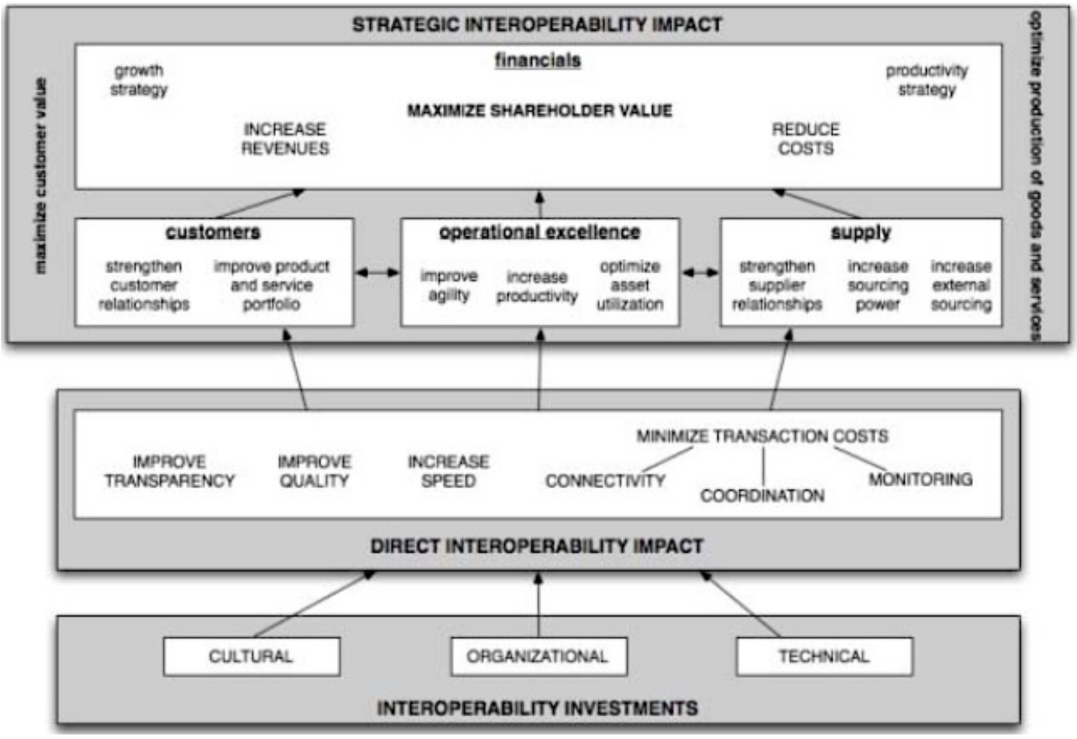


Figure 2.17. Interoperability impact map (ATHENA, 2007b).

Direct interoperability impact, or operational impact, depicts the impacts that can be directly quantified through the transactions costs (ATHENA, 2007b): connectivity (nonrecurring expenses to setup or improve a business relationship), coordination (costs of executing the transaction) and monitoring costs (costs to ensure the quality of the transaction). These costs are measured through two criteria: reliability, which is considered the ability to provide the receiving process with accurate information; and processability, that is related to the semantic compatibility of data.

Indirect or strategic impact reflects how the investment in interoperability will permit to achieve operational excellence and, in turn, what benefits these brings towards suppliers and customers. Through operational excellence, ATHENA (2007b) suggests agility improvement, productivity increase and asset utilization optimization, as measures to meet the strategic targets at a supply chain level.

The customer focus is achieved by strengthening the relationships and through the improvement of product and service portfolio. ATHENA (2007b) affirms that an interoperable service provide a unique value to the customer, and interoperability investments might also contribute to improve the overall attractiveness of a company's product mix, either through bundling effects or by demonstrating the technology lead of the firm.

Last, the supplier side of interoperability indirect impact is achieved through the assumption that reducing the costs of interoperability will strengthen the supplier relationships helping them become more competitive. Additionally, ATHENA (2007b) affirm that interoperability increases the sourcing power and permits to shift power to the market side. And increasing outsourcing will reduce costs in terms of coordination and monitoring, permitting to emphasize on the value added of products or services.

The contributions of measuring the interoperability impact in terms of operational and strategic perspectives of business makes IIAM a unique and relevant framework. This was one of the earliest contributions to operational and strategic measurement that induce a perspective of layering the impact of interoperability, instead of trying to measure it directly using performance measures or trying to assess qualitatively or quantitatively. IIAM allows mapping causes and effects of interoperability in complex business settings, through a problem breakdown in a low level (see Figure 2.17) or a detailed level (see and example in Figure 2.18) decompositions.

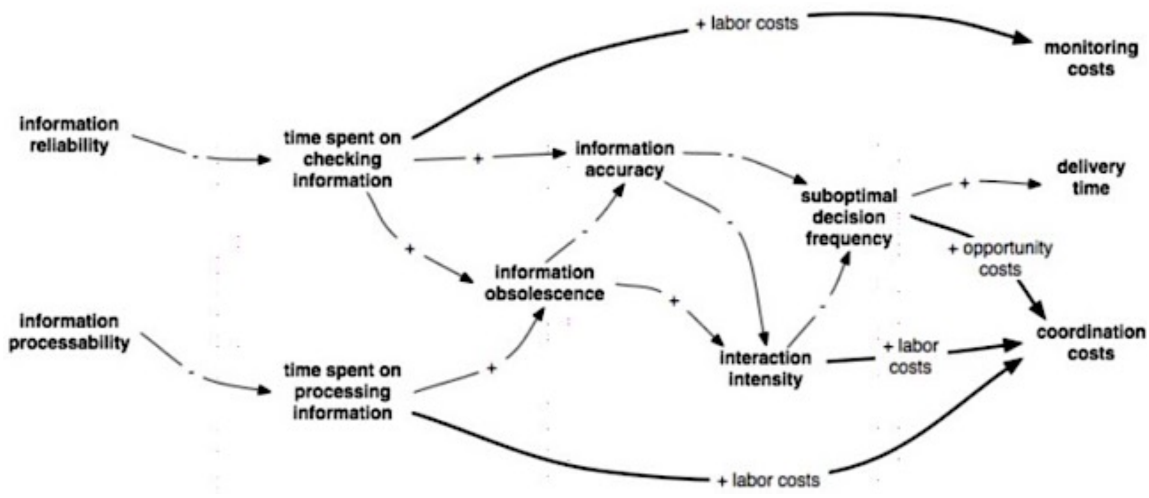


Figure 2.18. Example of information reliability and processability influence in costs (ATHENA, 2007b).

2.3.10. Enterprise Interoperability Framework (INTEROP)

The Enterprise Interoperability Framework (INTEROP) (David Chen, 2006) is a barriers-driven approach to improve enterprise interoperability (EI). Its underlying assumption is that enterprises are not interoperable because of barriers to interoperability (David Chen, 2006), considering in this vision that barriers are incompatibilities of various kinds and at various enterprise levels. Hence, INTEROP defines three basic dimensions concerning enterprise interoperability (see Figure 2.19) (Yves 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 organisational); and interoperability approaches that represent the different ways in which barriers can be removed (integrated, unified, and federated).

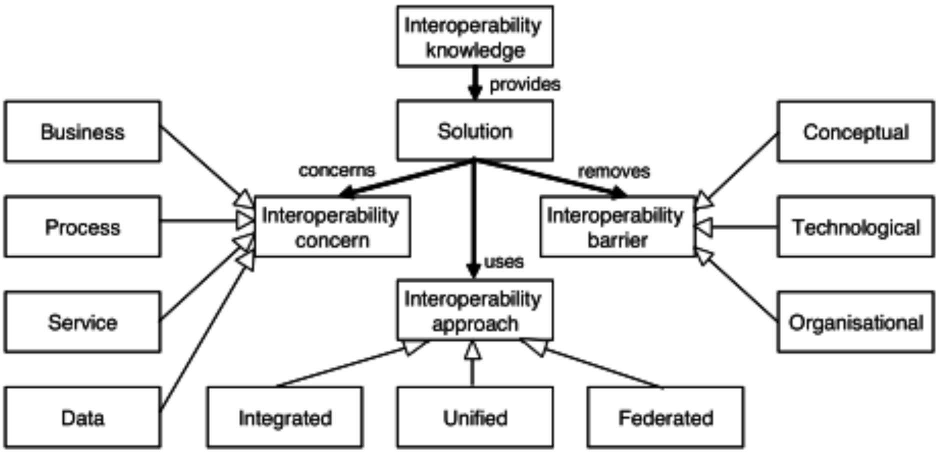


Figure 2.19. Basic concepts of enterprise interoperability (David Chen, 2006).

In a two-dimensional perspective, INTEROP allows to organise interoperability knowledge that enable interoperability (i.e., removes barriers) (see Figure 2.20). A piece of knowledge is considered as relevant to interoperability if it contributes to remove at least one barrier at one level, and it may concern more than one barrier and cover more than one level (David Chen, 2006).

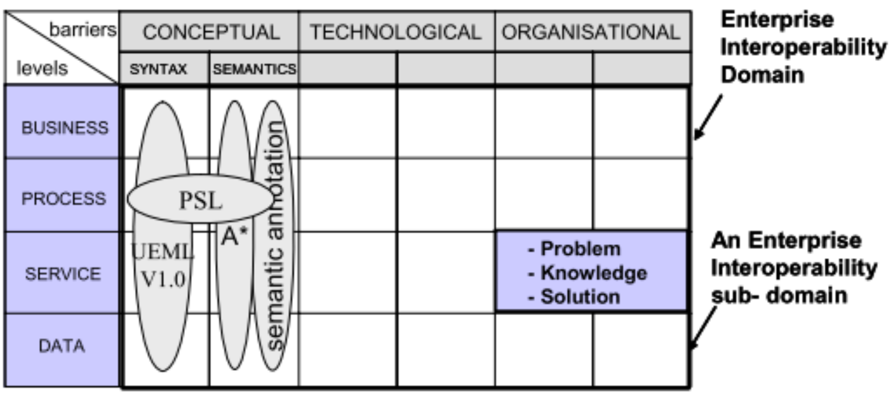


Figure 2.20. Two-dimensional perspective of Enterprise Interoperability Framework (David Chen, 2006).

At a three-dimensional perspective, the full scale of INTEROP is implemented and the interoperability knowledge is organized in concerns, barriers and approaches (see Figure 2.21). The solutions found in the two-dimensional model are organized by kind of approach, being it integrated, unified or federated.

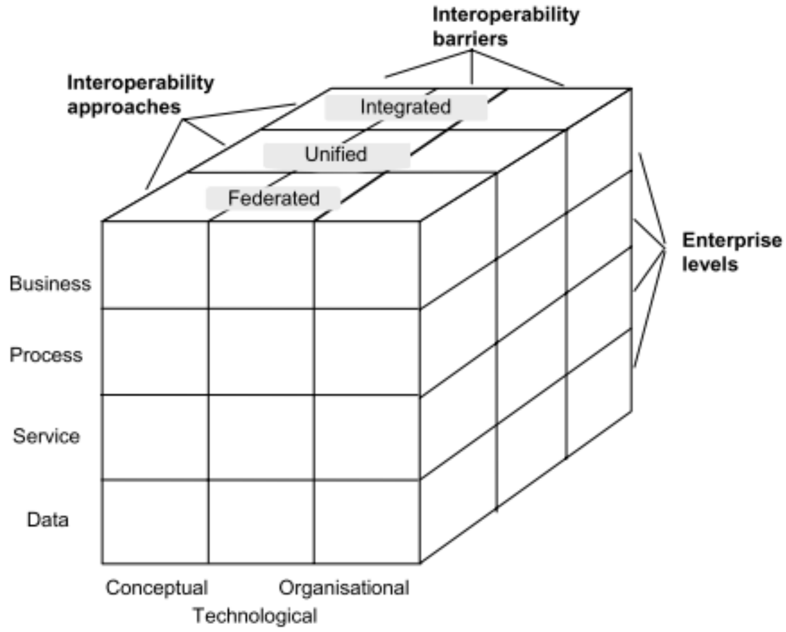


Figure 2.21. Three dimensional perspective of Enterprise interoperability framework (David Chen, 2006).

Although the applicability of the framework fits beneath EI and enterprise architectures (EA), it is a good methodology to identify interoperability concerns, characterize problems and identify subsequent solutions that enable interoperability.

2.4. Interoperability types and perspectives: the decomposition of Business Interoperability

The decomposition of the concept of business interoperability (BI) is a crucial factor if one attempts to deepen in a particular interoperability area. Taxonomy of BI serves the purpose of allowing this deepening to be accomplished and, later on, permits to track interoperability aspects with regard of one perspective to another. The main idea portrayed in interoperability frameworks is that interoperability is composed by a set of interoperability types or perspectives. For instance, IDEAS (2003) considers interoperability a product of business, knowledge, ICT systems and semantic interoperability. These ones are accepted to be a requirement for existing interoperability between firms. So, at a certain point, one can admit that interoperability types or perspectives act as components, being a component defined on Merriam-Webster's dictionary one of the parts of something. Fulfilling the requirements of these components, one can achieve interoperability or, at least, the interoperability vision portrayed by the authors of each framework.

Each framework analysed in section 2.3 provide a decomposition of interoperability, either in interoperability types, as well as assessment criteria, requirements and interoperability metrics. Though, one of the problems when dealing with interoperability taxonomy is the different perspectives portrayed in several frameworks by different authors. Depending on the period the framework was proposed, and in the kind of approach and even the knowledge area (for instance, IT or business), different decompositions and different level of detail are provided in the frameworks. Some terms complement each other, but another ones overlap and sometimes vary in the definition of the same interoperability perspective. Whence, the concept of interoperability has grown from its IT origins into a complex and multidimensional concept, in an unstructured manner. With regards to enterprise interoperability, the authors from D. Chen et al. (2008) suggest that an interoperability domain framework needs to be elaborated so that interoperability research issues can be precisely identified and structured. Works from (Jardim-goncalves, Grilo, Agostinho, Lampathaki, & Charalabidis, 2012; Koussouris & Lampathaki, 2011; Rezaei et al., 2013) provide a deep insight in the interoperability body-of-knowledge structuring, with regards to the concept of enterprise interoperability. The mapping and organisation of interoperability types into levels of detail (granularity levels) is one of the contributions that fit the scope of decomposing BI. A structured decomposition provides a univocal mapping of interoperability aspects in assessment, modelling and performance measurement.

As a starting point to decompose BI, the first step was to define the concept (section 2.1). The selected definition is given by (ATHENA, 2007a; Legner & Wende, 2006), that considers it as “the organisational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business with the objective to create value”. This top-down vision emphasizes the business perspective of interoperability, having in consideration the IT infrastructure and subsequent aspects that allow electronic business to be performed (in opposition to a business-centred vision). Accordingly, interoperability types that enable BI should be considered under its body-of-knowledge.

Henceforth, at the highest-level BI may be tackled in three general levels: organisational, knowledge and technical interoperability.

According to (IDABC, 2010), organisational interoperability (OI) is an interoperability type that concerns the definition of business goals, modelling business processes, that expect to perform information exchanging, considering the inherent organisational structures and individual processes. T. C. Ford et al. (2003) classifies this interoperability perspective as non-technical. Yet, OI relies on successful exchange of information through the successful interoperability of the technical, syntactic, and semantic aspects (Gionis & Charalabidis, 2007). Yves Ducq & Chen (2008a) further add that this perspective allows the collaboration between services of different enterprises that are different in their organisation and in the structure of their operations. Role and responsibility assignment, information accuracy, procedure standardization and/or creation of intermediate processes to allow link between companies, are some of the critical aspects of OI referred by the authors. F. B. Vernadat (2010) also denote that OI issues also include: different human and organizational behaviours, different senses of value creation networks, different business goals, different legal bases, legislations, cultures or methods of work and different decision-making approaches. As operational measures of success, Yves Ducq & Chen (2008a) emphasize on cost, quality and lead-time metrics stressing on systems efficiency, information accuracy and on-time information. There is a compromise between

cooperation objectives and information, which is mediated by the harmonized processes that the two companies fulfil on a daily basis. Though, the fulfilment of these processes have into account the different requirements and organisational conditions.
Knowledge interoperability (KI) is perceived in the ability of two or more different entities to share their intellectual assets, taking immediate advantage of the mutual knowledge and utilize it, and to further extend them through cooperation (Koussouris & Lampathaki, 2011; Rezaei et al., 2013). Interoperability at knowledge level should be seen as the compatibility of the skills, competencies, and knowledge assets of an enterprise with those of other enterprises (David Chen & Doumeingts, 2003). According to (IDEAS, 2003), KI concerns three different levels: organisation level (organisation roles, skills and competencies, knowledge assets, human resources management, laws and regulations, legal obligations and relationships with public institutions); technical level (knowledge data); and Semantics (knowledge ontologies).
Though, while data exchange is performed mostly electronically, knowledge is handled by employees in collaborating organizations (Bock, Zmud, Kim, & Lee, 2005; Gottschalk, 2009; Wickramasinghe, 2006). Human resources are the creators and carriers of knowledge within the boundaries of companies (Koussouris & Lampathaki, 2011). Though, works in KI address it mostly through semantics for constructing common dictionaries that will support and ease out the operations of sharing and acquiring, structuring and representing and spreading the collective/personal knowledge of an enterprise (David Chen & Doumeingts, 2003; Koussouris & Lampathaki, 2011).
Technical Interoperability is the most common form of interoperability and the support for electronic interaction. Being near to the original concept of interoperability, it refers to technical issues of linking computers systems and services, and it is associated with hardware and software, systems, platforms, that enable machine-to-machine and human-to-machine interaction (Dahmann & Salisbury, 1999; IDABC, 2010; Rezaei et al., 2013). Most of the existing publications refer to this kind of interoperability often focusing on communication protocols and the infrastructure required for those protocols to function (Rezaei, Chiew, & Lee, 2014; Van Der Veer & Wiles, 2008). Also, includes key aspects such as open interfaces, interconnection services, data integration and middleware, data presentation and exchange, accessibility and security services (IDABC, 2010).
These three types of interoperability portray a low-detailed decomposition of the BI concept. They cover most of the description of BI, and incorporate partially the rest of the interoperability perspectives. Though, they don't act as isolated components of interoperability, but as interacting perspectives. There is dependency between these areas, and that is perceived in subsequent types of interoperability. So, as a second degree of decomposition, the interoperability types are suggested: business strategy, relationship management, cultural interoperability, rules interoperability, human resources, process interoperability, data interoperability, software and services interoperability and objects and hardware interoperability.

Business strategy (BS) concerns with how companies set up the collaboration by the formalisation of business objectives. BS is seen both as the companies' individual strategic aspirations and the collective goals that enable cooperation. Some of the critical factors in BS include the identification companies' individual goals (Clark et al., 1999; Tolk, 2003b), strategy alignment or harmonization (ATHENA, 2005; Tolk, 2003b), and the establishment of cooperation goals (ATHENA, 2007a), settled by an agreement specifying the conditions and liabilities. In a collaborative perspective of BS, firms should aim at win-win situations where all participants collaborate to achieve business synergy to compete with other chains or networks (Paulraj et al., 2006), and failure to establish cooperation goals may result in faulty relationships. For this reason, BS should be considered reflecting the utmost interoperability level (Zutshi, Grilo, & Jardim-Goncalves, 2012a). This top governance interoperability aspect addresses the harmonization between individual and collective objectives, which subsequently impacts interoperability dimensions and the value chain.

The notion of cooperative advantage presuppose the establishment of mutual goals, that are seen as the degree to which partners share goals that can only be accomplished through joint action and the maintenance of the relationship (Wilson, 1995). Relationship management (RM) becomes a crucial point to achieve interoperability at this level, accompanying the life-cycle of the cooperation, covering all aspects of realising and sustaining the relationship until its termination (ATHENA, 2007a). Critical factors of interoperability involve the relationship life-cycle, by selecting partners, assigning roles and responsibilities to actors, managing and monitoring the collaboration during its realisation and managing risks and conflicts between partners (ATHENA, 2005, 2007a; Zutshi, Grilo, & Jardim-Goncalves, 2012a). SCM is an abundant area on this subject, providing several managerial buyer-supplier relationship practices (Mondini et al., 2014; Perona & Saccani, 2004) that cover most of this relationship aspects (for instance, strategic sourcing, supplier-base reduction, long-term relationships, etc.). Apart from the relationship life cycle, some other issues emerge regarding power distribution, trust and knowledge management. RM is a complex interoperability dimension enforcing the companies' and collaboration objectives, mediating the activities in the partnership. Hence, relationship governance (Ritter, 2007) and trust (ATHENA, 2007a; Wilson, 1995) leverage, and may constrain, the decision-making between partners. Additionally, the intellectual identity of companies is another issue addressed in RM. Since companies' competencies to generated and exchanged knowledge (in terms of knowledge assets or IPR[5]), knowledge should be managed and assessed in terms of knowledge quality (Tolk & Muguira, 2003) and the competencies reviewed (IDEAS, 2003).

Cultural Interoperability (CI) concerns the impact of companies' individual culture in business activities. People and companies have different languages and different cultural aspects such as politics, religion, regional art, traditions and social customs (Cayir & Basoglu, 2008; Koussouris &

[5] IPR – Intellectual property rights.

Lampathaki, 2011). Various cultures have different constraints and different objectives, and culture impacts business (Kotzé & Neaga, 2010). Therefore, lack of understanding of diversity in culture is a barrier for trust building, efficient team-working and constructive communication (Wulan & Petrovic, 2012b). Faulty CI may lead to "us and them" attitude (ATHENA, 2007a) culture clash phenomena and unclear agreements and different expectations (Elfving, 2007). So, to be interoperable the exchange of knowledge and data across dissimilar cultures in different native languages is a necessity (Clark et al., 1999; Whitman & Panetto, 2006).

Rules interoperability (RI) is another BI branch that concerns the rules that constrain or enable business. Two perspectives exist beneath RI: internal and external rules. The internal rules, according to (Gionis & Charalabidis, 2007; Koussouris & Lampathaki, 2011) concern ability of business entities to align and match their business and legal rules for conducting legitimate automated transactions that are also compatible with the internal business operation rules of each other (Gionis & Charalabidis, 2007; Koussouris & Lampathaki, 2011). Koussouris & Lampathaki (2011) reinforces that incompatibility or failure to negotiate adequate business rules may lead to differentiation in terms of business models and business mentality of the transacting entities. In the external perspective of RI, frameworks such as LISI (DoD, 1998), OIM (Clark et al., 1999) and EIMM (ATHENA, 2005) consider the influence of legislation (government or cross-borders) in processes. LISI, for instance, incorporates the regular assessment of government legislation into the LISI Interoperability Assessment Process. OIM and EIMM pursue the same vision that legislation may constrain or support the processes. Every decision taken in these frameworks should review thoroughly governmental rules.

Human resources (HR) perspective is one of the key areas to accomplish BI. Relationships among people and teams are what give organisations their added value and build collective competencies (Harmel, Bonjour, & Dulmet, 2006b). Since the traditional business era, IT evolution allowed to shift most of the human tasks turning them into automated ones. Though, most activities are still performed by users, and interoperability problems may occur because information is neither perfectly available nor fully processable for the human actors (bounded rationality) (ATHENA, 2007b). The HR perspective is complex because it concerns OI, KI and TI issues of BI. The authors from (ATHENA, 2005) stress on the fact that human (and organisation) behaviours could be incompatible with interoperability. Issues like trust, visibility, responsibility and motivation characterize the behavioural and organisational perspective of HR. On the KI perspective, when HR interprets, understands and believes in the message communicated information, it becomes knowledge (Elfving, 2007). The capability to deal with information and IT tasks is affected to the role and responsibility assigned to the employee, as well as the competences and knowledge skills to deal both with the performed task and with IT (TI perspective) (ATHENA, 2005, 2007a). Inadequate HR interoperability may result in delays caused by human factors (such as rigid and centralized organization, long human reaction delay etc.) reflected in organisational performance (David Chen, Vallespir, & Daclin, 2008).

Process Interoperability (PI) is the core of BI. Strategic objectives, relationship set up, and the use of technical (IT and tools) and human resources are bound together by the processes that permit to accomplish individual and collective objectives (ATHENA, 2005; Berre et al., 2007). Processes allow to gather knowledge, recognize improvement opportunities, align practices to business objectives, and measure performance (ATHENA, 2005). Internally, processes are established and sequenced according to the specific needs of a company to accomplish their objectives (David Chen, Doumeingts, et al., 2008). Though, when two companies cooperate, the internal business processes of the cooperative enterprises should interact to pursue common objectives that will be profitable for all the parts (Alfaro, Rodriguez-Rodriguez, Verdecho, & Ortiz, 2009). Interface processes alignment becomes a crucial task to achieve PI. This will allow to exchange data and to conduct business in a seamless way (Koussouris & Lampathaki, 2011).

Data interoperability (DI) is related to the management, documents, messages and/or processing of different and exchange structures by different collaborating entities (Berre et al., 2007). Many companies' information systems have their own databases that are heterogeneous in terms of structures, types and data formats (Pang, Zhong, Fang, & Huang, 2015). DI makes work together different data models with different query languages to share information coming from heterogeneous systems (Guédria, Naudet, & Chen, 2013). At a TI perspective, DI deals with both the data format (syntactic interoperability) and its meaning (semantic interoperability) (DoD, 1998). Beyond semantic and syntactic representation of data, TI deals also with the wrong instantiation of data models and different data restrictions (ATHENA, 2007c). Operationally, DI requires highly collaborative capacity to accomplish tasks through information transmissions, data sharing, and database operations (Pang et al., 2015). The context of data (pragmatic interoperability) in its application differs from the format and meaning (Morris et al., 2004). The use of data must be mutually understood between collaborating systems (Asuncion & Van Sinderen, 2010), and will differ depending on the business, process and other organisational context, and must be addressed independently from the technical perspective.

Software and systems interoperability (SSI) is a TI dimension that incorporates the notions of "services interoperability", "software systems interoperability", "systems interoperability" and "application interoperability". Though having different designations, these notions portray the same main idea. According to Chen (2006), this perspective it is concerned with identifying, composing and making function together various applications (designed and implemented independently), by solving the syntactic and semantic differences as well as finding the connections to the various heterogeneous data bases (ATHENA, 2007c; Guédria et al., 2013). Though the term software concerns applications in computer systems, the term 'service' is not limited to this notion, and also considers functions of companies and networked enterprises (David Chen, Doumeingts, et al., 2008). Services are an abstraction and an encapsulation of the functionality provided by an autonomous entity (Berre et al., 2007). Hence, SSI concerns the soft part of TI and the interaction between different companies' systems and the applications and services that support this interaction.

Last, objects and hardware interoperability (OHI) concerns the physical infrastructure that supports and enables electronic data input, output, exchange, storage and processing. It refers to the networked interconnection and cooperation of devices and hardware components (Rezaei et al., 2013). IT hardware has gone through evolution and, nowadays, most of manual and human-dependent tasks have been transformed into automated ones (Koussouris & Lampathaki, 2011). Apart from computer processing, the use of handheld devices (e.g. barcode and RFID) and recent developments in Internet of Things (Gershenfeld, Krikorian, & Cohen, 2004), extended the use of IT hardware to most human tasks that required parallel computer processing. Simultaneously, the coexistence of new systems with legacy systems, forces the backward compatibility and limits the technological evolution (Curry, 2012). Like in the concept of interoperability itself, the hardware part has several definitions that fit the scope of this component. Examples of that are the physical interoperability (Dahmann & Salisbury, 1999; T. Ford, 2008; T. C. Ford et al., 2003; Tolk & Muguira, 2003), infrastructures (DoD, 1998), computer interoperability (Gottschalk, 2009) and hardware compatibility (Dahmann & Salisbury, 1999).

The BI decomposition framework (see Figure 2.22), developed by Espadinha-Cruz & Grilo (2014), schematizes the decomposition of BI into these twelve interoperability perspectives. Though, each type of interoperability may not be seen as an independent one. Each perspective coexists and depends from another kinds of interoperability. For instance, from level 1 to 2 OI, KI and TI perspectives are present in BS. Also, among interoperability types from the same level, some dependencies (sequential and reciprocal) exist, like in the case of PI. Processes permit companies to fulfil they're objectives, which makes PI depend on BS. Though, to operationalize internal and interface processes, technical and human resources are required, as well as adequate data needs identification and correct interoperability requirements.

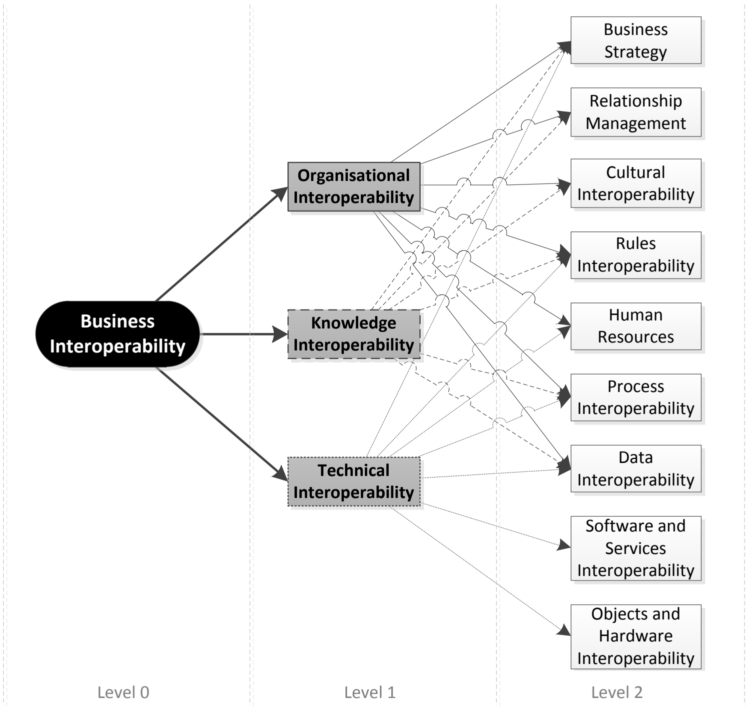


Figure 2.22. Business Interoperability decomposition framework (Espadinha-Cruz & Grilo, 2014).

The focus of the BI decomposition framework is to provide a systematic view of business interoperability for the application of the Axiomatic Design Theory (AD). The framework allows one to detail business interaction according to the identified types of interoperability, which permits a systematic approach to each interoperability subject that rule BI in the context of the relationship. This allows one to look at the interoperability drivers and observe the isolated perspective of each matter and how it guarantees to obtain an interoperable dyadic relationship. Subsequent knowledge areas may be considered in the adequate perspective.

2.5. The measurement and quantification of interoperability

One branch of the existing interoperability literature is dedicated to the measurement and quantification of interoperability. The need to measure and quantify interoperability is well recognised. Kasunic (2001) affirms that measuring, assessing, and reporting interoperability in a visible way is essential to set the right priorities. Further, C. Chen, Lin, & Huang (2006) add that it allows a company knowing its strengths and weaknesses to interoperate with a third company and to prioritize actions to improve their collaboration ability. Though, interoperability is not measured as an absolute property, but in relation to another interoperability state, which usually corresponds to an improvement. A common aspect in interoperability measurement literature is the “as-is” to “to-be” benchmark. Benchmarking between “as-is” and “to-be” states allows companies to define the current interoperability setting and define the optimal or desirable state to interoperate with another companies

(ATHENA, 2007b). Nevertheless, the as "as-is" to "to-be" is not only a transition of states, but it is also a decision analysis related to considering the various alternatives (Razavi & Aliee, 2009).

The concepts of optimal and perfect interoperability are strongly debated among interoperability measurement literature. The maximum level of interoperability (or perfect interoperability) is not always what is desirable, or possible, and exists in contradiction with the optimal level of interoperability. T. Ford (2008) stresses on the relevance of quality of the interoperations instead of the quantity. Most TI articles focus on quality aspects, as well as systems performance measures like in the case of (Leite, 1998) or (Kasunic, 2001). But in the perspective of BI, Lebreton & Legner (2007) affirm that the desirable level of interoperability is characterized by a set of contingency factors (e.g. industry dynamics, e-business maturity). Hence, the optimal level of interoperability is uncertain and depends on the business contexts and requires deep study to determine how much interoperable companies need to be, as well as the study of value generated from the ability to interoperate, what prerequisites and agreements should be in place between companies, and which technical and organisational measures have to be put in action (Legner & Lebreton, 2007).

The measurement of interoperability is also a complex task. The multidimensional and complex nature of interoperability makes difficult to one to assess it directly (Kasunic, 2001). If in one hand, it hinders the existence of a multi-purpose model, in the other hand, focused-methods may lead to problem fracturing (T. Ford, 2008). Existing measurement methods are, commonly, perspective-centred and most of them focus technical issues rather than organisational or knowledge issues. In the specific case of BI, there are few contributions and, most of them, either qualify BI (e.g. (ATHENA, 2007a)) or attempt to quantify it using subjective information modelling and Multi-criteria decision-making (MCDM) models (e.g. (Espadinha-Cruz, 2012; Espadinha-Cruz, Grilo, & Cruz-Machado, 2012; Zutshi, Grilo, & Jardim-Gonçalves, 2012)).

From the analysis of the existing literature, interoperability measurement may be classified according to the types presented in Figure 2.23.

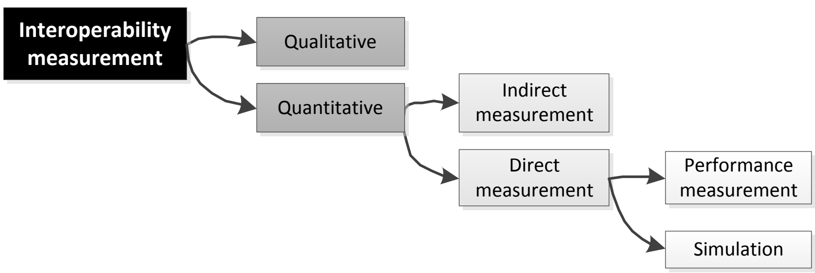


Figure 2.23. Types of interoperability measurement methods.

Interoperability measurement models can be mainly classified either as qualitative or quantitative (M. S. Camara et al., 2013). Qualitative models make use of levels and maturity levels which assign the current interoperability state to a certain degree of sophistication (T. Ford & Colombi, 2007; Tolk &

Muguira, 2003). Usually these interoperability levels are associated with a certain type of interoperability. They permit to infer about interoperability making them correspond to a scale. This kind of measurement is useful to characterize interoperability and to identify what assets are required to improve towards higher levels of interoperability. Though, most of the measurements are performed in a subjective manner, providing a low precision assessment (M. S. Camara et al., 2013).

Another branch in interoperability measurement literature is provided by the existence of quantitative models. In opposition to qualitative models, numerical values are usually assigned to a specific interoperability condition (M. S. Camara et al., 2013). Those numerical values may be either measured or obtained converting a specific level of interoperability into a numerical value. A subdivision of quantitative models dedicated to convert interoperability into numerical values. "The interoperability score (i-Score)" (T. Ford & Colombi, 2007), for instance, is a methodology to measure the current state of interoperability, determine the optimum i-Score state and using matrix calculation to compute the gap between the two states. MCDM models are also used to model subjective information into numerical parameters. Typically, these latter ones are used to compare scenarios (e.g. (Zutshi, Grilo, & Jardim-Goncalves, 2012a) using ANP[6] models, and (Razavi & Aliee, 2009) using AHP[7] model) or analyse a set of practices that permit to achieve higher levels of interoperability ((Espadinha-Cruz, 2012; Espadinha-Cruz et al., 2012), using AHP and Fuzzy TOPSIS[8] models). Though, this kind of quantitative measurement relies on the selection of a vast amount of criteria, which vary depending on the subject and the researcher of manager that uses the model. For this reason, the computed result accuracy may be as good as the measurement using qualitative models. Nevertheless, these indirect quantitative measurement models are useful not only to infer about the current interoperability state (like in the case of qualitative models), but to compare scenarios by combining several criteria simultaneously, and determine which one will be adequate to improve interoperability.

Interoperability performance measurement is another kind of quantitative measurement that, in opposition to the previous one, attempts to measure directly the interoperability of an on-going system or a simulated one. D. Chen (2006) defends the position that if interoperability can be improved means that there exists metrics for measuring the degree of interoperability. Hence, interoperability performance measurement relies on the identification of performance metrics and key performance indicators (KPI) (Yves Ducq & Chen, 2008). The impact of interoperability is measured in this branch, and early work in this area focuses on measuring systems performance, providing operational metrics such as time of interoperation or systems connectivity (Leite, 1998), which are associated with the systems performance. More recent approaches connect interoperability performance to business processes (Alfaro et al., 2009) and to companies' objectives (ATHENA, 2007b; M. S. Camara et al.,

[6] ANP – Analytical Network Process
[7] AHP – Analytical Hierarchy Process
[8] TOPSIS - Technique for Order Preference by Similarity to Ideal Solution

2013). Collaborative performance is a subject that gained attention in interoperability (Alfaro et al., 2009; ATHENA, 2007b; Galasso, Ducq, Lauras, Gourc, & Camara, 2014). If, in one hand, systems performance refers to the performance between the interaction of two different systems, in the other hand, collaborative performance is measured through process and business performance in metrics. The failure to accomplish a set of partnership performance values would reflect an interoperability problem between business partners (Yves Ducq & Chen, 2008).

Though, despite the evolution in terms of interoperability performance, it isn't known a direct way to correlate the interoperability issues, or the companies' decisions with the interoperability measurements (ATHENA, 2007b, 2007c; David Chen, Vallespir, et al., 2008; Yves Ducq & Chen, 2008). Performance measurement literature extends beyond interoperability. Some interoperability authors incorporate performance measurement systems (PMS) (e.g. balanced Scorecard, performance prism, ECOGRAI, IDPMS or QMPMS) and causal performance measurement models (CPMM) methods (e.g. balanced Scorecard strategy map, action-profit linkage (APL) or graph of decomposition) (Blanc et al., 2007; M. S. Camara et al., 2013; Y Ducq & Berrah, 2009; Yves Ducq & Chen, 2008). PMS are a set of metrics used to quantify both the efficiency and effectiveness of actions (Kaplan & Norton, 2005). While, CPMMs are used to outline the specific path that a company will follow to achieve its strategy (Niven, 2002). However, all these methods being mainly developed for generic PIs, none of them are dedicated to the measurement of interoperability performance (Galasso et al., 2014). In Chapter 5 interoperability performance measurement will be discussed in more detail, as well as the supply chain collaboration and buyer-supplier dyad performance measuring methods that fit the scope of BI.

One particular of performance measurement is that it should be done during the operational phase to evaluate the ability of interoperation between two cooperating enterprises (Yves Ducq & Chen, 2008). Though, companies' current metrics implementation doesn't contemplate interoperability metrics. And, also, the study of better interoperability scenarios in a real system would require manipulating variables, which would be time and resource-consuming. The approached solution is the use of computer simulation. Literature in interoperability simulation is mostly related to technical simulation. Few contributions focus on the process aspect of interoperability. Camara et al. (2013), for instance, makes an approach to interoperability simulation based in a CPMM model making use of business process simulation to study the impact of interoperability in partners' objectives. A more technical approach is provided by (Gan et al., 2000), which makes a comparison between two distributed simulation technologies - high level architecture run-time infrastructure (HLA-RTI) and extended asynchronous simulation protocol using the message passing interface (MPI-ASP) – to chose the more adequate method to simulate the planning phase of supply chains between companies. Although this simulation proposal is of a technical nature, its biggest contribution is the simulation analysis outside companies' boundaries between firms, instead of focusing on internal aspects of one firm.

Nevertheless, the area of interoperability simulation is currently missing approaches to collaborative processes between firms in dyads and networks to show the influence of BI aspects in performance. The BI body-of-knowledge provides several clues that allow creating and model new interoperability scenarios, which may affect process arrangement and resource utilization. Computer simulation would allow to study the impact of these ones and determine, using an “as-is” to “to-be” benchmarking approach, which solutions are more appropriate for the collaborations performance. In the work from (M. S. Camara et al., 2013) an “as-is” to “to-be” benchmarking is suggested in order to study the SOA-based[9] solutions to remove interoperability barriers. The same philosophy could be useful to study another interoperability factors.

From the reviewed literature in interoperability measurement, the works portrayed in Table 2.2 are distinguished for their contribution to each of the previously address types of measurement. Is to be noted that some publications fall in several categories at the same time. Every interoperability problem depends on a detailed characterization, and qualitative assessment becomes always a necessity to scope the problem and determine its dimension. Most of the existing interoperability frameworks fall into this category because they provide the adequate structure to look at a problem, and also the means to put it in scale in terms of levels or maturity levels. Even those ones that don’t provide the means for the assessment provide a framework to decompose the problem, like in the case of (IDEAS, 2003). Hence, the qualitative aspect becomes a necessity in interoperability measurement literature, even if it doesn’t provide a measurement. It will scope the problem further and allows simplifying some areas and detailing another ones.

Indirect quantitative methods go beyond problem characterization, and put it in scale towards the problem itself, or towards new objectives (e.g., partner selection, practices implementation) or another interoperability solution. The contribution of this kind of measurement is to give a quick assessment and to study what are the adequate scenarios to solve an interoperability problem. Though, these methods depend of the experience of the managers who implement these solutions. Problem characterization and identification, criteria selection and alternatives study are some of the crucial aspects to measure interoperability. Precise measurements will depend strongly on the model robustness and the experience of the users. As consequence, some measurements may be as precise as any qualitative model assessment. Though, one feature that distinguishes mathematical models from the qualitative ones is the ability to reason several alternatives and criteria simultaneously. Aggregated interoperability scores are useful to give a quick notion of the interoperability performance in companies, or to prioritize another subjects in analysis.

[9] SOA – Service oriented architecture

Table 2.2. Interoperability literature by type of measurement.

Type of measurement			References
Qualitative			LISI (DoD, 1998), OIM (Clark et al., 1999), LCI (Tolk & Muguira, 2003), IAM (Leite, 1998), EIMM (ATHENA, 2005), BIF (ATHENA, 2007a), SoSI (Morris et al., 2004), OIAM (Kingston, Fewell, & Richer, 2005), NC3TA (NATO, 2003), Potentiality and compatibility measures (David Chen, Vallespir, et al., 2008).
Quantitative	Indirect		i-Score (T. Ford & Colombi, 2007), BIQMM (Zutshi, Grilo, & Jardim-Goncalves, 2012b), AHP model (Espadinha-Cruz, 2012), AHP model (Razavi & Aliee, 2009), Fuzzy TOPSIS model (Espadinha-Cruz et al., 2012), Probabilistic model (Sulton, 1999), Computing of interoperability levels/degrees (Elmir, Alrajeh, & Bounabat, 2011), BI ratio (Guo, 2007), computing of maturity levels (Guédria et al., 2013).
Quantitative	Direct	Performance measurement	IAM (Leite, 1998), IIAM (ATHENA, 2007b), PMS-based measurement (Alfaro et al., 2009), Causal model (Sulton, 1999), Interoperability metrics (Elmir et al., 2011), Interoperability metrics (Kasunic, 2001), Interoperability metrics (David Chen, Vallespir, et al., 2008; Yves Ducq & Chen, 2008), CPMM (M. S. Camara et al., 2013; Galasso et al., 2014), Interoperability metrics (ATHENA, 2007c), PMS (Y Ducq & Berrah, 2009), Cost-based (Brunnermeier & Martin, 2002).
Quantitative	Direct	Simulation	Business process simulation (M. S. Camara et al., 2013)(Galasso et al., 2014), HLA-RTI and MPI-ASP simulation across companies' boundaries (Gan et al., 2000), framework for emergency response (Jain & McLean, 2003).

Performance measurement literature provides means to measure interoperability directly during companies' operation, or in the simulation of the real system. Comparatively, this kind of measurement may provide more accurate measurements, instead of approximations or conversion into numerical values. Though, it relies in the establishment of an effective PMS. Interoperability metrics and KPIs should be incorporated in companies' objectives in order to devise the mechanisms to monitor in real-time. Still, some interoperability aspects are more subjective than objective. Interoperability aspects would require deep study to understand the final impact in interoperability, or the use of combined models with another types of measurement. The advantage of qualitative and indirect quantitative measurement models is that they can provide an approximation to measure subjective aspects. Mixed-models would guarantee to cover all the scope of interoperability. Hence, interoperability measurement types are not mutually exclusive. In opposition, they provide different insights of interoperability problems and can be combined to keep track of another interoperability issues that can be resolved later on. For instance, in the context of INTEROP (David Chen, 2006), D. Chen, Vallespir, et al. (2008) proposed three measures: interoperability potentiality measure, which can be used at any time; interoperability compatibility measure, which may be applied in interoperability projects' start and end phases; and interoperability performance measure, to assess on-going interoperation. This model joins together qualitative (potentiality and compatibility) and performance measures for the purpose of developing or improving enterprise interoperability, addressing different stages of the interoperability project life cycle.

2.6. Interoperability criteria: further decomposition of business interoperability

Interoperability problem characterization and measurement depends on the selection of criteria that fit the analysed objectives. An interoperability criterion is adequate when we make a judgment of a certain interoperability topic. Though, some interoperability aspects are relevant despite if we analyse an interoperability problem. When modelling issues are addressed, for instance, interoperability aspects surpass the criterions and may act as terms for consideration or requirements. Either if authors make a problem description (e.g. identification of cooperation targets (ATHENA, 2007c)), assessment (e.g. measure time of interoperation (Kasunic, 2001)) or a design a more interoperable solution (e.g. guidelines to implement AIF according to EIMM maturity levels (ATHENA, 2007c)), interoperability criteria assumes many forms: a description to give detail of a problem in a specific point of view; an aspect which we measure its accuracy according to a scale or a performance metric; or a requirement to design a new system. Hence, interoperability criteria provide clues of what aspects to look, in practice, when we tackle an interoperability issue.

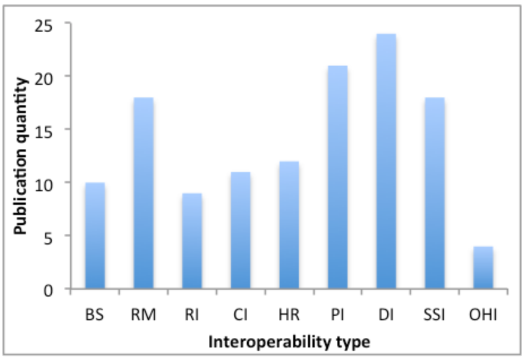


Figure 2.24. Interoperability measurement publications that provide criteria, classified by interoperability type.

Interoperability literature presents a vast quantity of criteria that fit different purposes of problem characterization and assessment. Almost every author mentioned in Table 2.2 provides a set o criteria to support the proposed model. Figure 2.24 represents an analysis of interoperability articles and to which interoperability types they contribute. Existing articles cover most of the BI interoperability types. Though, they contribute most RM, PI, DI and SSI.

Regarding interoperability criteria, the found contributions cover the interoperability types but the growth of disparate interoperability models has lead to divergences and convergences in some of the advocated criteria. For instance, “process alignment” (ATHENA, 2007c) conveys the same idea than “aligned operations” (Tolk, 2003b) or “to connect internal processes of separate companies to accomplish a networked process” (David Chen, 2006; David Chen, Doumeingts, et al., 2008). Figure 2.25 presents the total and aggregated number of found criteria, which will be introduced in Table 2.3.

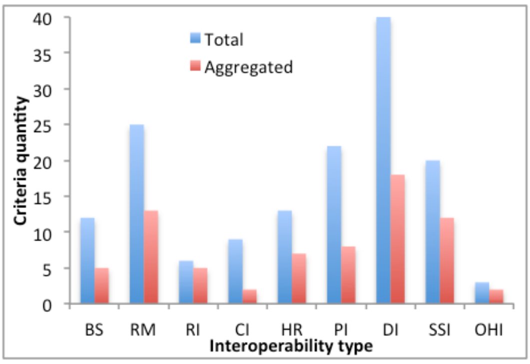


Figure 2.25. Total and aggregated criteria by interoperability type.

Depending on the proposed models and frameworks, the context of each criterion is different. Each criterion was classified according to four categories of application:

- **Descriptive –** descriptive category refers to criteria used without any specific measurement. They correspond to framework assets, interoperability requirements, modelling aspects, etc. that are provided by authors to frame the interoperability issues. The description of those aspects doesn't make a qualification of the interoperability, but allows identifying the key aspects that permit to infer about the interoperability setting.
- **Qualitative** – qualitative criteria allows one to put in scale a certain interinoman1operability aspect towards another level of interoperability, or another alternative to the current situation. Usually this kind of criteria is of a subjective nature, although they classify interoperability towards a measurement scale that normally is a level of interoperability.
- **Quantitative –** quantitative criteria refer to aspects used in numerical measurement of interoperability. These criteria are mostly used with measurement models that allow the computing of interoperability subjective issues. Scoring models and MCDM are examples of measurement models used to compute this kind of criterion as an interoperability score or evaluation towards another levels of interoperability or different alternatives.
- **Performance –** performance criteria correspond to interoperability metrics that allows the direct measurement of interoperability using a PMS or a CPMM. In contrast with previous categories, this kind of criteria do not reflect a specific level of interoperability, but allows one to measure the impact of interoperability at operational and technical levels.

Most of the existing publications propose criteria on the context of problem description and qualitative assessments. Few of them apply them in the context of quantitative and performance measurements (see Figure 2.26).

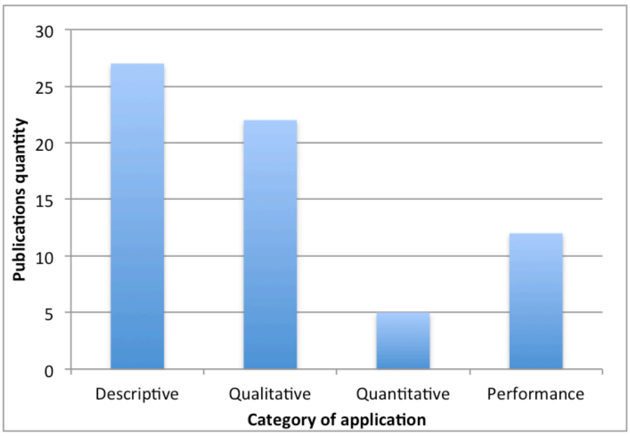


Figure 2.26. Interoperability measurement publications that provide criteria, classified by application category.

In Table 2.3 is presented the criteria that fit the scope of each BI interoperability type, and the application categories.

Table 2.3. Business Interoperability criteria by: interoperability type (by level in Figure 2.22), criteria type and reference.

Interoperability type 2nd level	Interoperability type 1st level	BI Criteria	Application type	References
BS	OI	Business goals identification	Descriptive Qualitative Quantitative	[1], [2], [3], [4], [5], [6]
		Clarity in strategic goals	Descriptive Qualitative Quantitative	[1], [2], [3], [5]
		Business strategy alignment	Descriptive Qualitative	[1], [2], [3], [7], [8], [9]
	KI	IPR protection	Qualitative Quantitative	[5]
	TI	Agreed security	Qualitative	[10]
RM	OI	Partner selection	Descriptive Qualitative Quantitative	[1], [2], [3], [5], [6]
		Definition of the cooperation model	Descriptive Qualitative	[1], [2], [3], [11]
		Compatibility of organisational structures	Qualitative Quantitative	[5], [12]
		Cooperation realisation management	Qualitative	[1], [2], [3]
		Collaboration termination management	Descriptive Quantitative	[5], [13]
		Cooperation monitoring	Descriptive Quantitative	[1], [2], [3]
		Role and responsibility assignment	Descriptive Qualitative Quantitative	[1], [2], [3], [5]
		Definition of contact points	Qualitative Quantitative	[2], [3], [5]
		Conflict and risk management	Descriptive Qualitative Quantitative	[1], [2], [3], [4], [5]
		Governance distribution	Descriptive Qualitative	[2], [14], [15], [16], [17], [18], [19], [20]
	KI	Knowledge management	Descriptive	[1], [2], [3], [5], [11]

Interoperability type 2nd level	Interoperability type 1st level	BI Criteria	Application type	References
			Qualitative Quantitative	
		Competencies revision	Descriptive Qualitative	[6], [7], [11], [21]
		Knowledge quality	Descriptive	[22]
CI	OI	Culture harmonization	Descriptive Qualitative	[1], [23], [24], [25], [26], [27], [28]
		Language barriers	Descriptive Quantitative	[4], [5], [8], [25], [28], [29]
RI	OI	Applicable legislation	Descriptive Qualitative	[2], [3], [23], [24]
		Rules incompatibility	Descriptive	[7], [8]
		Rules alignment	Descriptive Qualitative	[8], [30]
	KI	IPR protection	Qualitative Quantitative	[5]
	TI	Alignment of security requirements	Descriptive	[6]
HR	OI	Trust	Descriptive Qualitative	[2], [3], [31]
		Visibility	Descriptive Qualitative	[2], [3], [31]
		Responsibility assignment	Quantitative	[5], [12], [32]
		Human factors	Descriptive Quantitative	[1], [8], [12], [29], [32]
	KI	Knowledge and skills	Descriptive Qualitative	[6], [33], [34]
	TI	Skills for interoperation/IT	Qualitative Quantitative	[6], [33]
PI	OI	Process identification	Descriptive	[6], [34]
		Process sequencing	Descriptive	[23], [24]
		Process monitoring	Descriptive Performance	[1], [35], [36]
		Collaboration modelling	Descriptive	[1]
		Process alignment	Descriptive Qualitative Quantitative	[1], [2], [4], [5], [6], [7], [8], [23], [24], [30]
		Organisational alignment	Descriptive Qualitative	[12], [23], [32], [37]
	KI	Work methods	Descriptive Qualitative	[2], [3], [6], [23], [24], [34]
	TI	Process logic	Descriptive	[11], [21]
DI	OI	Semantic Alignment	Descriptive Qualitative	[2], [4]
		Product data	Descriptive Qualitative Quantitative	[2], [11], [38]
		Process data	Descriptive	[11]
		Semantic agreement	Descriptive	[4], [8]
		Time of interoperation	Performance	[1], [12], [32], [34], [35], [39]
		Information quality	Descriptive Qualitative	[2], [22], [40], [41]
		Communication paths	Descriptive Qualitative	[1], [2], [3]
		Contact points	Qualitative Quantitative	[3], [5]
	KI	Knowledge data	Descriptive	[11]
		Knowledge ontologies	Descriptive	[11]
		Communication methods	Descriptive	[42]
	TI	Make heterogeneous databases work together	Descriptive	[23], [24]
		Communication requirements	Descriptive	[7]
		Syntax compatibility	Qualitative Quantitative	[1], [43]

Interoperability type 2nd level	Interoperability type 1st level	BI Criteria	Application type	References
			Performance	
		Protocol interoperability	Descriptive Qualitative	[7], [8], [41]
		Quality of interoperation	Performance	[1], [12], [35], [44], [45]
		Cycle time	Performance	[35], [44]
		Processability	Performance	[44], [45]
		Connectivity	Qualitative Performance	[2], [8], [35], [41], [46]
		Connectivity costs	Performance	[31]
		Data latency	Performance	[8], [35], [41], [46]
		Cost of interoperation	Performance	[12], [32], [35], [36], [47]
SSI	TI	Application interoperability	Descriptive	[5], [23], [24], [48]
		Security	Descriptive Qualitative Quantitative	[1], [2], [4], [5], [10]
		Solution management	Descriptive	[2], [11], [49]
		Application logic	Descriptive	[2], [11], [49]
		Standards compatibility	Descriptive Qualitative	[2], [10], [29]
		Systems architecture	Descriptive	[42]
		Applications ontology	Descriptive	[11], [23], [49]
		Legacy systems	Qualitative	[42]
		Technological compatibility	Qualitative Quantitative Performance	[12], [43]
		Capacity	Performance	[41], [46]
		Systems overload	Performance	[41], [46]
		Underutilization	Performance	[41], [46]
		Undercapacity	Performance	[41], [46]
OHI	TI	Types of interaction	Qualitative	[2], [11], [45]
		Hardware compatibility	Descriptive	[10]

Acronyms: 1st level interoperability types: OI – Organisational interoperability, KI – Knowledge interoperability; TI – Technical interoperability; 2nd level interoperability types: BS – Business strategy; RM – Relationship management; CI – Cultural interoperability; RI – Rules interoperability; HR – Human resources; PI – Process interoperability; DI – Data interoperability; SSI – Software and systems interoperability; OHI – Objects and hardware interoperability.

References: [1] - (ATHENA, 2007c); [2] - (ATHENA, 2007a); [3] - (Legner & Wende, 2006); [4] - (IDABC, 2010); [5] - (Zutshi, Grilo, & Jardim-Goncalves, 2012b); [6] - (ATHENA, 2005); [7] - (Tolk & Muguira, 2003); [8] - (Rezaei et al., 2013); [9] - (Sarantis, Charalabidis, & Psarras, 2008); [10] - (Dahmann & Salisbury, 1999); [11] - (IDEAS, 2003); [12] - (David Chen, Vallespir, et al., 2008); [13] - (Giller & Matear, 2001); [14] - (Ritter, 2007); [15] - (Guo, 2007); [16] - (Guo, 2008); [17] - (Legner & Lebreton, 2007); [18] - (NEHTA, 2005); [19] - (Gottschalk, 2009); [20] - (Wilson, 1995); [21] - (David Chen & Doumeingts, 2003); [22] - (Tolk, 2003a); [23] - (David Chen, 2006); [24] - (David Chen, Doumeingts, et al., 2008); [25] - (Whitman & Panetto, 2006); [26] – (Wende & Legner, 2006); [27] - (Greiner, Legner, Lippe, & Wende, 2007); [28] - (Elfving, 2007); [29] - (Mensh et al., 1998); [30] - (Koussouris & Lampathaki, 2011); [31] - (ATHENA, 2007b); [32] - (Yves Ducq & Chen, 2008); [33] - (Guédria et al., 2013); [34] - (Pazos Corella, Chalmeta Rosaleñ, & Martínez Simarro, 2013); [35] - (M. Camara, Ducq, & Dupas, 2010); [36] - (M. S. Camara et al., 2013); [37] - (Harmel, Bonjour, & Dulmet, 2006a); [38] - (Brunnermeier & Martin, 2002); [39] - (Razavi & Aliee, 2009); [40] - (Klischewski & Scholl, 2006); [41] - (Leite, 1998); [42] - (Morris et al., 2004); [43] - (David Chen & Daclin, 2007); [44] - (Lebreton & Legner, 2007); [45] -(ATHENA, 2007b); [46] - (Kasunic, 2001); [47] - (Daclin, Chen, & Vallespir, 2006).

A broader approach to interoperability characterization and measurement is provided by some of the qualitative methods introduced in section 2.5. In opposition to the criteria presented in Table 2.3, which are more issue-focused, interoperability levels and maturity levels present a transversal characterization of interoperability states. They cover several interoperability perspectives and represent the scaling-up in all the areas involved. The conveyed idea is that the improvements in interoperability must be well sustained in all the involved areas (IDEAS, 2003). Table 2.4 presents the found levels and maturity levels and the addressed interoperability type.

Table 2.4. Levels and maturity levels by interoperability type.

Designation	Level description	Interoperability type
Levels of information systems interoperability (DoD, 1998)	- Level 0: isolated - Level 1: connected - Level 2: functional - Level 3: domain - Level 4: enterprise	TI, DI, SSI
Levels of organisational maturity (Clark et al., 1999)	- Level 0: independent - Level 1: ad-hoc - Level 2: collaborative - Level 3: integrated - Level 4: unified	OI, TI
Degrees of interoperability (NATO, 2003)	- Degree 1: unstructured data exchange - Degree 2: structured data exchange - Degree 3: seamless data sharing - Degree 4: seamless information sharing	TI, DI
Levels of conceptual interoperability (Tolk & Muguira, 2003)	- Level 0: system specific data - Level 1: documented data - Level 2: aligned static data - Level 3: aligned dynamic data - Level 4: harmonized data	TI, DI, SSI
Maturity levels (ATHENA, 2005)	- Level 1: performed - Level 2: modelled - Level 3: integrated - Level 4: interoperable - Level 5: optimised	OI, TI, BS, PI, KI, RI
Levels of information sharing (NEHTA, 2005)	- Level 1: Non-electronic data exchange - Level 2: Machine transportable data - Level 3: Machine organised data - Level 4: Machine interpretable data transmission	TI, DI
Levels of Business Interoperability (ATHENA, 2007a)	- Level 1: none - Level 2: minimum - Level 3: moderate - Level 4: qualified - Level 5: fully interoperable	OI, BS, RM, HR, PI, TI, SSI, OHI

Acronyms: 1st level interoperability types: OI – Organisational interoperability, KI – Knowledge interoperability; TI – Technical interoperability; 2nd level interoperability types: BS – Business strategy; RM – Relationship management; CI – Cultural interoperability; RI – Rules interoperability; HR – Human resources; PI – Process interoperability; DI – Data interoperability; SSI – Software and systems interoperability; OHI – Objects and hardware interoperability.

Chapter 3 - The Design of Interoperable Systems

Achieving an interoperable system is a difficult task due to considering interoperability as an external factor or a consequence of systems instead of a requirement for effective and efficient IT-supported interactions. An effective design methodology should be provided to encompass the several interoperability issues, allowing equating between the business interoperability performance and the effective use of IT to support business.

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 et al., 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. That occurs, mostly, due to not considering interoperability as requirement but as a problem that needs to be solved every time a new business relationship is set up. The solution, though, is as complex as the concept of interoperability. Choosing a better software or system does not guarantee a quick solution to interoperability problems (J. J. S. Shang, Li, Tadikamalla, & Tadikamalla*, 2004). One needs to comprehend both the interoperability dimensions and the business context that rule the interactions.

In the previous chapter, inter-firms relationships and interoperability perspectives and criteria were explored, permitting a look in depth on different issues of business interoperability (BI). Although the focus of most of this research is problem characterization and quantification, each approach provides the rationale behind every interoperable decision to accomplish better interoperability conditions, having into account their impact in performance. That research clubs the interoperable systems design by establishing the main foundations of the interoperability problem. In this chapter, the objective is to explore methods to design interoperable systems, considering the interoperability perspectives and criteria, the main challenges, the knowledge assets and artefacts and what methodologies are fit to address the interoperable systems design.

3.1. The state-of-play in interoperable systems design

The 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 addresses the design of interoperable systems approaching the BI perspective.

In the development of the Business Interoperability Framework (BIF), (Legner & Wende, 2006) parted from an enterprise-centric vision and considered that BI performance is affected both by organisational and information systems design decisions. With that in mind, BIF was developed providing the knowledge base to comprehend BI, and the main decisions to accomplish in each level of interoperability. That is also true, not only to BIF, but to the other research articles referred in Chapter 2 as the basis for the BI decomposition and BI criteria. The qualitative methods provide the interoperability infrastructure and the influence map that each decision taken to achieve interoperability. Those decisions are portrayed as levels and maturity levels. Quantitative and performance measures focus on the impact in interoperability. Multi-criteria decision-making (MCDM) makes a decisional analysis that allows selecting alternatives. While, performance measurement methods add value by proposing metrics and influence maps to track the impact of interoperability. Those methods constitute guidelines to accomplish interoperable systems. Though, the common approach in these cases is to identify problems and provide means to solve them. The systematic design of the solutions or new systems is an issue that few articles address regarding the business perspective.

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 (David Chen, 2006) (see section 2.3.10), defending the position that the use of design principles to design interoperability is an alternative approach compared to holistic approaches (Dassisti et al., 2010). Hence, Dassisti et al. (2010) provides a set of 8 design principles acting on the underlying design principle:

"In the design process of a system it is possible, starting from the design solution found at a more aggregated level, to devise detailed design specifications of its components consistent with the overall system behaviour" (Dassisti et al., 2010).

The eight design principles encompass the interoperating companies and systems identification, the identification of reference frameworks for interacting patterns (in this case, SCOR for the SC's interactions), establish a meta-model and a decisional-model (using a GRAI[10] grid combined with SCOR), 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 the 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. Having its basis on an analysis perspective, the authors propose 5 main axioms: analysis axiom (AA), meta-modelling axiom (MMA), modelling axiom

[10] GRAI - Graphs with Results and Actions Inter-related

(MA), systemic axiom (SA), and interfacing axiom (IA). The first axiom (AA) serves to define the scope interaction, define actors' intrinsic features and study the main interactions that require improvement. The steps from MMA to MA are based on the identification of the main features that rule the interaction between actors by identifying reference models for interaction (in MMA) and translate it into physical interactions, by means of modelling (in MA). Systemic and interfacing axioms (SA and IA) detail particular cases of process models accomplished in MA. Process alignment and synchronization are some of the examples proposed by the authors for these axioms, as well as syntax and semantic alignments on the interface (IA).

This axiomatic approach encompasses the 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. 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. Although, the proposed model is problem-centred, 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 (see Figure 3.1) 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 (DSS), which consist in a PMS that acts at business, process management, knowledge, human resources, ICT and semantics perspectives.

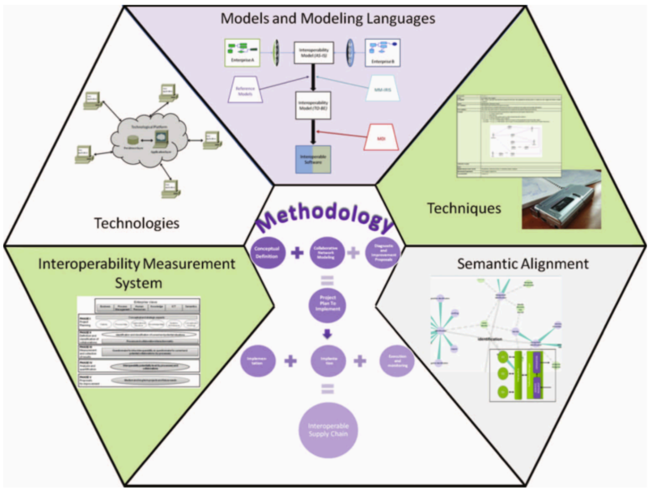


Figure 3.1. SCIF-IRIS framework (Pazos Corella et al., 2013).

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 specific problem-solution approach.

3.2. 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, organisations and strategies (Pazos Corella et al., 2013; Tolk, 2003a; F. B. 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. In chapter 3 the nature of interoperability issues was addressed, and is patent that it is an issue subject to be addressed in different fronts. 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-dependant. Organisations 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 organisations' 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.

3.3. Axiomatic design as a solution to design interoperable systems

The complex and multidisciplinary nature of BI requires a comprehensive method that can cope with the challenges enounced in section 3.2. Axiomatic Design Theory (AD) is the engineering design approach suggested in this thesis to deal with such attributes. Suh (1990) developed AD with the underlying hypothesis that there exist certain fundamental principles that govern a good design practice (Goncalves-Coelho, 2004a). Its objective is to enhance creativity, reduce result randomness, and minimize iterative processes in order to achieve the best design (Suh, 1990). What makes AD particularly fit to interoperable systems is that it makes possible to achieve a good design, keeping structural integrity of the system, allowing the systematic deepening on every functional aspects of the design. Design domains, axioms, hierarchies and the mapping process are features of AD that make possible to achieve the so-called good 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 (see Figure 3.2). 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).

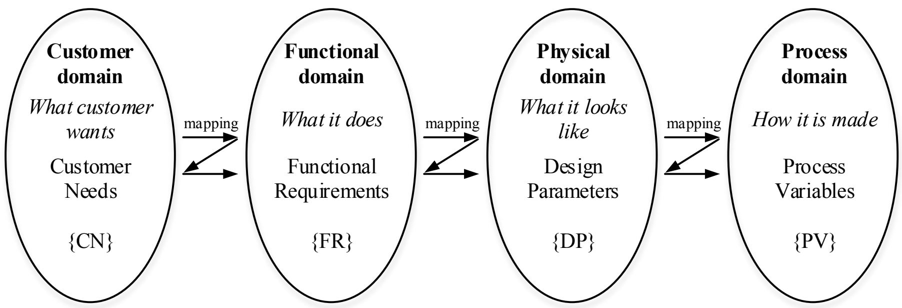


Figure 3.2. Lateral decomposition of Design Structure into Design Domains (adapted from (Brown, 2005; Goncalves-Coelho, 2004b)).

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). This process maybe called as zigzagging, or lateral decomposition, and is depicted in Figure 3.3.

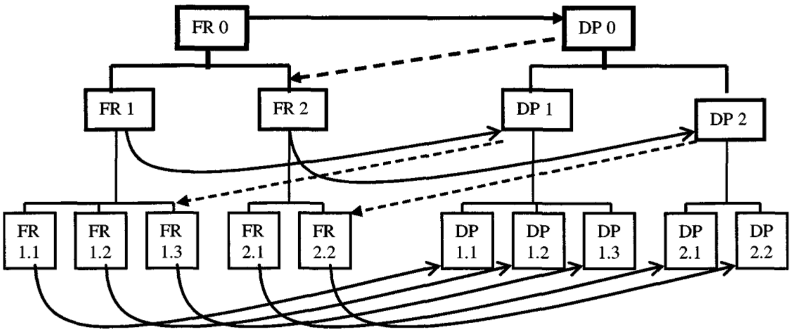


Figure 3.3. Process of zigzagging between design domains (Suh, 1990, 2001).

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). These axioms are stated as (Suh, 1990):

- *The Independence Axiom (axiom 1):* Maintain the independence of FRs.
- *The Information Axiom (axiom 2):* Minimize the information content of the design.

Good design solutions are the ones that conform to the independence axiom (Goncalves-Coelho, 2004a). During the mapping process, we must make the right design decisions using this Axiom (Suh, 2005). The stages of product design may lead to different solutions, represented by different sets of DPs for a certain hierarchy of FRs. In turn, there are three basic design types (see Table 3.1): uncoupled, decoupled and coupled design.

Table 3.1. Types of design matrix couplings (for a 3x3 matrix).

Types of coupling	Design Equation
Uncoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad (3.1)$
Decoupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad (3.2)$
Coupled design	$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix} \quad (3.3)$

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.
When several designs satisfy functionally the independence axiom, the information axiom can be used to select the best design (Suh, 2005). The information axiom states that one with the highest probability of success is the best design (Suh, 1998). Hence, the information content (I) is associated with the probability of satisfying a given FR (p) by equation (3.4).

$$I = -\log_2 p \tag{3.4}$$

The information axiom states that the design that has the smallest I is the best design, since requires the least amount of information to achieve the design goals (Suh, 1998). In counterpart, a design is considered complex if p has a value near zero, because if we need to provide much information to the system, the higher it is its complexity (Cavique, 2010).
The probability of success can be computed by specifying the design range (dr) for the FR, and by determining the system range (sr) that the proposed design can provide to satisfy the FR (Suh, 2003) (see Figure 3.4).

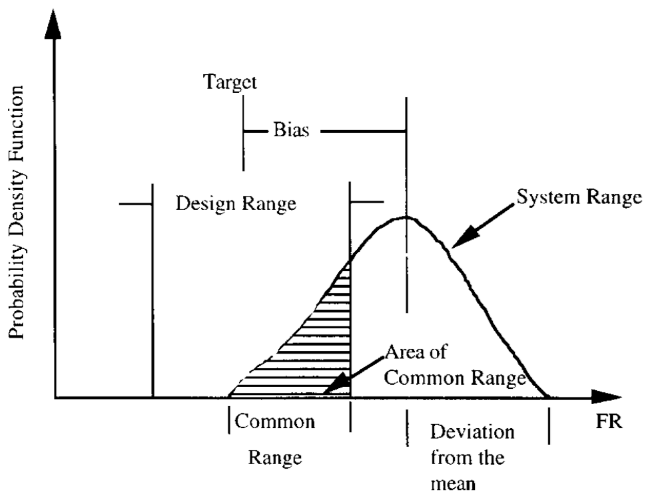


Figure 3.4.Design range, system range and common range in the plot of the probability density function (Suh, 1998).

The overlap between design range and system range is called common range (cr), and represents the region where the FRs are satisfied (Suh, 1998). The information axiom complements the independence axiom by providing a criterion to help making design decisions (Suh, 2005).
Additionally to axioms, design domains and mapping techniques, Suh (1990) provided theorems and corollaries. Those complement the definition of FRs, the mapping and the application of axioms by aiding in decision-making during the design.

Although AD is often regarded just as one more engineering design tool, the literature shows that it can be used to design business platforms of diverse kinds. According to Kulak, Cebi, & Kahraman (2010b), the main areas where AD is applied are product design, systems design, manufacturing systems design, software design and decision-making. Though, Suh (2001) emphasizes that every existing system may be designed using AD. The author provides its insights in addressing the context of customer, functional, physical and process domains in different application areas (see Table 3.2).

Table 3.2. Customer, functional, physical and process domains in different application areas (adapted from (Suh, 2001)).

Application area	Customer Domain	Functional Domain	Physical Domain	Process Domain
Manufacturing	Attributes which consumers desire	FRs specified for the product	Physical variables which can satisfy the FRs	Process variables that can control DPs
Materials	Desired performance	Required properties	Micro-structure	Processes
Business	Return of investment (ROI)	Business goals	Business structure	Human and financial resource
Organisation	Customer satisfaction	Functions of the organisation	Programs or Offices or Activities	People and other resources that can support the programs
Systems	Attribute desired of the overall system	FRs of the system	Machines or components, sub-components	Resources (human, financial, materials, etc.)
Software	Attributes desired in the software	Output specifications of program codes	Input variables or algorithms modules or program code	Sub-routines machine codes compilers modules

Interoperability problems are composed by organisational, knowledge and technical infrastructures, as well as inter-firm relationships and business-contexts that rule interactions. Hence, designs on interoperability point-of-view will have inherent complexity and multi-domain approaches. Therefore, BI design should feature business, organisation and system areas referred in Table 3.2, and the respective design domains. Also, the manufacturing systems design area fits the BI problems. Most process interoperability (PI) approaches are featured in this domain. Process improvements by means of Lean Manufacturing or process re-design are examples of AD applications that comply with PI. In BI literature there are missing articles in interoperable systems design that apply AD. Hence, some contributions to this area are found outside of BI body-of-knowledge.

One concern in designing in a multi-domain environment is the question whether we should make a single top-down design or several designs. Exploring the motivations for different design approaches, Thompson (2014) addresses conceptually this issue, referring that sometimes the design domains must be viewed as a continuum that extend beyond boundaries of the artefact (see Figure 3.5). The author refers to the example of product design with the intent to increase return of investment (ROI). ROI should be seen as an extrinsic feature of the product domain, belonging to the business domain. Hence, the business function should be seen as a feature outside the artefact characteristics. Business objectives drive the approach, but they don't provide the functionality for the artefact.

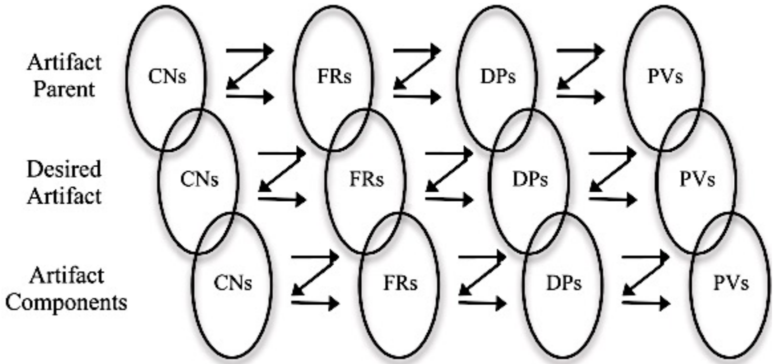


Figure 3.5. Design domains of an artefact, its parent systems and its components (Thompson, 2014).

The hypothesis that interoperability systems design should aim at several designs instead of a top-down approach is related to the difficulty some authors noted in creating general interoperability methods. With regard to interoperability measurement, T. Ford (2008) argued that this fact led to problem fracturing, instead of integrated approaches. That ultimately conducted to the different perspectives addressed in section 2.4, illustrated in Figure 2.22. In contradiction, authors (Legner & Lebreton, 2007) defend that we should aim at a systematic approach of strategic, organisational and operational issues. An integrated top-down design would permit to map issues since strategic issues to operational and technological aspects.

Another feature of interoperability systems design is the "as-is" to "to-be" benchmarking. Improving interoperability means that we come from an actual situation ("as-is") to a more desirable interoperability state ("to-be"). In terms of AD, we are coming from an existing design and develop an improvement of the current design. Park & Fallis (2007) addresses this situation, stating that the AD axioms should be applied in different situations: if the independence axiom is not satisfied, a new design should be made to satisfy the independence axiom; if the independence axiom is satisfied, DPs should be defined to minimize the information content (information axiom). AM Goncalves-Coelho (2004) provides an example to re-designing an existing design, emphasizing that, when addressing DPs to readjust a certain FR, one must change all the subsequently affected DPs and PVs. This re-design feature of AD is particularly useful to provide different interoperability solutions to a problem.

AD literature provides several applications to design improvements resourcing to the axioms. With regards to the independence axiom, decoupling methods are a common approach to achieve better design solutions. Helander (2007) applies the first axiom to reduce couplings and complexity in ergonomic systems. Nakao, Kobayashi, Hamada, Totsuka, & Yamada (2007) uses the same decomposition principles to establish rules to eliminate loops and feedbacks in an automated manufacturing, with the objective of reducing lead-time. Durmusoglu & Kulak (2008) addressed the design of office cells, focusing on the elimination of non-value added activities and the revision of the organisational structures, which ultimately led to a cooperative process model reducing lead-time.

In another AD literature segment, authors focus on the application of the second axiom to improve designs. Additionally to the application of the first axiom, Helander (2007) also applies the second axiom to compare the supplied range with the system range of microscope stations to determine which solution minimizes the information content and, therefore, should be the best design. Cavique & Gonçalves-coelho (2013) applies the second axiom to choose an HVAC[11] system for a datacom centre. A. M. Gonçalves-Coelho & Mourão (2007) exemplifies the application of the second axiom to select manufacturing technologies. Kreuzer, Nitsche, & Kantola (2014) uses the second axiom to choose a bicycle fork that complies with the bicycle body requirements.

In sum, 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 -, both axioms are compatible with the interoperability scope.

[11] HVAC – Heating, ventilating, and air conditioning

Chapter 4 - Modelling Interoperability

Modelling is a crucial task to represent interoperability problems. Existing modelling techniques allow this representation in informal, graphical and mathematical languages, portraying different aspects of interaction. Still, process and business process modelling portray a special part in interoperability, representing the core of business interoperability interactions. Adequate modelling techniques will allow determining interoperability points of improvement to obtain optimized interoperable scenarios.

The activity of modelling is an intrinsic feature if one attempts to represent a system or organisation. It consists of externalising company's knowledge and know-how, by representing the company in terms of its organisation and functions (activities, information, resources, organisation units, and system infrastructure and architecture) (F. B. Vernadat, 1996; Yahia, Bigand, Bourey, & Castelain, 2009). In the particular case of interoperability, Vallespir et al. (2005) affirms that interoperability modelling aims at answering the questions: "how to model the capability of a system to be interoperable?"; and "how to model several systems that are interoperating?". In Chapter 3, the multidimensional aspect of business interoperability (BI) was discussed, and it was patent that it is an issue subject to be addressed in several fronts. Accordingly, many existing modelling techniques represent the operation of companies from several points of view: functional, decisional, information system, and business process (Blanc et al., 2007). Though, in spite of interoperability literature providing contributions that fit most of these areas, there is still lack of consensus in what seems to be the appropriate modelling technique for each case. In the work from D. Chen & Doumeingts (2003), the authors concluded that there exists more than 300 modelling techniques and, still, they are weak in terms of representing dynamic roles, collaboration overtime and the support of situated processes.

From the several perspectives tackled in interoperability (see sections 2.4 and 2.6), processes portray a fundamental part in business interaction, since they are first in line when dealing with interoperability (Koussouris & Lampathaki, 2011). Processes work as the middle ground between top strategic and tactical management levels and resources (human and technical). With regards to business objectives, the processes are the core business function that permits companies to achieve certain outputs alone, internally, or together in inter-organisational relationships (ATHENA, 2007a). Operationally, processes correlate the business objectives and functions with resources. They strive to adapt the capacity of human and technical resources to the requirements of the networked enterprise (Dassisti et al., 2010). Two perspectives exist with regards to processes: internal and external. While internal processes are shaped according to specific needs of companies (David Chen, Doumeingts, et al., 2008), collaboration between companies forces internal business processes to interact to pursue common objectives that will be profitable for all the parts (Alfaro et al., 2009). In this sense, several approaches refer to external processes through different designations: public processes, collaborative business processes, extended business processes, collaboration process, inter-organisational process, cross-organisational business processes, interface processes, etc. (Alfaro et al., 2009; ATHENA, 2007a; U. Bititci, Mendibil, Martinez, & Albores, 2005; David Chen, 2006). Processes on the interface between companies are, mostly, an abstraction of the interaction between companies, regarded by ATHENA (2007a) as a "black box". According to these authors, formal establishment and documentation of interface processes are a requirement to achieve higher levels of BI. Process interoperability (PI) and business process interoperability portray a special part herein. These disciplines aim at aligning business processes of different entities, in order to conduct business in a seamless way. Still, at a wider scale, PI is correlated with other interoperability aspects. For instance, business strategy (BS) or relationship management (RM) affect PI but also depend on its efficient execution. In other hand, PI depends on effective information exchange (traduced by technical aspects as DI[12] and SSI[13]), technical (SSI and OHI[14]) and human resources (HR) as well as knowledge (KI) (see interoperability types in section 2.4). Existing interoperability modelling techniques allow depicting the operational perspective and how it affects strategic and tactical levels. For example, Business process modelling notation (BPMN) (OMG, 2011) provides a process-oriented approach to address business-specific processes. Unified Modelling Language (UML) (OMG, 2015) captures the same essence of business processes through a software-oriented approach and is used to assist in software development. GRAI[15] grids (D. Chen & Doumeingts, 1996) are one of the modelling tools found in interoperability literature to address decision making. Although the scope of the present work is to address interoperability types reviewed in section 2.4, the reviewed literature in interoperability modelling emphasized most of the attempts to address processes at the core of business interaction.

4.1. State-of-the art in interoperability modelling

In the scope of INTEROP project (addressed in section 2.3.10) several contributions were made with regards to interoperability modelling. Vallespir et al. (2005) reviewed different issues of interoperability that can be solved using enterprise modelling (EM) techniques, mapping interoperability domains and the adequate modelling techniques for each one. For DI (or communication interoperability), the authors suggest any data flow modelling techniques addressing syntactic and semantic issues. In turn, semantics issues are proposed to be address by means of ontologies or UML class diagram and knowledge by language modelling or UEML[16] (F. Vernadat, 2002). With regards to business process interoperability, the authors suggested two approaches: standardisation and mutual adjustment. To achieve those, the authors suggest business-oriented

[12] DI – Data interoperability
[13] SSI – Software and systems interoperability
[14] OHI – Objects and hardware interoperability
[15] GRAI - Graphs with Results and Actions Inter-related
[16] UEML – Unified enterprise modelling language

modelling languages for standardisation and synchronization issues. In this sense, the authors emphasize time aspects regarding synchronisation, and the specific cases of design and engineering, where interoperability issue can be addressed by decomposing methods into elements. The authors also made contributions regarding the modelling of business objectives and coordination, suggesting GRAI grids as an approach to express coordination links.

Blanc et al. (2007) suggest ontologies to address information exchange and EM for enterprise organisation, synchronisation and harmonisation of practices. The authors use an "as-is" to "to-be" benchmarking method to eradicate heterogeneity in SCs. Graph-based, GRAI and ECOGRAI grids are used to model organisational, semantic and material heterogeneity from and "as-is" to a "to-be" standpoint. The method is assisted by a PMS that assesses interoperability throughout the modelling process.

Y Ducq & Berrah (2009) combined the Supply Chain Operations Reference model (SCOR) (Supply Chain Council, 2010) with GRAI grids to address interoperability problems in supply chains. The use of the modelling techniques is assisted by a performance measurement system (PMS).

Dassisti et al. (2010) proposed an interoperability design method, using process and decisional modelling tools based on SCOR combined with GRAI grid. The modelling techniques support the establishment of meta-models that aim at a prior assessment of interoperability.

Dassisti & Chen (2011) proposed and axiomatic based approach to design interoperable systems. Through the several axioms, the authors suggest process-modelling approaches to detail the interaction between companies. Interoperability matrices and business process modelling are suggested as means to represent high-level models (in matrix and general business process models), and particular cases of interaction (e.g., synchronization of interface processes).

In the scope of ATHENA project, ATHENA (2007a) addresses process interoperability, with regards to the notion of collaborative business processes (CBP). Although the authors don't present an application of modelling techniques, they propose the use of standardised approaches like SCOR (for supply chains) and ODETTE (for automotive industry) for interface process establishment. The authors further suggest that semantic alignment should be performed during the interface modelling.

Yahia, Bigand, Bourey, & Castelain (2009) acts on the process interoperability perspective, and uses BPMN to propose supply chain patterns for international trading purpose. The authors recommend the use of BPMN as a process-oriented approach, in opposition to UML, which is adequate to software-oriented approaches. Still, recognizing the limitations of BPMN, which only aims at information and documentary flows, the authors propose addressing physical flows (goods, material, equipment) and financial flows.

M. Camara et al. (2010) proposes a methodology to evaluate interoperability performance, considering a business process modelling approach. The authors suggest that business processes may be decomposed according to business activities and interoperability activities. Interoperability activities are seen as non-value added (NVA) efforts to enable information exchange between partners. In M. S.

Camara et al. (2013), this methodology was implemented along with the use of Causal performance measurement models (CPMM) and business process simulation to assess the performance evolution from "as-is" to "to-be" scenarios, studying the impact of interoperability on the achievement of partners objectives.

Galasso et al. (2014) proposed a method to select interoperable options by means of BPMN combined with simulation. While BPMN is used to represent collaborative activities and network nodes, emphasizing operations sequence and flows, simulation has the purpose of measuring performance in current and improved scenarios.

4.2. Modelling contributions for supply chain processes and operations

Interoperability modelling literature provides several clues on how one should address processes, and further make a representation of the interacting organisations. The establishment of interface processes is a well-recognized aspect in firms' interoperation. Regarding business process interoperability, Vallespir et al. (2005) suggest standardisation and mutual adjustment of processes as means to synchronize the flow of products or services (see Figure 4.1). Standardisation provides means to avoid redundancy in activities such as quality control or order confirmation. The authors emphasize that this method benefits from the establishment of requirements for Enterprise Resource Planning (ERP) systems, and from the consolidation of common objectives and decisions through coordination.

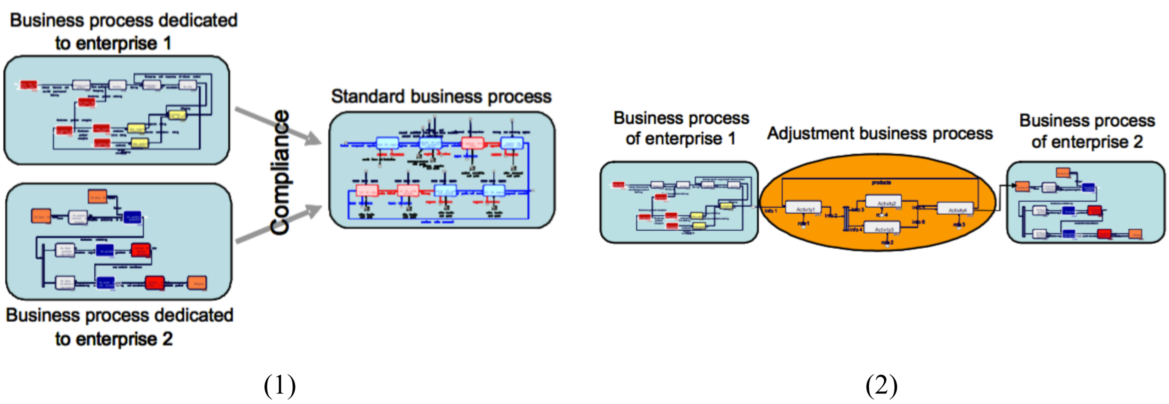


Figure 4.1. Standardisation (1) and mutual adjustment of processes (2) to establish interface processes (Vallespir et al., 2005).

The second approach consists in adding activities placed on the interface to make compatible distinct business processes. The advantage is not interfering in the business processes' structure and sequence. ATHENA (2007a) recommended multilateral agreements or public processes defined by the governing partner, whereas standardised approaches should aid the establishment of interface processes. In this scope, a common approach is found in interoperability modelling literature that acts on the supply chain context: the use of SCOR as a reference model. This one constitutes a business-specific interaction pattern which aids in SC process modelling (Dassisti et al., 2010). It provides a common framework and standard terminology settled in four main pillars: process modelling and re-engineering, performance measurements, best practices and people's training skills. SCOR encompasses three levels of hierarchy detail (see Figure 4.2): level 1, process types; level 2, process categories (configuration level) and level 3, process elements (decomposition of processes) (Drzymalski, Odrey, & Lehigh University, 2006). At the highest level (level 1), the SCOR model is organized around five business process types: plan, source, make, deliver and return (Supply Chain Council, 2010). This level defines the scope and content of the core management processes (Lockamy & McCormack, 2004). At level 2, or configuration level, the company is shaping its "as is" SC and the "to be" by implementing its operation strategies within the core processes: planning, execution and enable (Y Ducq & Berrah, 2009). Level 3 (decomposition of processes) processes describe the steps performed to execute the level 2 processes. The sequence in which these processes are executed influences the performance of the level 2 processes and the overall supply chain (Supply Chain Council, 2010). Inputs, outputs, description and the basic flow of process elements are captured at this level of the SCOR model (Lockamy & McCormack, 2004). Additionally, a forth level (implementation level) is provided by SCOR. Although SCOR acknowledges this level, this one lies outside of its current scope. According to (Supply Chain Council, 2010), organisations and industries should develop their own level 4 processes.

According to Y Ducq & Berrah (2009) the SCOR model is highly scalable and can be used to configure and improve the complete extended SC or only a small part of it. Proof of that, is that interoperability modelling literature either uses it as a reference for process modelling or combines with another modelling approaches. Yahia, Bigand, Bourey, & Castelain (2009) and M. S. Camara et al. (2013) addressed the modelling approach through BPMN. SCOR serves as a base model to identify and decompose into elementary activities. Yahia, Bigand, Bourey, & Castelain (2009) detail business process patterns to address SC, and extended the functionality of BPMN to address four flows:

1. The physical flows that correspond in practice to the flows of products going from the upstream of the logistic chain until its approval,
2. The information flows that encompass all the information exchanged between the actors of the studied system,
3. The financial flows that correspond to the fund transfers by means of checks or cash,
4. The documentary flows that are all the documents exchanged between the actors of the studied system.

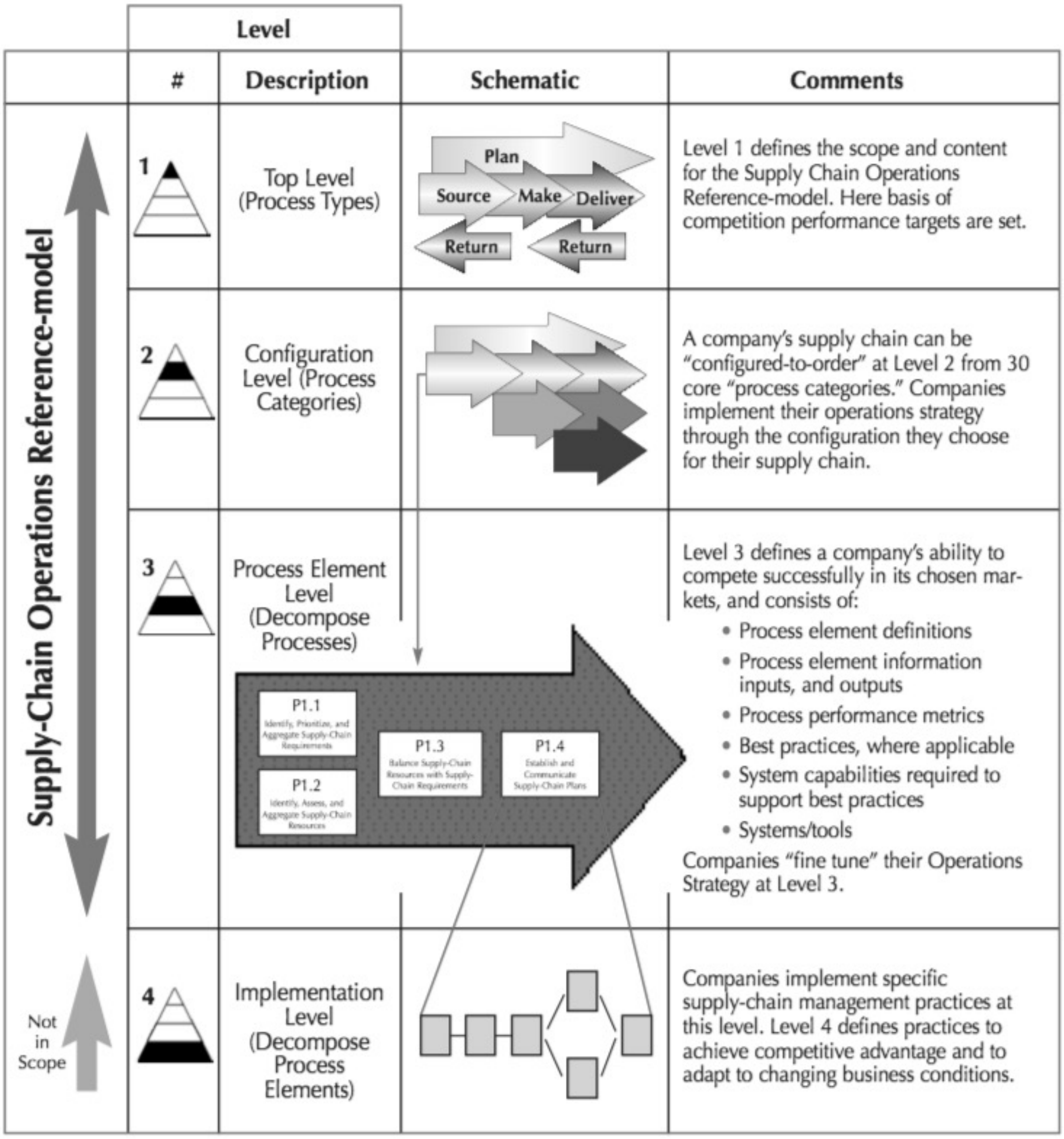


Figure 4.2. Supply chain operations reference model (SCOR) (Supply Chain Council, 2005).

M. S. Camara et al. (2013) used the same decomposition principle to distinguish business activities, which fulfil the purpose of SC, and interoperability activities or NVA. The authors studied how improvements in business process impact business at operational level, using business process simulation, and at strategic and tactical levels, studied by means of CPMM approaches.

The "as-is" to "to-be" benchmark is another common feature in interoperability modelling literature. Successive models represent the path between current and improved or optimized scenarios, resulting in business and technical specifications that allow achieving better interoperability. In the work of Blanc et al. (2007), for instance, it is proposed a method to study the evolution of interoperability in successive models with the objective of eradicating heterogeneity in supply chains and, consequently, improve interoperability.

The followed approaches in this thesis focus on business process modelling (by means of BPMN), process modelling using Design Structure Matrix (DSM) and simulation. Despite other perspectives of interoperability being considered as part of BI, aspects as BS, RM, HR, cultural interoperability (CI), DI, SSI and OHI are addressed by means of the Axiomatic Design theory (AD), introduced on Chapter 3. Still, findings on the interoperability modelling literature are incorporated in AD in order to aid in re-design of buyer-supplier dyads, as it is the objective of this research work. The main body of the methodology is the AD, and modelling techniques are used as an integrating part to convey a standard representation of business processes, which traduce the sequencing of operations and flows. The graphical notation of BPMN facilitates the understanding of the performance collaborations and business transactions between organizations (F. B. Vernadat, 2010). In turn, DSM is a system engineering tool that uses matrices to model and analyse complex projects, processes or systems (Browning, 2001). Its graphical nature of the matrix display format captures the structure of interactions, interdependencies and interfaces highlighting product elements and system's architecture (Eppinger & Browning, 2012; Stiassnie & Shpitalni, 2011). The applications in organisational and process modelling and associated optimization algorithms provide a helpful insight in addressing interoperability issues as process sequencing, and process and organisational alignment. Last, simulation of business processes aids in testing different scenarios, from "as-is" to a "to-be" optimized scenario. This last one can be improved using optimization methods such as Design of Experiments (DOE) or Taguchi methods.

Chapter 5 - Measuring Interoperability Performance

The notion that interoperability can be improved means that it can be measured. Though, in the context of firms' collaboration, interoperability performance measurement is characterized by a duality of technical and operational perspectives. Despite evolution in interoperability assessment, most contributions are grounded in technical measurements of interoperability, and in the use of industry-specific metrics to address interoperability impact at operational, tactical and strategic levels. To achieve value in the interoperation, performance metrics and methods should be provided to track how interoperability influences business relationships.

Performance measurement portrays a special part in interoperability assessment. While other assessment methods focus on qualifying and quantifying subjectively interoperability, addressing specific interoperability factors, performance measurement aims to evaluate how interoperability impacts a system as a whole. The main problem is that it isn't known a direct way to correlate the interoperability issues, or the companies' decisions, with the interoperability measurements (ATHENA, 2007b, 2007c; David Chen, Vallespir, et al., 2008; Yves Ducq & Chen, 2008). With regards to technical aspects of interoperability, the literature provides measures to assess systems performance. Though, the interoperability performance measurement is not only concerned with the technology aspect (IT systems) but also human and organisational ones (David Chen, Vallespir, et al., 2008). Measuring performance in BI pressuposes the notion of a business-context where interoperability problems are found. Performance measurement is a task that should be performed during companies' operation (Yves Ducq & Chen, 2008). Still, companies' current metrics implementation doesn't contemplate interoperability metrics. In one hand, business metrics present the operative, tactical and strategic levels of performance, and in the other hand, they miss the aspects that refer to interoperability. The common approach in literature is a hybrid mix of these aspects. For instance, M. S. Camara et al. (2013) uses supply chain management (SCM) performance metrics side-by-side with interoperability metrics as time, cost and quality of interoperation.

Research gaps on organisational and business interoperability literature are filled with findings beyond interoperability. Those measures include performance indicators (PI), key performance indicators (KPI), as well as, performance measurement systems (PMS) (e.g. Balanced scorecard, performance prism, ECOGRAI, IDPMS or QMPMS) and causal performance measurement models (CPMM) methods (e.g. balanced Scorecard strategy map, action-profit linkage (APL) or graph of decomposition) (Blanc et al., 2007; M. S. Camara et al., 2013; Y Ducq & Berrah, 2009; Yves Ducq & Chen, 2008). PMS provide us a set of metrics used to quantify both the efficiency and effectiveness of actions (Kaplan & Norton, 2005), while CPMMs are used to outline the specific path that a company will follow to achieve its strategy (Niven, 2002). Though, despite this methods being adaptable and may be used for several kinds of performance measurements and PIs, none of them are dedicated to measure interoperability performance (Yves Ducq & Chen, 2008; Galasso et al., 2014).

5.1. State-of-the-art in interoperability performance measurement

Research in interoperability performance measurement has been subject to evolution, addressed in different perspectives of measurement and applied to different kinds of interoperability (see Table 5.1). The main trends in literature are the following:

- **The proposal/use of technical interoperability metrics -** Early research proposes and uses metrics that fit technical perspectives of interoperability. These ones accompanied recent literature and have been applied in several different aspects of measurement.
- **Performance measurement as a complement to other methodologies** – Performance measurement is been used as a form to assess the development of a new system or as measure to assess during simulation of the real system, test and implementation or in operation.
- **Causal approaches** – Correspond to the mapping of interoperability conditions that have impact on performance.
- **Qualitative measurements combined with performance measurement** – Qualitative measurement are used to measure intangible interoperability factors accompanied by performance measures, which address tangible assets and already known metrics. Also, these two kinds of measurement are conciliated to address different stages of measurement. Qualitative serves conceptual and prior assessment phase of a system, mostly, due the fact that companies do not apply, currently, interoperability metrics. And performance measurement is used afterwards during testing or operation, with the implementation of interoperability metrics or a PMS supporting system.
- **"As-is" to "to-be" benchmark aided by performance measurement** – Performance measurement serves the purpose of assessing interoperability from the current system ("as-is") towards an optimized one ("to-be").
- **PMS** – Authors propose a PMSs to monitor interoperability performance during system testing and operation.
- **CPMM** – Approach used in the mapping of interoperability and operational conditions and their influence in tactical and strategic levels. The outlined paths serve as a decisional model to assess the influence of decisions in the performance.
- **Interoperability metrics with industry-specific metrics** – Operational and process interoperability approaches using the existing technical interoperability metrics and industry-specific (e.g. SCM metrics) to measure the influence of interoperability in the operational performance.
- **Inter-firm approaches** – Research that aims at measuring the performance between companies, in opposition to the common intra-firm performance measuring.

Table 5.1. Interoperability performance literature by type of approach.

Type of approach	Interoperability performance literature							
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Proposed/used of technical interoperability metrics	x	x	x		x			x
Performance measurement complements methodologies	x		x	x			x	
Causal approaches		x		x				
Qualitative measurements combined with performance measurement		x			x			
“As-is” to “to-be” benchmark aided by performance measurement					x			x
PMS					x	x		x
CPMM								x
Interoperability metrics with industry-specific metrics					x			x
Inter-firm approaches						x		

References: [1] - (Leite, 1998); [2] - (Sulton, 1999); [3] - (Kasunic, 2001); [4] – IIAM (ATHENA, 2007b; Lebreton & Legner, 2007); [5] – INTEROP (Blanc et al., 2007; David Chen & Daclin, 2007; David Chen, Vallespir, et al., 2008; Y Ducq & Berrah, 2009; Yves Ducq & Chen, 2008); [6] - (Alfaro et al., 2009); [7] - (Elmir et al., 2011); [8] - (M. Camara et al., 2010; M. S. Camara et al., 2013).

The earliest proposal to interoperability performance measuring was made by Leite (1998). As an integrating part of the Interoperability assessment methodology (IAM) (see section 2.3.3), Leite (1998) suggested six metrics that complement the assessment procedure: node connectivity, system overload, system underutilization, system overcapacity and data latency. Those act as intermediary measurements to achieve the appropriate target-level leading to an interoperable system.

Sulton (1999) developed a causal model to evaluate performance when changing interoperability factors. Factors are hypothesized to include policy, strategy, objectives, plans, requirements, rules, interfaces, specifications, standards, designs, tests, measurements, metrics, decisions, procedures, resources, technology, and training. For each factor, Sulton (1999) proposes that quantifiable metrics must be established. On the impossibility of using a quantifiable metric, Sulton (1999) suggests a proxy measure based on the probability of system success for specified interoperability levels, conditions and requirements, considering the interoperability failure rate in a project time.

Based on the findings from Levels of information systems interoperability (LISI) (DoD, 1998), Kasunic (2001) aimed at the LISI’s limitations and proposed the performance metrics developed by Leite (1998) to complement the LISI interoperability assessment process: connectivity, capacity, system overload, underutilization, undercapacity, data latency and information interpretation and utilization. Kasunic (2001) further recommended measures that act on standards, systems interoperability, operational interoperability and management.

The Interoperability impact analysis model (IIAM) (ATHENA, 2007b) (see section 2.3.9), complements the Business interoperability framework (BIF) (ATHENA, 2007a) by addressing value creation in a cost-based approach, tracking the impact of cultural, organisational and technical investments in the value chain. The performance measurement is made in a causal approach, named “strategy maps” (see Figure 2.17 in section 2.3.9), mapping interoperability investment and their direct and indirect interoperability impacts (Lebreton & Legner, 2007). The IIAM endorses the multidimensional assessment to investigate the value created by interoperability investments and determine their contribution to the competitive strategy of a firm (Lebreton & Legner, 2007).

In the execution of INTEROP (David Chen, 2006) (see section 2.3.10), several contributions were made in the past years that encompass organisational and technical interoperability performance measurement.

Based on the findings of INTEROP (David Chen, 2006) and Enterprise interoperability maturity model (EIMM) frameworks (ATHENA, 2005) (see section 2.3.7), D. Chen & Daclin (2007) proposed a barriers-driven methodology, which addresses interoperability improvement in an "as-is" to "to-be" approach, encompassing the stages: definition of objectives, analysis of the current system, solution selection, test and improvement. Complementary to this method, D. Chen & Daclin (2007) suggest three measurements: potential, compatibility and performance measurement. While the first two measure quality and quantify interoperability in systems during the conceptual stage, performance measurement is used in the operational stage, to evaluate the ability of interoperation between two cooperating firms (David Chen & Daclin, 2007). Criteria such as cost, delay and quality can be used to measure the performance with respect to barriers and concerns during a basic interoperation cycle (David Chen & Daclin, 2007).

Yves Ducq & Chen (2008b) detail the measurements proposed in D. Chen & Daclin (2007). Cost, time and quality of interoperation are adopted to measure the operational performance for interoperable systems (David Chen, Vallespir, et al., 2008). They apply this concept of performance measurement to organisational interoperability, proposing a method to measure the effort of organisational interoperability (see Figure 5.1), based on a GRAI grid and modelling approaches, the authors propose the performance measurement as means to improve organisational interoperability.

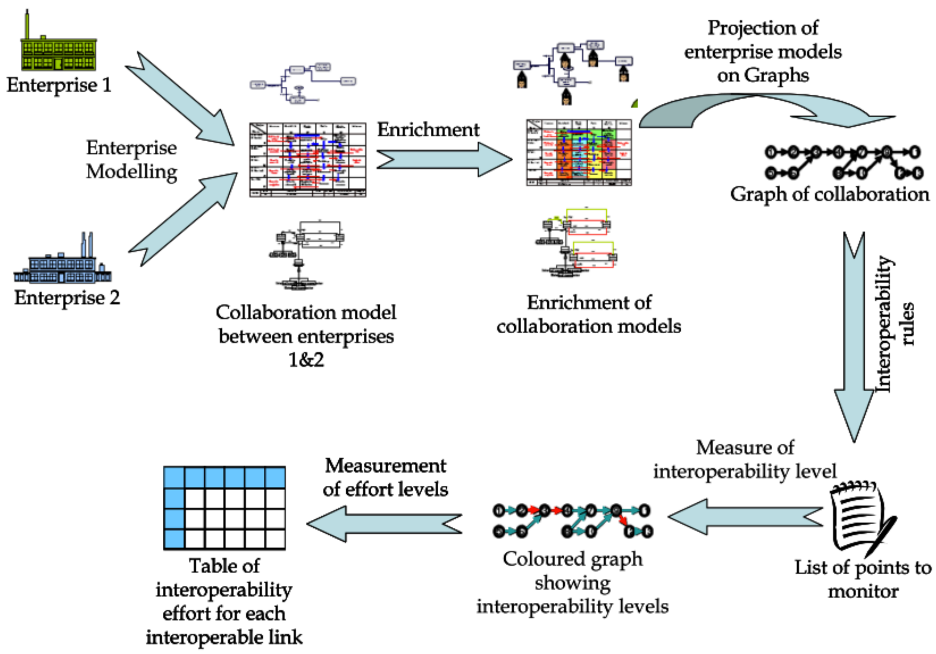


Figure 5.1. Global approach to measure effort for organisation interoperability (Yves Ducq & Chen, 2008).

Y Ducq & Berrah (2009) extended the approach to measure effort for organisation interoperability, to SCM by using SCOR and GRAI to complement SCM issues with interoperability. Also, proposed a PMS's software to aid in decision-making in the improvement and management of SC's operations. The system measures context-specific (SCM) metrics: overload for each partner/normal capacity, number of products produced in advance, supplementary capacity hours/total capacity hours, number of orders delivered on time / total number of deliveries.

Blanc et al. (2007) approached interoperability in SCM providing a method to improve interoperability at semantic and organisational levels, which aims and mitigating heterogeneity by tracking the evolution of systems towards the achievement of effective cooperation. Conciliated with ontology and enterprise modelling, Blanc et al. (2007) propose a performance measurement system that uses two different measurements: performance system to manage evolution (PMSE) and performance measurement system to manage the supply chain (PMSSC). The two measurements accompany different stages on interoperability improvement (see Figure 5.2). PMSE is readapted at the end of each step and is transformed into the PMSSC when the collaboration becomes effective (Blanc et al., 2007).

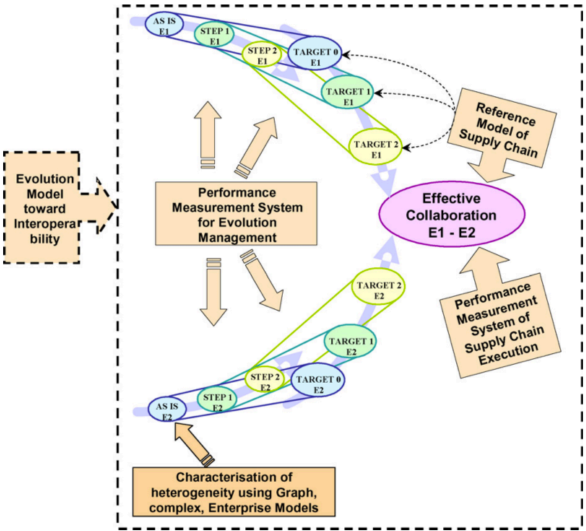


Figure 5.2. Method to solve heterogeneity (Blanc et al., 2007).

In the work from Elmir et al. (2011), it is provided an assessment method grounded in INTEROP findings. Additionally to interoperability potentiality, compatibility and performance measures, Elmir et al. (2011) suggests two additional tasks: delineating the scope of the study, and aggregating the degree of interoperability. Delineating the scope of the study is prior to the assessments, where the study focuses on macro business processes consisting in a set of sub automated processes in independent departments (Elmir et al., 2011). After implementing the INTEROP metrics, the aggregation of results is performed via arithmetic mean. This method serves to monitor business processes on e-Government context. These authors also suggest a meta-model and a software to calculate this metrics in real-time.

On the literature revision performed by Alfaro et al. (2009), the authors aimed at business process interoperability analysing the existing PMSs. Alfaro et al. (2009b) reinforced that performance should be measured both in intra and inter-firm perspectives, in the so-called extended or interface business processes.

M. Camara et al. (2010) suggest that interoperability can be assessed by the metrics: quality of exchange, connectivity, time of interoperation, data latency, cycle time, reliability and conformity.

M. S. Camara et al. (2013) propose an interoperability evaluation framework (see Figure 5.3), which aims to track interoperability impact in three layers: interoperability investment, operational impact and tactical and strategic impact layers. Using a business process approach, the authors propose to map the interoperability investments analysing elements located in the physical system (barriers, solutions for interoperability and collaborative business processes, and NVA activities). Operational objectives are measured on the operational impact layer by PIs and KPIs. Quality of exchange, connectivity, time of interoperation, data latency, cycle time, reliability and conformity are the suggested metrics (M. Camara et al., 2010). Tactical and strategic impact layer uses KPIs to measure the impact of interoperability in high-level objectives. A CPMM is herein used to map the influence on the partners' objectives, and a PMS is used to measure a mixture of interoperability and business-specific metrics.

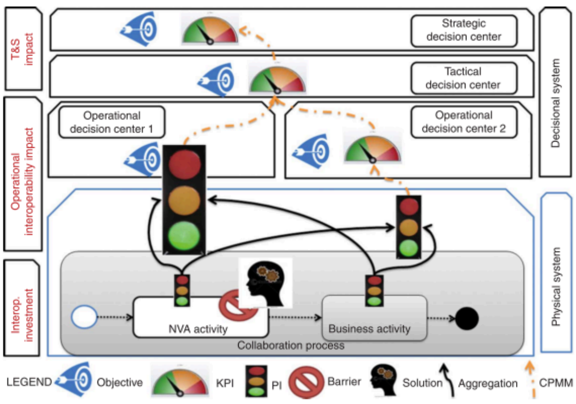


Figure 5.3. The interoperability evaluation framework (M. S. Camara et al., 2013).

The portrayed interoperability performance measurement works provide different approaches that permit addressing performance in systems at the operational, tactical and strategic levels. Though, despite their contribution, most of the provided interoperability measures are limited to technical interoperability. Those are resumed in Table 5.2.

Table 5.2. Interoperability metrics by dimension.

Dimension	Interoperability metrics	References
Time	Time of interoperation Request time Treatment of request time Return time Time of use	[1], [2], [3], [4], [5], [6], [7]
	Cycle time	[5], [8]
	Data latency	[5], [9], [10], [11]
Cost	Cost of interoperation Cost of information Exchange Cost to make information usable	[1], [2], [3], [5], [7], [12]
	Coordination costs	[8], [13]
	Control costs	[13]
	Connectivity costs	[8], [13], [14]
Quality	Syntax compatibility	[1], [15]
	Quality of interoperation Quality of exchange Quality of use Quality of conformity	[1], [2], [3], [5], [7], [8], [12], [14]
	Reliability	[14]
	Conformity	[2]
	Processability	[8], [14]
	Connectivity	[5], [9], [10], [11], [16]
	Capacity	[10], [11]
	Systems overload	[10], [11]
	Underutilization	[10], [11]
	Undercapacity	[10], [11]

References: [1] - (ATHENA, 2007c); [2] - (David Chen, Vallespir, et al., 2008); [3] - (Yves Ducq & Chen, 2008); [4] - (Pazos Corella et al., 2013); [5] - (M. Camara et al., 2010); [6] - (Razavi & Aliee, 2009); [7] - (M. S. Camara et al., 2013); [8] - (Lebreton & Legner, 2007); [9] - (Rezaei et al., 2013); [10] - (Leite, 1998); [11] - (Kasunic, 2001); [12] – (Daclin et al., 2006); [13] - (Legner & Lebreton, 2007); [14] - (ATHENA, 2007b); [15] - (David Chen & Daclin, 2007); [16] - (ATHENA, 2007a).

The provided metrics cover technical aspects as data interoperability (DI), and software and services interoperability (SSI). Organisational and knowledge interoperability metrics are lacking in literature. The inclusion of industry-specific metrics attempts to cover most of the operational aspects found beneath interoperation problems. Though, the problem in using them is that they are not fit to measure interoperability. At some point, they may reflect interoperability problems, but they do not serve as a measure of interoperability. In the next section this gap is explored for the measures that fit the supply chain operations common in the buyer-supplier dyads. With those, the objective is to address the operations that involve cooperation supported by IT, where the interoperability problems can be addressed and should be measured.

5.2. Supply chain performance measurement: contributions to interoperability performance measurement

In section 2.2.2, buyer-supplier dyads were reviewed establishing what are the main SCM constructs that rule such SC interaction. The constructs cover the collaboration aspects in terms of shared goals, relationship management, resource, knowledge sharing and information sharing. Sections 2.4 and 2.6 introduced the main attributes (BI types and criteria) of an interoperable relationship, which details organisational, knowledge and technical perspectives. To address performance measurement in interoperable buyer-supplier dyads one should consider both of these perspectives. In the previous section, interoperability performance measurement models were reviewed, having accomplished that works in this area are scarce and only cover technical aspects of interaction, despite the fact that it is known that interoperability is composed also from knowledge and organisational views. Hence, in the present section supply chain performance measurement (SCPM) is addressed in order to review the similarities with the BI body-of-knowledge and find out what attributes are adequate to measure performance.

The purpose of SCPM is the establishment of supply chain goals, supply chain performance evaluation and to determine future supply chain directions and activities (Gunasekaran, Patel, & McGaughey, 2004). Collaborative performance measurement (CPM) is one of the most recent approaches. In this perspective, company performance depends strongly on its ability to optimize relations with partners, suppliers or providers, to interface and to integrate its information system and decision-makings, and to synchronize its products flows and activities (Gruat La Forme, Genoulaz, & Campagne, 2007). While traditional approaches focus on the SC actors within themselves (Folan * & Browne, 2005), CPM focuses on extended processes, cross-organisational teams, integrated IT and knowledge sharing (Busi & Bititci, 2006). The vision is based on the same strategic fundaments as the buyer-supplier dyads in section 2.2.2, where the collaborative advantage is seen as a foundation for such unifying feature between SC companies.

5.2.1. Literature review in SCPM

Reviewed SCPM literature addresses the collaborative perspective as well as the following perspectives: alignment of performance metrics with business goals (e.g. BSC); intra and inter-organisational approaches (network, dyad and EE[17]); the use of SCOR; process-based performance measurements, featuring internal and extended processes; and the use of IT. Table 5.3 summarizes the contributions in the reviewed articles.

Beamon (1999) portrays the interacting perspective of SC, by considering three measurement dimensions: resource measurement and management, addressing the adequacy of resources for internal and customer needs; output measurements, which addresses internal and external issues like profit (internal) or on-time deliveries (customer focused); and flexibility, addressing the ability to respond to uncertainty.

Gunasekaran et al. (2001) and Gunasekaran et al. (2004) made an approach to performance measurements in SCs strongly grounded in the collaborative perspective, emphasizing on strategies as supplier partnerships, cross-functional teams, strategic alliances, and supplier evaluation. Accordingly, authors focus on: a balanced approach, suggesting financial and non-financial metrics appropriate for

[17] EE – Extended enterprise

strategic and operational measurements, respectively; the distribution in strategic, tactical and operational measurement levels; and the SCOR operations (plan, source, make and deliver). As a result, the authors proposed a framework that suggests metrics that fit those objectives, permitting to address ordering procedures, SC partnerships, production, delivery and customer service and satisfaction.

Table 5.3. Perspectives on supply chain performance measurement.

Perspectives of SCPM	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]
BSC-based			x	x				x	x						x		
SCC/Collaborative PM	x	x		x	x	x	x			x	x		x			x	x
Inter-organisational PM																	
Generic	x						x				x		x	x	x		
Network approach			x														
Dyadic approach					x							x					
EE PM								x	x								
SCOR-based		x	x			x				x		x			x	x	
Process-based			x	x							x		x				
Inter-enterprise processes/extended business processes											x						
IT-supported activities										x	x		x			x	
Metrics proposal	x	x		x	x			x		x		x	x	x	x		x
Proposed framework		x			x			x	x		x		x		x		

References: [1] - (Beamon, 1999); [2] - (Gunasekaran et al., 2004; Gunasekaran, Patel, & Tirtiroglu, 2001); [3] - (Bullinger, Kühner, & Van Hoof, 2002); [4] - (Chan, 2003); [5] - (I. J. Chen & Paulraj, 2004); [6] - (Lockamy & McCormack, 2004); [7] - (Schmitz & Platts, 2004); [8] - (Folan * & Browne, 2005); [9] - (U. Bititci et al., 2005); [10] - (Angerhofer & Angelides, 2006); [11] - (Busi & Bititci, 2006); [12] - (H Forslund & Jonsson, 2010; Helena Forslund & Jonsson, 2007); [13] - (Gruat La Forme et al., 2007); [14] - (Martin & Patterson, 2009); [15] - (Thakkar, Kanda, & Deshmukh, 2009); [16] - (Arzu Akyuz & Erman Erkan, 2010); [17] - (Vunjak, Buha, Zulfiu, & Tangiri, 2013)

Bullinger, Kühner, & Van Hoof (2002) proposes an approach addressing SC networks in an integrated performance measurement that combines network BSC with SCOR performance metrics. The integrated measurement system is accompanied by the modelling of the SC network, whereas SCOR operations are subsequently decomposed into processes that are implemented internally and externally with suppliers and customers. The BSC accompanies the logistics business objectives, while the metrics assess financial, customer, organisational and innovation perspectives in three developmental stages: functional, process and supply chain excellence.

Chan & Qi (2003b) also aimed at a collaborative approach to SCPM, referring that SC should be viewed as a single entity and managed as whole, whereas partners strive to achieve mutual goals. Accordingly, the author proposes a process-based approach where performance measuring is the ground for a continuous improvement philosophy. At its core considers the SC objectives, and sets the core processes and decomposes in subsequent sub-processes and activities. To support the process-based SCPM, the authors suggest performance metrics that Chan (2003) classified as quantitative (cost and resource utilization) and qualitative (quality, flexibility, visibility, trust and innovativeness).

I. J. Chen & Paulraj (2004) focuses on buyer-supplier dyads to address performance at two levels: supplier performance and buyer performance. On the supplier side, the authors propose quality, cost, flexibility, delivery and prompt response dimensions. On the buyer side, they ground performance measurement in financial performance. I. J. Chen & Paulraj (2004) argue that financial measures are most likely to reflect the assessment of a firm by factors outside the dyad's boundaries. The identified metrics encompass: time-based performance, such as delivery speed, manufacturing lead-time and customer responsiveness; financial performance, like return on investment (ROI), profit, present value and net income.

Lockamy & McCormack (2004) investigated the relationship between nine key supply chain management planning practices (planning processes, collaboration, teaming, process measures, process credibility, process integration, IT support, process documentation and process ownership) and four decision areas in the SCOR model (plan, source, make, deliver). The authors accomplished that collaborative practices have direct impact on SC performance.

Schmitz & Platts (2004) focused on a inter-organisational perspective and studied the implementation of supplier evaluation practices, addressing aspects as joint strategy formulation, information management, communication, decision-making, coordination and alignment, exchanged documents and learning. The authors concluded that most performance measurements are used as a communication tool (e.g. to communicate dissatisfaction) and that they affect the power structure, and authority (e.g. to leverage supplier action when faced with poor supplier performance).

Folan * & Browne (2005) contributed to inter-organisational performance measurement in specific case of extended enterprise (EE) performance measurement. The authors suggest a PMS based on BSC applied to internal, supplier, customer and EE perspectives. Each perspective is supported by a set of related performance measures.

U. Bititci, Mendibil, Martinez, & Albores (2005) also explores PM in EE, and proposes a model that acts at three levels: EE, business unit and business process levels. The application of the model is made in an inter-organisational perspective, mapping from strategic to operational coordination measures in scorecards for each enterprise involved in the EE relationships.

Angerhofer & Angelides (2006) proposes a collaborative approach to SCPM providing a model with a process approach based on SCOR and a PMS to measure collaborative performance. The authors consider the collaborative supply chain a result of six interacting elements: stakeholders, levels of collaboration, business strategy, processes, enabling technology and technology. For each element a set of performance indicators is proposed to assess it.

Busi & Bititci (2006) addressed the collaborative performance measurement (CPM) analysing existing SCPM literature to identify the main gaps in this research area. The author presents a framework for CPM, whereas this one is influenced by: enterprise collaboration, operations management and business process management, performance management and decision support, information and communication management, and organisational behaviour and knowledge management. The authors accomplished that, in order to develop and implement an effective CPM, SCPM research should aim at understanding internal and extended processes, what measures are adequate for collaboration, develop a structured management process and the specification of integrated/interoperable collaborative IT. The authors emphasize that collaborative business models involve: operational, technical and behavioural issues.

Forslund & Jonsson (2007) described performance measuring as a process that consists in five activities: selecting performance variables, defining metrics, target setting, measurement and analysis. The authors enforce that this process should be integrated in SC dyads. The successful performance measurement depends on the use of validated, measurable and sufficient detailed definitions of metrics, with clearly formulated targets and the use of standardised metrics found in SCOR (H Forslund & Jonsson, 2010).

Gruat La Forme, Genoulaz, & Campagne (2007) addresses collaboration in SC in IT supported interaction, being information sharing one of the factors that interlink companies. The authors propose two models: collaboration characterization model and collaboration-oriented performance model. The first one identifies the main processes internal, downstream and upstream the SC. In those, the authors propose maturity levels to assess the collaborative practices and the collaboration profile. The second model ties collaborative practices with performance metrics. The authors propose a radar diagram to represent the performance of each indicator to address the collaborative practices, and a collaborative profile to represent the process performance.

Martin & Patterson (2009) considered performance measures as inventory, cycle time and financials to study the impact of SC relationship with suppliers and customers through practices: organisational structure, partnering, supplier agreements and process improvements. The authors discovered that there were significant differences between firms that practice SCM, although the financial performance portrays no meaningless changes. Further, the authors also argued that while financial measurements are appropriate for strategic decisions, operational measurements are more fit for operational measurements.

Thakkar et al. (2009) aimed at a need to identify appropriate processes to design and implement SCM-based PMS by proposing an integrated SCOR-BSC (Balance score card). The authors proposed an integrated SCPM framework for small and medium scale enterprises (SMEs). Performance indicators were also suggested for supply chain processes: plan, source, make and deliver. These ones are distributed according to four BSC categories: customer service, finance and marketing, internal business and innovation and learning.

Focusing on integration, collaboration and the use of IT, Arzu Akyuz & Erman Erkan (2010) reviewed the existing SCPM literature addressing the use of IT, business process management and the proposal of performance metrics. The authors advocate the vision that maturity models should be supported by SCOR in order to enable benchmarking. Also, they suggest that metrics should be developed to assess the IT suitability in SC.

In a study motivated by the equality of the use of effectiveness and efficiency performance metrics, Vunjak et al. (2013) concluded that SC's companies are focusing on offering value to customers, which is strongly correlated with the increasing degree of trust amongst partners and the use of qualitative metrics. Efficiency metrics encompass quality and visibility (delivery time, accuracy in operations and cycle time) and flexibility and trust (consistency and reliance on partners) dimensions; while, effectiveness suggests customer responsiveness metrics (ability to accommodate special or non-routine requests and ability to handle unexpected events).

In the reviewed literature, good practices for SCPM are found regarding the collaboration in SCs. At a global perspective, three management levels should be addressed: strategic, tactical and operational. Strategic level measures influence on the top level management decisions, tactical level deals with resource allocation and operational level measurements assess the results of decisions of low level managers (Fauske, Kollberg, Dreyer, & Bolseth, 2006; Gunasekaran et al., 2004). Due to the high coverage of BI regarding companies' interaction, these three levels are appropriate to capture the different implications of performance. SCPM should balance between financial and non-financial measures (Chan & Qi, 2003a; Gunasekaran et al., 2004). Martin & Patterson (2009) further emphasize that financial performance is adequate to assess strategic decisions and, non-financial measures support operational measures.

At the top management level, the performance measurement is also strategic and essential because most companies realize that SCM needs not only to be assessed for its performance but also SCM processes must be well-defined and controlled (Azevedo, Carvalho, & Cruz-Machado, 2011; Gunasekaran et al., 2004). Hence, performance measurement should be aligned with the overall strategy of the supply chain (Fauske et al., 2006). Arzu Akyuz & Erman Erkan (2010) stresses that since many measurement systems lacked strategy alignment, companies have difficulty in systematically identify the most appropriate metrics. Therefore, the measurement system should make relationships between objectives and decisions (Kaplan & Norton, 2005; Martin & Patterson, 2009), providing feedback whether the objectives have been met, and inform about which areas need improvement (U. S. Bititci, Carrie, & McDevitt, 1997; Thakkar et al., 2009; Vunjak et al., 2013). Approaches in this perspective attempt to map performance towards objectives using BSC approach (U. Bititci et al., 2005; Bullinger et al., 2002; Chan, 2003; Folan * & Browne, 2005; Thakkar et al., 2009).

The application of SCOR model is defended as a good practice for SCPM. At its core, the SCPM should have the ability to capture the essence of organisational performance (Gunasekaran et al., 2004). SCOR provides an opportunity to include measure that capture the performance of activities in SC (Thakkar et al., 2009). Arzu Akyuz & Erman Erkan (2010) defends that it provides a standardised look to SC processes, and emphasizes process-orientation, instead of functional orientation. From the reviewed work, SCOR-based PM is frequent and often combined with another approaches. Contributions in this field (see Table 5.3) provide measures that are process-oriented easy to capture the operation context. Arzu Akyuz & Erman Erkan (2010) further recommends the development of performance measurement systems based on SCOR in the form of maturity models, in order to enable benchmarking and assess the suitability of IT in SCM. Considering the existing contributions in interoperability regarding maturity and interoperability levels, this recommendation is well fit to address performance on IT-based processes and tasks that may be subject to automation.

Another perspective portrayed in most process-based SCPM's is the focus on internal and external processes. Authors Alfaro et al. (2009) and Thakkar et al. (2009) stress that the assessment should focus on internal and linkage with external partners. Performance is seen as a result of not only a single firm but of all members involved (partners, suppliers, etc.) (I. J. Chen & Paulraj, 2004). Holmberg (2000)(cited by (Busi & Bititci, 2006)) defends that single-firm management approaches when managing collaborative enterprises are likely to obstruct partners' integration. Hence, the preferred approach to SCPM in collaboration is made by addressing dyads, networks, the entire supply chain; and in approaches to external processes, such as collaborative business processes, extended enterprise (EE) and virtual enterprise (VE) contexts.

Last, an effective SCPM for buyer-supplier dyads should be a managerial tool that aids in pinpointing areas that require improvement (Fauske et al., 2006). Gunasekaran et al. (2004) consider that the metrics that are used in SCPM and improvement should be those that truly capture the essence of organisational performance. They should provide information about what issues are faulty in dyad operation and should enable appropriate decision-making (Fauske et al., 2006). The lack of appropriate SC metrics may lead to issues as sub-optimization of the organization performance and conflicts within the SC (Azevedo et al., 2011; Lambert & Pohlen, 2001). The ultimate goal is to achieve operational excellence, meaning that companies are able to execute operations and service in an efficient manner (Algren & Kotzab, 2011).

In sum, the good practices for an adequate SCPM to address interoperable buyer-supplier dyads, and general collaboration in SC, are the following:

- Distribute metrics in strategic, tactical and operational management levels;
- Align the SCPM to overall business strategy;
- Use SCOR as a reference to standardised processes;
- Approach dyads, networks and the full SC;
- Focus on intra and inter-organizational processes;
- Combine SCOR with maturity models to benchmark IT adequacy;
- Provide metrics to measure IT suitability;
- Capture the essence of the organisation;
- Provide relevant metrics;
- Provide a managerial tool.

5.2.2. Performance metrics for interoperable buyer-supplier dyads and SC collaboration

In the addressed SCPM literature authors provide or use performance metrics that operationalize the performance measurement in the different context of buyer-supplier dyads and overall SC collaboration. The relevant dimensions to approach interoperability in these contexts aim at business relationships and operations perspectives. Business relationship metrics refer to the supplier and customer performance measurement. These ones assess aspects such as delivery performance, trust, reliability, quality, etc., which refer to partnerships' health. The operational perspective refers to the SCOR processes in two distinct standpoints: internal business and customer service. Internal business refer to the inside perspective of processes and resources allocated to enable material flows in the dyad, while customer service address the visible process that interact with the business partner (for instance in the context of sourcing and delivery). In turn, operations performance is presented in two dimensions relevant for interoperability: process performance and information processing performance. Process performance refers to time, quality or flexibility of operations internally and in the interaction between peers. Information processing performance addresses the cost, quality, time and flexibility of information-based processes. From the reviewed articles, the metrics were organised according to strategic, tactical and operational management levels and operations perspective in a similar method to Gunasekaran et al. (2004). Table 5.4 presents the relevant performance metrics that address such perspectives.

Table 5.4. Performance metrics for interoperable buyer-supplier dyads and SC collaboration.

SCOR operation	Perspective/process	Metrics	Reference
Strategic			
Plan	Economic performance	Information processing cost	[1], [2]
	Internal business	Order lead-time	[1], [2], [3], [4]
		Total cycle time	[1], [2], [5], [6]
		Accuracy of documentation	[7]
		Accuracy of operations	[6]
	Business relationships	Trust (consistency)	[6], [7]
		Level of collaboration	[8]
		Level of strategy alignment	[9]
		Supplier evaluation	[1], [2]
Deliver	Internal business	Effectiveness of enterprise distribution planning schedule	[1], [2]
	Customer service	On-time delivery	[1], [2], [3], [4], [6], [7], [8], [10], [11], [12]
		Order fill rate	[3], [4], [7], [10]
Tactical			
Plan	Customer service	Customer query time	[1], [2], [4], [6], [10]
	Internal business	Order entry methods	[1], [2]
		Human resource productivity	[1], [2]
Source	Business relationships	Supplier delivery performance	[1], [2]
		Supplier lead-time against norm	[1], [2]
		Promised lead-time	[11]
		Supplier booking procedures	[1], [2]
	Internal business	Efficiency of purchase order cycle time	[1], [2], [12]
		Accurate orders	[12]
Deliver	Customer service	Flexibility of service system to meet customer needs	[1], [2], [4], [6], [10], [12]
		Flexibility for urgent orders	[6]
		Customer complaints	[3], [6], [10]
		Customer order path	[1], [2]
	Internal business	Effectiveness of enterprise	[1], [2]

SCOR operation	Perspective/process	Metrics	Reference
		distribution planning schedule	
		Effectiveness of delivery invoice methods	[1], [2]
	Business relationships	Delivery reliability performance	[1], [2]
Operational			
Plan	Internal business	Order entry methods	[1], [2]
		Human resource productivity	[1], [2]
	Economic performance	Information processing cost	[1], [2]
Source	Internal business	Efficiency of purchase order cycle time	[1], [2], [12]
		Accurate orders	[12]
Make	Internal business	Human resource productivity	[1], [2]
Deliver	Customer service	On-time delivery	[1], [2], [3], [4], [6], [7], [8], [10], [11], [12]
		Percentage of urgent deliveries	[1], [2]
		Information richness carrying out delivery	[1], [2]
	Internal business	Effectiveness of delivery invoice methods	[1], [2]
		Number of faultless delivery notes invoiced	[1], [2]
	Business relationships	Delivery reliability performance	[1], [2]

References: [1] - (Gunasekaran et al., 2004); [2] - (Gunasekaran et al., 2001); [3] - (Chan, 2003); [4] - (Gruat La Forme et al., 2007); [5] - (Martin & Patterson, 2009); [6] - (Vunjak et al., 2013); [7] - (Thakkar et al., 2009); [8] - (Folan * & Browne, 2005); [9] - (Angerhofer & Angelides, 2006); [10] - (Beamon, 1999); [11] - (Helena Forslund & Jonsson, 2007); [12] - (H Forslund & Jonsson, 2010).

Comparing these SCPM metrics with the interoperability metrics in Table 5.2 (section 5.1), there are similarities with some of the advocated concepts under the time, cost and quality of interoperation dimensions (e.g. time of interoperation and customer query time). In both bodies-of-knowledge there are some shared attributes that can be used to approach interoperable buyer-supplier dyads. Also, were interoperability performance measurement fails to address the business-context, SCPM literature provide means which may comply with interoperability perspectives. Table 5.4 presents the metrics that look at the interacting perspective of dyads in SC that cover BS, RM, PI, KI, HR and DI interoperability perspectives discussed in sections 2.4 and 2.6. The use of these complementary attributes allow one to address interoperation in SC dyads in order to support assessment, design and operation activities, looking at the different perspectives of interoperation beyond technical issues.

Chapter 6 - The ADADOP method

To carry out research, based on literature findings, in this chapter are described the methodological steps and decisions that guided through the answering of the research questions. The first contributions aimed at the business interoperability body-of-knowledge, which is considered unstructured. In that sense, knowledge systematization is proposed in order to apply it to the design, modelling and performance measurement of interoperable buyer-supplier dyads. In the last part, a contribution is made to solve the research problem, by providing a method to analyse and re-design the buyer supplier dyads.

6.1. Theoretical framework for interoperable buyer-supplier dyads

The framework presented in Figure 6.1 supports the establishment of effective and efficient interoperable buyer-supplier dyads. This relationship is settled on the collaborative advantage, which is enforced by win-win relationships, mutual benefits and competitive synergy achieved in the dyad as a whole, instead of competition between firms. The aim of the interoperable dyad is to achieve optimal interoperability, traduced in improved performance and increased value to customer. The dyad is, hence, focused on the final customer, whereas interoperability is seen as a service that delivers value added, distinguishing companies for their attractiveness and technology leadership, allowing cost reduction that, in turn, strengthens relationships helping them become competitive.

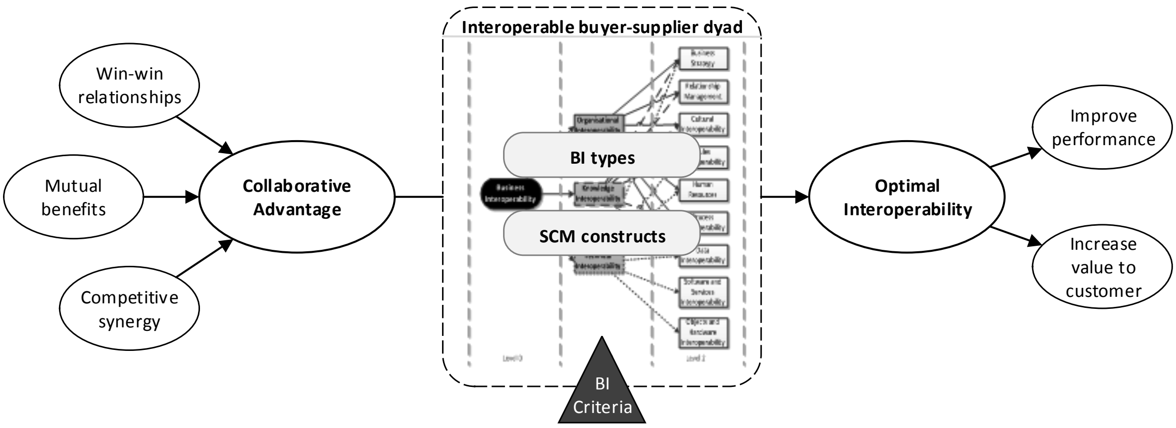


Figure 6.1. Framework for business interoperability impact in buyer-supplier dyads.

The progression from the strategic foundations to the impact that BI has on the dyad's performance is represented in the framework, and the scope of action of the proposed method acts on how to achieve the adequate configuration of the BI perspectives that deliver optimal values of interoperability, in opposition to perfect (or maximum) interoperability. These BI perspectives and related SCM constructs act as the driving force that establish the ground for interaction between firms at different levels from business strategy to the technology that supports the business interactions. Decision-making in each of those perspectives is crucial for their effective an efficient execution permitting to accomplish optimal interoperability. Though, the complexity of the interactions rules out the possibility of a direct connection between interoperability perspectives and the impact BI has on the dyad's performance. Problems in cooperation are affected by lack of interoperability in each of those perspectives, and BI criteria permit to characterize those problems and attempt to map the issues that have impact on performance. The higher proposition of this thesis aims at interconnecting interoperability issues in a systematic manner so one can identify the ones that require improvement, and limit interaction, in order to accomplish a considered interoperable buyer-supplier dyad, which features higher performance and value created.

The first proposition aims at the existing distinct frameworks and models that attempt a classification of interoperability issues. These ones address interoperability in different perspectives and different levels of detail. The taxonomy of BI perspectives and types was the proposed approach to accomplish the systematization of the BI body-of-knowledge (BoK). In section 2.4 this BI decomposition was explained, whereas is proposed that BI can be addressed in two levels of detail: the first level, in organisational interoperability (OI), knowledge interoperability (KI) and technical interoperability (TI); and, the second level, in business strategy (BS), relationship management (RM), cultural interoperability (CI), rules interoperability (RI), human resources (HR), process interoperability (PI), data interoperability (DI), software and services interoperability (SSI), and objects and hardware interoperability (OHI). While this BI perspective decomposition aids in the mapping of issues in literature, its purpose herein is to provide the reasoning for decision-making in each perspective. In subsequent propositions, the decomposition rationale is used to relate BI perspectives, business-context, criteria and performance metrics, which are represented in the methodology through an axiomatic design (AD) framework.

Still in the scope of detailing interaction and classification of interoperability issues, SCM literature was revised regarding the subject of supply chain collaboration (SCC) and, in the particular case of the thesis object: the buyer-supplier dyads. SCM literature acts on the same strategic foundations, proposing collaborative practices or constructs that share similarities with the BI perspectives and criteria addresses in sections 2.4 and 2.6, respectively. In Table 6.1 is proposed an alignment of those constructs with the corresponding BI perspectives.

By existing an analogy with regards to buyer-supplier dyad's interaction in SCM and BI literature, the use of those constructs is suggested, considering them fit to provide a business-specific context for the BI perspectives and criteria. Those ones retain the business attributes that act in the same scope as BI. Still, the constructs lack covering some aspects addressed in BI. The proposition herein is to extend buyer-supplied dyad's knowledge base, not only covering the collaborative practices, but also refer to strategic, relationship management, processes and resources (human and technical) that act as the driving force for interaction. Those are reflected in supply chain (SC) operations, decision-making, criteria and performance measurement that, in turn, will aid in addressing material and information flows, as well as the information technology (IT) that supports the SC activities.

Table 6.1. SCM practices and constructs correspondence to BI perspectives.

SCM construct/practice	BI perspective
Strategy alignment	BS
Incentive alignment	BS, RM
Buyer-supplier financing alignment	BS, RM
Contractual clauses	BS
Mutuality/mutual benefits	BS
Strategic sourcing	RM
Supplier evaluation systems	RM
Supplier involvement	RM
Supplier-base reduction	RM
Long-term relationships	RM
Governance/power distribution	RM
Monitoring	RM
Cross-functional teams	RM, PI, HR
Joint relationship effort	RM
Trust	RM
Resource sharing	RM, PI, SSI, OHI
Cultural issues	CI
Joint knowledge creation	KI
Knowledge sharing	KI
Information sharing	DI, SSI, OHI
Collaborative communication	SSI, OHI

Acronyms: BS – business strategy; RM – relationship management; PI – process interoperability; HR – human resources; SSI – software and services interoperability; OHI – objects and hardware interoperability; CI – cultural interoperability; DI – data interoperability.

The classification and assessment of interoperability is another proposition to decompose further the buyer-supplier dyad. If, in one hand, the BI perspectives and SCM constructs present the matrix of interaction between firms, in the other hand, the BI criteria and methods (see sections 2.5 and 2.6) act as a second proposition, allowing determining how interoperable firms and systems are in those BI perspectives. The criteria suggested in section 2.6 are arranged in BI perspectives to convey the adequate aspects in which those perspectives can be addressed. The use of each one depends on the type of classification or measurement portrayed. As was reviewed in section 2.5, the main trends in interoperability measurement fit the categories qualitative and quantitative. In turn, quantitative approaches are subdivided in indirect and direct, through performance measurement and simulation. In the context of the proposed method, the types of measurement are qualitative and performance measurement using simulation. Another types of assessment were discarded due to the use of AD to convey the dyad's interoperable conditions. BI criteria aids in providing the rationale to determine how interoperable firms are, and how far they are from the highest conceptual level of interoperability. Later on, the objective is to model the interaction and simulate it to accomplish the impact of those interoperability conditions in performance.

In Figure 6.2 are represented the BI perspectives, the main BI criteria and the SCM constructs that are addressed in the buyer-supplier dyad's interaction context.

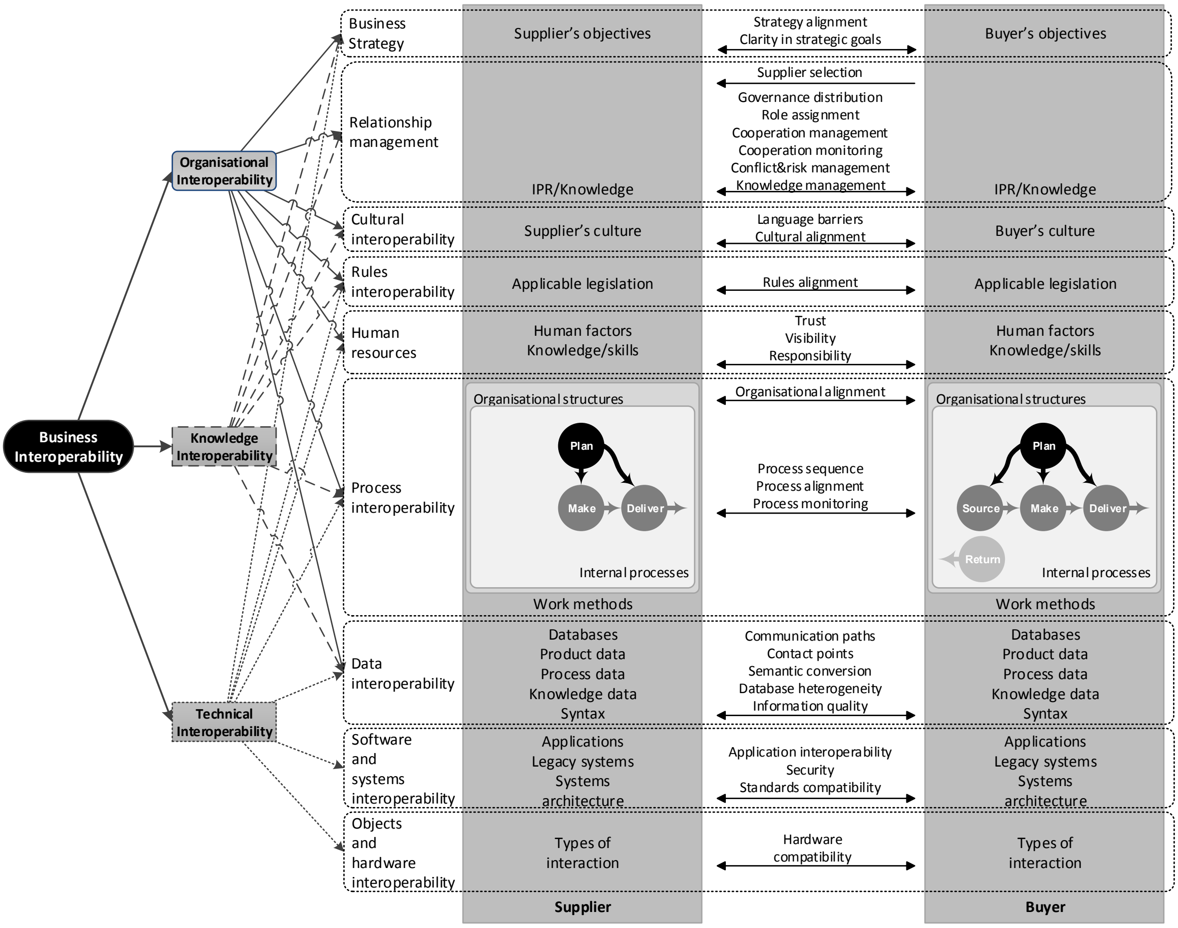


Figure 6.2. Representation of the buyer-supplied dyad in the main BI perspectives, BI criteria and SCM constructs.

This structured decomposition allows mapping the BI issues raised in the business set-up. The top-down layers (from BS to OHI), represent the different areas in which interoperation can be addressed. Regarding the interaction between buyers and suppliers, four main points of view exist: the individual supplier and buyer perspectives, the interface, and the dyad as a whole. The decisions taken place in those perspectives help us to set an interoperability profile, which features the characteristics that make the dyad unique with the specific interoperability properties that will result in a more or less interoperable scenario. BI criteria and contextual SCM constructs characterize those decisions at the different BI perspectives and in those four points of view. In section 6.2.2 the qualitative characterisation is explained, whereas levels are proposed to characterize the interoperability settings each dyad could aim towards the adequate degree of interaction. They are proposed in scale, referring to lower and higher levels of interoperability, which can fit different objectives in the interoperation.

Still, the underlying proposition herein contradicts the proposition of IDEAS framework (introduced in section 2.3.5). In IDEAS framework is proposed that, to achieve BI, is required to be achieved interoperability in all the layers of interoperability (business, knowledge and ICT[18] systems). The defended position regarding this aspect is set on the notion of optimal versus maximum interoperability, posing that certain interoperability conditions may permit to achieve the optimal level of interoperability, resulting in better performance outcome than the maximum levels of interoperability, achieved in every BI perspective. In the proposed method, this position is enforced to determine the required interoperability conditions to achieve optimal performance and, in the case of intending to scale-up interoperability, what decisions are required, and what interoperability conditions provide higher performance and value creation that the current dyad's interoperability conditions.

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

6.2. The ADADOP method to analyse and re-design interoperable buyer-supplier dyads

The framework in Figure 6.1 and the representation of the dyad in Figure 6.2 into BI perspectives, criteria and SCM constructs represent, conceptually, the empirical proposition of this thesis. This multidisciplinary framework embodies the strategic fundament and the BI considerations that one should attend to obtain optimal interoperability in buyer-supplier dyads. In order to fulfil the objectives of this thesis, the second part of the research is concerned on how to systemize the design of this dyad to improve performance and value created. Accordingly, in chapters 3, 4 and 5 was reviewed the state-of-the-art in design, modelling and performance measurement in interoperability. Those areas are the ones proposed to make the link between interoperability conditions and the impact they have on the buyer-supplier dyad's performance.

The methodological approach to establish the link between the interoperability conditions and the dyad's performance is given in Figure 6.3. Here is proposed the ADADOP method, which stands for A+D stages, AD framework and Optimisation Procedure, applied to analyse and re-design

[18]ICT - Information and communication technology

interoperable buyer-supplier dyads. In this method, is proposed a two stages model encompassing the determination of the buyer-supplier dyad's BI conditions - first stage - and the optimization procedure - second stage -, to accomplish an optimally interoperable dyad.

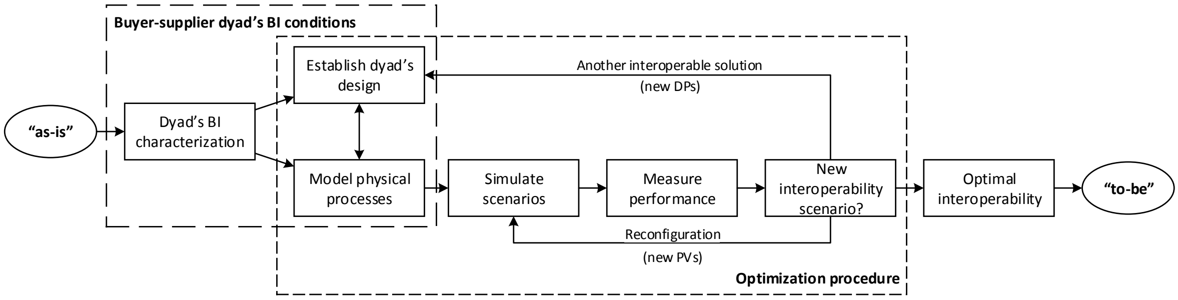


Figure 6.3. The ADADOP method to analyse and re-design interoperable buyer-supplier dyads.

The overall process is accomplished by an "as-is" to "to-be" benchmark, which aims at identifying BI conditions, tracking the influence of BI perspectives in one another, set the modelling implications on the physical processes, simulate those processes, and an iteration procedure, from conceptual to process levels of design, allowing to accomplish the interoperable conditions or new interoperable design solutions, which will, in turn, permit achieving the optimal interoperability in the dyad.

The first task is to characterize the dyad's BI conditions. This one is achieved by a qualitative assessment of each of the BI perspectives and characterized by the BI criteria. Both firms are assessed for those items, and it is determined to which degree they are interoperable in each perspective. Afterwards, the procedure to determine the dyad's BI conditions is followed by two complementary tasks: the establishment of the design and the modelling of physical processes. The dyad's design is accomplished by establishing an axiomatic design (AD) framework, which contains the required information to characterize the dyad, as well as, to convey the functional requirements, physical and process implications of the interoperation. The AD provides the main attributes in which the dyad was decomposed, portraying the relationship between those in design matrices. For each interoperability requirement (functional requirement – FR), an interoperable solution (design parameter – DP) is provided which, in turn, relies on process variables (PVs) that allow the dyad to interoperate. Certain interoperability aspects are addressed in qualitative terms, and are kept documented in the AD framework. Examples of those are the business strategy (BS), which has no direct implication on the physical model. Still, the relationships portrayed in the AD framework allow identifying which of those BS conditions (for instance, business agreements between firms) had impact on dyad's interface processes. In counterpart, interoperability issues passible of being documented in the physical model are represented in the modelling task. There is a synergy between the AD framework and the process, business process modelling and simulation approaches. While the AD framework may be fit for conveying the process attributes, the complexity of the interoperation processes, and the associated resources (represented in SSI, OHI and HR); the representation in terms of FRs, DPs, PVs and design matrices would require that theories and data to support those ones. Without theories or practical data, additional documentation is required to support solution space to interoperability requirements. The existence of modelling approaches allows to convert some of the issues in BI to the physical perspective, which is addressed in DPs and PVs. Hence, the modelling activity has the objective of representing the BI issues, supporting the AD framework on the physical space. With this last task, it is accomplished the process of characterizing the buyer-supplier dyad's BI conditions. The qualitative aspects of interoperation are converted into interoperability requirements, to which correspond an interoperable decision (or solution) that, in turn, has representation on the physical dyad. This first stage allows moving into the second phase: optimize the dyad's interoperation.

The second stage of the ADADOP method - optimisation procedure - is accomplished by considering the existing dyad's conditions to devise interoperable solutions, or new configurations, that enhance the interoperability by improving performance and increase value. From the physical model obtained on the first stage, a simulation model represents both the interoperable solutions (DPs) and the PVs that support the interoperable system. The simulation aims at determining the influence that the BI conditions have on the dyad's performance. Accordingly, performance metrics matching the SC operations should be selected. In turn, the next forwarding task is to devise new scenarios that match the interaction profile of the dyad, and attempt improving interoperability. Those can be of two natures: reconfiguration of the existing interoperable solutions, or the proposal of new solutions. Scenarios that that comply best with the 1st axiom and deliver better performance results should be considered as means to improve the buyer-supplier dyad. The implementation of the selected scenario ("to-be") consists on applying the interoperable solutions and associated PVs that provide optimal values for dyad's performance.

6.2.1. Stages of analysis and decomposition (A+D stages)

To determine the dyad's BI conditions 15 stages, called A+D stages, are suggested to accompany the process of analysing interoperability conditions and the subsequent modelling. To keep the integrity of the dyad, the A+D stages have the purpose of guiding through the assessment and modelling with as much detail as necessary to comprehend the BI issues. The objective is not an exhaustive approach to each issue, but, to keep track of each BI perspective, basic information is registered to allow plotting conditions that may have influence on the dyad's interoperation. In this approach, the objective is to maintain the basic functionality of the dyad, translated in the 9 BI perspectives, and detail the ones that are relevant for the improvement procedures.

The analysis (A) and the modelling (D) stages provide the sequence to study interoperability in the 9 considered perspectives. The procedure is process oriented, whereas early stages (BS, RM and RI) provide the main guidelines for processes, the subsequent stages, referring to resources (HR, SSI, OHI and CI), are associated to specific processes. Hence, the first four stages are:

1. **Business Strategy Analysis (BSA)** – The first step consists in the identification of the cooperation objectives to verify if these ones are clear for both actors, and to what extent the strategy is aligned with individual objectives.
2. **Relationship Management Analysis (RMA) -** In this setting it is relevant to assess at which depth the companies made the selection and management in the initiation and in the cooperation duration, respectively. This assessment will permit to identify premature flaws in cooperation by missing a competencies revision and the appropriate management of the cooperation in its duration.
3. **Relationship Management Decomposition (RMD) -** The second part of the RM refers to the level of detail needed to understand the cooperation termination, cooperation monitoring, the allocation of roles and responsibilities to processes and activities, and the ways to mitigate conflicts.
4. **Rules Interoperability Analysis (RIA)** – Here it is relevant to analyse if there are incompatible business rules and country and continental legislation. These rules constrain the business cooperation, processes and the resources (IT and HR) used.

The considerations from those tasks set the main considerations for the business set-up in the conceptual form. Objectives, the form relationships are managed, and the rules each partner have to obey set the needs and constrains for the business processes both have to place internally and in the interface. Hence, the next tasks refer to the processes, which starts with the identification and modelling and, then, the assessment of those processes with regards to their interoperability. These two tasks are cited as follows:

5. **Process Interoperability Decomposition (PID)** –Hence, individual and interface process identification, sequencing, and monitoring are addressed here using modelling and supply chain practices implementation in order to study which aspects drive the cooperation towards better effectiveness and efficiency.
6. **Process Interoperability Analysis (PIA) -** After decomposing the processes, is suggested assessing the alignment, visibility and the adequacy of the organisational structures to the processes. Process and organisational alignment are criterions that are both addressed in qualitative and modelling form.

Adjacent to each business process, resources (human and technical) exist to enable those processes. For that reason, the BI perspectives DI, SSI, OHI, HR and CI are addressed with regards to the business process they are associated to. The A+D stages associated with these ones are the following:

7. **Data interoperability decomposition (DID)** – This stage is related with the information flows present in PID. Here is relevant to identify the knowledge, process and product data (contents and formats), communication paths, contact points and communication procedures.

8. **Data interoperability analysis (DIA)** – In this matter the objective is to assess the data exchangeability in terms of syntax and semantics, quality and database interoperability, as well as, the communication paths and contact point's definition.
9. **Software and Systems Interoperability Decomposition (SSID)** – In this stage is proposed to identify the systems used in processes and in data exchange.
10. **Software and Systems Interoperability Analysis (SSIA)** – For each information interface, assess application interoperability, security, and standards are assessed.
11. **Objects/Hardware Interoperability Decomposition (OHID)** – Along with the decomposition of processes, is proposed the designation of the type of interaction and the devices used (for instance, electronic labelling, communication devices, etc.).
12. **Objects/Hardware Interoperability Analysis (OHIA)** – In the physical part of technical interoperability, is proposed to assess the hardware compatibility, the connectivity, and the security of the networks.
13. **Human Resources Decomposition (HRD)** – The decomposition of this issue is also related with PID. It is necessary to distinguish the tasks that are performed by HR from the ones that are processed electronically.
14. **Human Resources Analysis (HRA)** – Each employee associated with an IT-based business activity is assessed with regards to human factors, knowledge and skills for IT. Employee efficiency is a result of aspects as human factors, trust and another motivational features, as well as the skills they possess to perform the tasks.
15. **Cultural Interoperability Analysis (CIA)** – In this subject, is proposed the assessment of two dimensions of business: the culture of the company and the communication perspective of culture (language). Due to employee cultural differences, this task is associated with HR instead of the firm as a whole. While company policies may establish that some languages and cultural rules may be a requirement, the cultural identity is seen as a feature of the individuals that perform interoperation, and interact with another employees of the partner firm.

The A+D stages are the first tasks suggested to tackle the buyer-supplier dyad's BI characterization. After the dyad's BI characterization, two activities are proposed (see Figure 6.4): establish dyad's design and modelling of physical processes. The AD framework supports the information from the A+D stages. Data is registered in FRs, DPs and PVs, and the dependencies are documented in matrices. Those represent the path from functional to process levels of the design. In turn, physical processes represent the physical implications of the interoperability conditions tracked through the A+D stages and the design process. The next three sections address the establishment of the dyad's design and the modelling of physical processes in three perspectives: the qualitative assessment of buyer-supplier dyad (A stages) (section 6.2.2); the establishment of the dyad's design (AD framework) (section 6.2.3); and the modelling implications on the physical processes (D stages) (section 6.2.4).

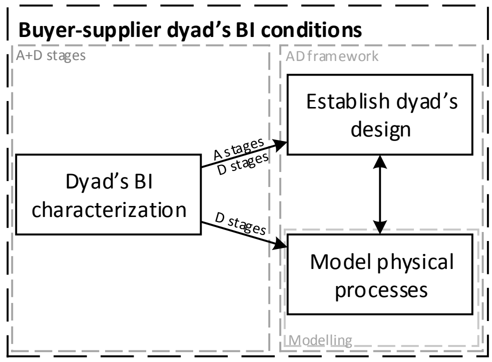


Figure 6.4. The scope of the A+D stages in the buyer-supplier dyad's BI characterization.

6.2.2. Qualitative assessment of the buyer-supplier dyad (A stages)

The proposed qualitative assessment serves to describe buyer-supplier dyad's interoperability conditions and to qualify them conceptually. The level representation is to represent the current interoperability conditions and the subsequent steps firms need to perform in order to increase higher interoperability.

The first principle to apply when analysing and decomposing a dyadic relationship is to assess the business strategy (BSA). Like stated before, it is intended to verify if the partners are aligned in the same objectives, if they are clear and to what extent the objectives are defined. On the organisational perspective of Business Strategy (BS), issues like business goals identification (BS_1) and clarity (BS_2), and business strategy alignment (BS_3) in dyad are relevant to assess. The objective of assessing BS_1 is to verify how well defined are the objectives for each actor of the dyad. For the assessment of the BS_2 (Clarity in Business Goals) criterion, a qualitative scale called "Levels of clarity in business goals" is proposed. Business strategy alignment (BS_3) refers to the assessment of both companies in what concerns the individual objectives alignment.

Still in the assessment of BS_1, it is proposed to identify which objectives were established. For this case, a checklist of objectives is proposed for each of the supply chain operations. These agreements encompass several other BI components rather than only the BS ones: service-level agreements (e.g. production objectives, lead-time, etc.) role assignment, terminology, IT agreements, costs and penalties.

On the knowledge interoperability (KI) perspective of BS, this one concerns with the knowledge assets exchanged between the actors and its protection against information disclosure. On the business strategy definition, is considered that knowledge assets and intellectual property may be previously agreed upon, establishing a contract that specifies the deliverables, the technical specifications exchanged, and the penalties in case of unauthorized use of this assets.

Last, in the technical interoperability (TI) perspective of BS, the agreement in security issues (BS_6) is addressed, establishing the security requirements and the level of authorization and access to information. In Table 6.2 a scale evaluation of 5 degrees is proposed for each of these three BS aspects.

Table 6.2. Levels to evaluate business goals definition (BS_1), clarity in business goals (BS_2), and strategy alignment (BS_3).

Criterion	Level of Interoperability				
	1	2	3	4	5
BS_1 *Levels of goals definition*	Not established (Ad-hoc planning)	Verbal contract	Signed contract with the conditions specified by the governing company	All the objectives and ground rules were previously agreed upon	All the competencies and capabilities were discussed in order to establish a win-to-win situation
BS_2 *Levels of clarity in business goals*	Not defined/not clear	Frequent failures in cooperation	Occasional failures in cooperation due to ill-defined objectives	Clear to both parties. All ground rules agreed and communicated	Comprehensive review of competencies
BS_3 *Levels of strategy alignment*	Isolated	Occasional ad-hoc partnering	Established partnership without strategy alignment	Partners share the same business strategy	Regular review of competencies (fully aligned)

The second step in the application of the A+D is the relationship management assessment (RMA) in the dyad. On the organisational perspective, RM concerns the activities that involve the initiation and the duration of the relationship. The first issue that arises is the partner selection (RM_1). However, in the present methodology, only it is assessed on-going cooperation, rather than another cooperation stages such as initiation or termination. Therefore, the reason to assess RM_1 is to verify the depth of the selection before the cooperation has begun, permitting to identify premature flaws on cooperation by lacking an appropriate selection mechanism. The cooperation duration is assessed by RM_2 and RM_3. In the first one, is verified if the actors meet to review progress and competencies (in terms of frequency), and the duration of the relationship. In RM_3, the objective is to verify which metrics the buyer and the supplier implement to monitor the dyad. In chapter 5 performance metrics were suggested to address interoperability in buyer-supplier dyads.

Roles and Responsibilities (RM_4) is a criterion that is both assessed and decomposed. With regards to the assessment, is proposed to verify if the actors consider that the roles and responsibilities are well defined or if there are many responsibility gaps leading to conflicts and problem occurrence. RM_6 concerns the power distribution on the dyad, addressing if both companies have the same power in decision-making or if one takes the decision that will rule the cooperation since beginning until its termination. Knowledge management is not considered an issue that requires further assessment for the purposes of this model. These two address also the new knowledge generation, integration and dissemination along the dyad. However, it was considered that assessing the Knowledge Skills (RM_9) is more appropriated to identify if the cooperating companies have the needed skills to work with each other, and if they have training programs with the business partners. Last, the competencies revision

(RM_{10}) issue is presented here, but is also portrayed in BS_3 and RM_3. It is considered that strategy alignment presupposes that companies speak openly and review regularly the competences. Hence, although this issue is presented in KI-RM, is closely related with BS_3. In Table 6.3 are presented the levels to evaluate each one of the referred RMA criteria.

Table 6.3. Levels to evaluate partner selection (RM_1), cooperation realisation management (RM_2), roles and responsibilities (RM_5), relationship power distribution (RM_7), and knowledge skills (RM_8).

Criterion	Level of Interoperability				
	1	2	3	4	5
RM_1 *Levels of partner selection*	None. Selected the first available company for partnership	Recommended by other companies (word of mouth)	Selection of a certified supplier	Technical capabilities and resources where reviewed, lower costs, etc.	Broad assessment of competencies (know-how, business scale-up, long-term relationship commitment)
RM_2 *Frequency of meetings to review progress and competencies*	Never – only when we established the contract.	Once per year	Once per Month	Once per week	On a daily basis
RM_2 *Relationship duration*	Short-term		Mid-term		Long-term
RM_5 *Levels of roles and responsibilities definition*	Poorly-defined. Too many responsibility gaps, leading to frequent conflict occurrence. ("Pass the buck syndrome")		Defined, but needs improvements. Occasional conflicts occur		Well-defined. The responsibility and roles assignment is not an issue.
RM_7 *Levels of power distribution in dyad*	Unilateral distribution. One of the partners is the governing company, and its decisions will have direct influence its partners.		There is a governing company, but partners cooperate in decision making.		Equal power distribution. Both companies have the same power of decision-making.
RM_8 *Levels of partner knowledge skills*	Our partner lacks knowledge and skills to achieve benefit.		Appropriate skills to perform the cooperation.		Our partner as the appropriate knowledge and skills to perform activities and scale-up this relationship.

Rules interoperability assessment (RIA) is the last stage before process interoperability. The identification of internal business rules and applicable national and cross-borders is suggested to verify if there is incompatibility of those between the supplier and the buyer in the dyad. The scale in Table 6.5 is suggested to assess the degree of rules and laws compatibility.

Table 6.4. Levels to evaluate rules compatibility (RI_1).

Criterion	Level of Interoperability				
	1	2	3	4	5
RI_1 *Levels of rules compatibility*	Incompatible. There exist overlapping rules between companies	Compatible. Business rules were discussed between partners	Rules follow the legislation in force	Rules imposed by contract	Business rules and laws are totally compatible.

After assessing how the business was set-up in the BS, RM and RI aspects, process interoperability (PI) is the BI aspect that follows. In its assessment (PIA), the objective is to identify on-going processes, internally, within the firms, and externally, on their interface. Process alignment (PI_4) and organisational alignment (PI_2) are the suggested qualitative measures to determine if responsibility assignment is well-performed (internally and externally) and if there is an efficient distribution of tasks matched with organisational sections (see Table 6.5).

Table 6.5. Levels to assess process alignment (PI_2) and organisational alignment (PI_4).

Criterion	Level of Interoperability				
	1	2	3	4	5
PI_2 *Levels of organisational alignment*	Inefficient activities distribution (Many tasks for one sector or many sectors for one task)		Functional distribution. A sector for each process/activity		Responsibility assignment and distribution well defined
PI_4 *Levels of process alignment*	Poorly aligned / Too much responsibility gaps resulting in conflict and problem occurrence		Well-aligned but with occasional problems		Well-aligned and visible to both partners / Responsibility is not an issue

Processes performed internally and on the interface are supported by data exchange. Data interoperability assessment (DIA) has the objective of determining how well this exchange is performed. At the organisational level, the assessment concerns with communication paths (DI_1), and contact points (DI_2) and information quality (DI_7). In the technical interoperability (TI) perspective, is proposed the assessment of semantic conversion (DI_4), heterogeneous databases (DI_5), and communication quality (DI_6).

In Table 6.6 are presented the respective levels to assess those criteria.

Table 6.6. Levels to assess communication paths (DI_1), contact points (DI_2), semantic conversion (DI_4), heterogeneous databases (DI_5), communication quality (DI_6), and information quality (DI_7).

Criterion	Level of Interoperability				
	1	2	3	4	5
DI_1 *Levels of communication paths definition*	Not defined / Communication is carried out case-by-case in several forms of ICTs	Poorly defined / Although exist several communication channels, additional contacts are required to solve a problem	Defined / there is a standard procedure for regular communications	Well-defined / Standard procedure for regular communications and alternative procedures to deal with exceptions	Preventive / Standard procedure for regular communications, alternative procedure to deal with exceptions and contingency plans to deal with communication failures
DI_2 *Levels of contact points definition*	Not defined / There were no defined responsibilities and our partner not properly communicates the personnel changes	Poorly defined / The responsibilities were defined, but our partner does not communicate the personal changes (e.g. vacation, job changes, etc.) occurring delays	Defined / The contact points have been defined		Well-defined / All changes in the section responsible are notified in advance
DI_4 *Levels of data conversion*	0	<10%	<20%	<30%	<40%
DI_5 *Levels of data exchange*	Manually we work in isolated databases, and data is exchanged manually		Electronically / We have separate databases but exchange data electronically	Domain level / We share the same data repository, but use different applications	Enterprise level / We share the same data repository and applications
DI_6 *Levels of communication speed*	Very slow / the ICT is inefficient to fulfil the business needs	Slow / The waiting time due to the resolution of the problem affects the performance of my company reflected in delays and cost	Average / Satisfies the needs but, occasionally, additional contacts are required	Quick / Requests are solved in useful time, not causing inconvenience to the company	Proactive / The application is carried out with minimal human interaction, being placed just in the information system. All the necessary information for decision-making is provided and only has to wait for resolution of the problem.
DI_6 *Frequency of failures*	Never	Once per year	Once per Month	Once per week	On a daily basis
DI_7 *Incorrect information percentage*	0	<10%	<20%	<30%	<40%
DI_7 *Information delays percentage*	0	<10%	<20%	<30%	<40%

The PI and DI perspectives present the flows (process and data) that are set inside and outside the firms to interoperate. Software and services interoperability (SSI), objects and hardware interoperability (OHI) and human resources (HR) compose the resource side of those flows. With regards to SSI assessment (SSIA), technical aspects refer to application interoperability (SSI_1), security (SSI_2), IT management (SSI_3), and legacy systems (SSI_4). Table 6.7 presents the levels to evaluate those criterions.

Table 6.7. Levels to assess application interoperability (SSI_1), operating systems interoperability (SSI_2), security (SSI_2), IT management (SSI_3), and legacy systems (SSI_4).

Criterion	Level of Interoperability				
	1	2	3	4	5
SSI_1 *Levels of services/software compatibility*	Incompatible / data must be converted before use		Compatible / similar software with the same data format and services		Integrated solution (e.g. ERP)
SSI_2 *Levels of security services in dyad*	No security		Independent security services		Security services defined bilaterally
SSI_3 *Evaluation of the IT management*	None		Internal IT department		External company shared with business partner
SSI_4 *Verification of legacy systems*	Yes		Partially		No

On the hardware side of systems, OHI deals with all the hardware involved in the internal processes that have influence on the interface processes. To assess those, is proposed the criterion hardware connectivity (OHI_2), which may be assessed by the levels of hardware compatibility in Table 6.8.

Table 6.8. Levels to assess hardware compatibility (OHI_2).

Criterion	Level of Interoperability				
	1	2	3	4	5
OHI_2 *Levels of hardware compatibility*	None / hardware works isolated for single purpose		Partial / usable with specific hardware and software		Complete / equipment communicates with all the company's devices

Employees are the ones who perform non-automated IT-based activities. Human resources assessment (HRA) deals with those employees by assessing the impact they have on interoperability. On the organisational perspective, is proposed to assess motivation (HR_1) by the frequency of absenteeism and their efficiency. On the KI perspective, the levels of SC competencies assess HR competencies (HR_2). Last, the levels of IT competencies assess the HR competencies for using IT (HR_3). Table 6.9 resumes those levels.

Table 6.9. Levels to assess motivation (HR_1), competencies (HR_2) and IT competencies (HR_3).

Criterion	Level of Interoperability				
	1	2	3	4	5
HR_1 *Frequency of absenteeism*	On a daily basis	Once per week	Once per month	Once per year	Never
HR_1 *Efficiency percentage*	0 - 20%	20 - 40%	40 - 60%	60 - 80%	100%
HR_2 *Levels of SC competencies*	Inadequate skills		Appropriate skills		Advanced skills.
HR_3 *Levels of IT competencies*	Inadequate skills		Appropriate skills		Advanced skills.

The last assessment refers with interpersonal contact between employees of the two firms. Culture harmonization (CI_1) is assessed by the existence of cross-organisational teams in the dyad, by evaluating the organisational culture and by the frequency of conflicts. Language barriers (CI_2) are verified individually and by verifying the existence of secondary languages to deal directly with the partner. Table 6.10 presents the levels to assess these two criterions.

Table 6.10. Levels to assess culture harmonization (CI_1) and language barriers (CI_2).

Criterion	Level of Interoperability				
	1	2	3	4	5
CI_1 *Existence of cross-organisational teams*	No				Yes
CI_1 *Evaluation of organisational culture*	No company culture / Each individual preserves its cultural identity (acculturation)		There is an organisational culture /employees share the values of the organisation		Cross-organisational culture / occasional meetings with partners to fortify relationships and diminish culture clash
CI_1 *Frequency of cultural conflicts*	On a daily basis	Once per week	Once per Month	Once per year	Never
CI_2 *Existence of linguistic barriers*	Yes				No
CI_2 *Existence of a secondary language*	No				Yes

6.2.3. The establishment of the dyad's design (AD framework)

In the previous sections, the determination of the buyer-supplier dyad's BI conditions and the respective assessment was described, respectively, through the so-called A+D and A stages. In the present section is addressed how the BI conditions are seen in practice. The selected approach to design interoperable buyer-supplier dyads is the axiomatic design theory (AD). To achieve the design of these dyads, one must comply with a multidisciplinary approach, deal with the inherent interoperability complexity, enable different levels of detail and retain the organisational functionality through a context-dependent approach (see "challenges in interoperable systems design" in section 3.2). In this sense, 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 aspects 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.

To achieve the 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).

The utmost objective for the buyer-supplier dyad is to achieve optimal interoperability reflected on the dyad's performance and in the value created (see Figure 6.1). This objective sets the overall need of the dyad, which characterizes the customer domain of the design. In a global perspective, the customer need (CN) can be stated as:

"CN: Achieve optimal interoperability in the buyer-supplier dyad".

This CN presents the main generic objective of a buyer-supplier dyad that expects to be interoperable. Specific cases of interaction between the two firms can be derived from this CN. If the objective is to improve a specific interaction of the SCOR operations (e.g. the purchasing interaction), CNs should be defined accordingly. For instance, the design of the interaction between purchasing and sales departments of the buyer and supplier's firms, the CN may be specified as:

"CN: Optimize interoperability in the purchasing interaction between buyer and supplier".

The 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 objective of wanting optimal interoperability on the buyer-supplier dyad has implications on how the design is organised. The advocated hypothesis is that changes on the BI conditions can deliver optimal values of interoperability, in opposition to requiring maximum levels of interoperability for every BI perspective to become interoperable. Hence, to achieve optimal interoperability, one must come from an existing design ("as-is") to a more desired state ("to-be"), where interoperability is considered optimal. The implication of this in AD is traduced by the dependency between interoperability perspectives and conditions. To re-design the dyad, changes to a DP to readjust an existing FR may require that other subsequent DPs and PVs should be changed accordingly. In this way, is expected to achieve optimal interoperability by making the necessary changes in the interoperable system without compromising the basic functions of the dyad.

Achieving optimal interoperability also requires a multidisciplinary approach on the subject. As consequence, the different perspectives of BI should be present on the dyad's design. Though, this multidisciplinarity could set the aim of the design to different objectives rather than the CN. To deal with organisational, knowledge and technical perspectives, one could require several designs instead of one solely design with the comprehensive vision of the dyad. In that sense, the proposed A+D stages serve the purpose of supporting an integrated top-down design. 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 way, only the aspects that refer to the CN are addressed subsequently in each BI perspective.

In Figure 6.5 is presented the main framework that represents the buyer-supplier design and the respective vertical and horizontal decompositions.

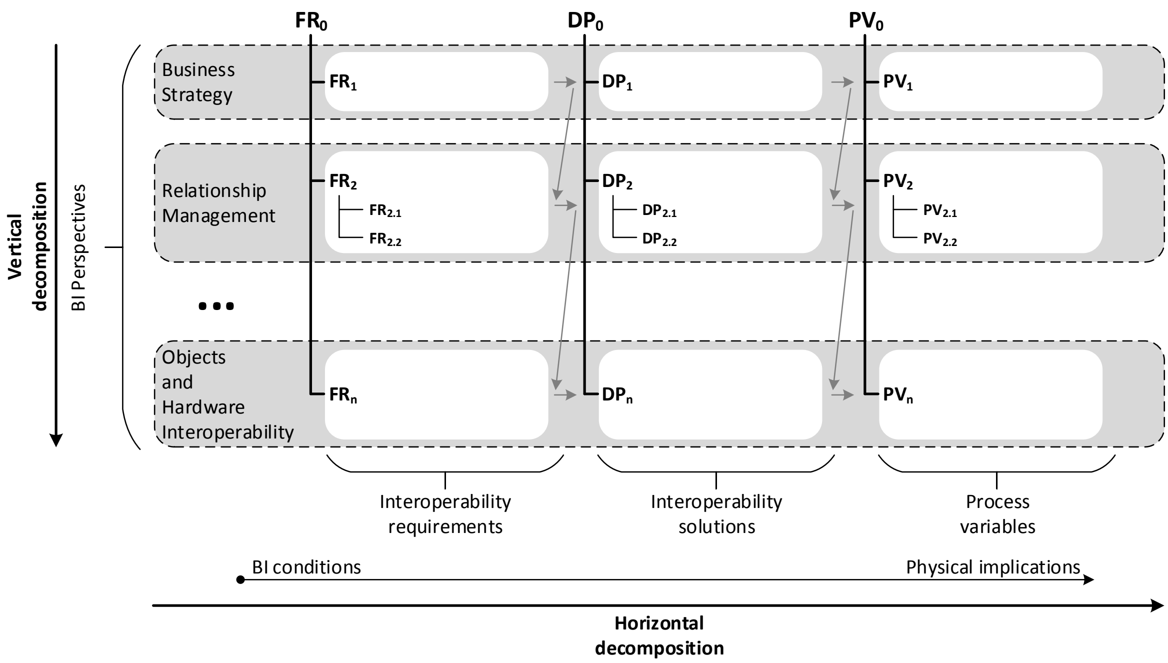


Figure 6.5. AD framework for interoperable buyer-supplier dyads.

The vertical decomposition refers to the BI perspectives mapped from BS to OHI. The sequence of those is made according to the A+D stages. Though, an alternative vertical decomposition is advised;

instead of a top-down layering of the BI issues, the decomposition process can be arranged from BS to PI, and subsequent perspectives are made with regards to the operation, process or interface process they relate to. The layered decomposition could 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.

6.2.3.1. 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 the A+D stages. 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.

- **Business strategy**

"For each business objective, decompose in three base FRs for business goals identification, clarity and business strategy alignment".

As the starting point, BS is addressed in the first FR, whereas is proposed that the dyad's companies "establish the cooperation goals for the dyad" (FR_1) through "the negotiation of the conditions and ground rules for business (DP_1)". Business conditions, agreements, role assignments and liabilities are examples of the settlement both companies need to achieve. Then, for each identified objective that is related to a specific operation, process or interface processes that fits beneath the CN, is suggested to breakdown into three main FRs (see Table 6.11), where the left column represents the parent BI criterion that leads to the subsequent FRs, DPs and PVs.

Table 6.11. Suggested lateral decomposition for each business objective on the BS perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
BS_1 *Business goals identification*	$FR_{1.1}$: Establish business goals for cooperation.	$DP_{1.1}$: Goals negotiation (see Levels of goals definition in Table 6.2).	$PV_{1.1}$: Features of the agreement (e.g. lead-time, SLAs, delivery procedures, etc.).
BS_2 *Clarity in business goals*	$FR_{1.2}$: Ensure clarity in business objectives.	$DP_{1.2}$: The communication of agreements and rules between parties (see Levels of clarity in business goals in Table 6.2).	$PV_{1.2}$: The activities to enforce the clear communication of objectives or the policy to deal with conflicts.
BS_3 *Business goals identification*	$FR_{1.3}$: Reconcile actor's individual strategy with cooperation strategy.	$DP_{1.3}$: The integration of cooperation strategy into individual strategy (see Levels of strategy alignment in Table 6.2).	$PV_{1.3}$: Methods to ensure the enforcement of the cooperation objectives (e.g. executing contract obligations, procedures dedicated to the partner, scheduling of meetings or audits to review competencies and capabilities, etc.).

- **Relationship management**

"Address RMA criterions through the levels of interoperability and map RMD criterions to the process level".

Relationship management (RM) is set on the requirement "manage cooperation" (FR_2) that is achieved by the "relationship measures to ensure cooperation duration and adequacy to the dyad's needs" (DP_2). Like was introduced in the A+D stages, RM has two viewpoints: the analysis (A) and modelling (D). On the first, levels were suggested on section 6.2.2 to address partner selection (RM_1), cooperation realisation management (RM_2), roles and responsibilities (RM_5), governance (RM_7) and knowledge management (RM_8). To each one of those, the mapping from FRs to DPs matches the conditions of the dyad. On the subsequent mapping to PVs, the procedures, methods and another programs are described to enable the RM assets.

The modelling stages (D stages) refer to aspects that do not match a specific level of interoperability. Yet, they describe qualitatively the interoperability aspects that have implication on the physical processes. With regards to RM, cooperation termination (RM_3), cooperation monitoring (RM_4), roles and responsibilities (RM_5), and conflicts and risk management (RM_6) are the suggested aspects to detail the way firms manage cooperation. The detail of those allows determining the decisions that have impact on processes when certain conditions are met. For instance, role assignment (RM_5) determines which processes are made by the buyer and by the supplier. Contingency plans may provide complementary or alternative procedures ($DP_{2.6}$) for communication disruption ($FR_{2.6}$). Horizontal decomposition of these ones allows mapping from the requirement to the practical implications. Matrix design tracks those conditions to the processes they have impact into. For instance, in the case of communication disruption ($FR_{2.6}$), the alternate procedure to communicate ($DP_{2.6}$) will add a secondary alternative procedure to the regular ordering process.

In Table 6.12 are presented the criteria for RM and respective horizontal mapping for the dyad's design.

Table 6.12. Suggested lateral decomposition for each business objective on the RM perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
RM_1 *Partner selection*	$FR_{2.1}$: Manage cooperation in its initiation.	$DP_{2.1}$: The depth of competencies analysis prior to business set-up (see "Levels of partner selection" in Table 6.3).	$PV_{2.1}$: The sourcing approach to select the supplier.
RM_2 *Cooperation realisation management*	$FR_{2.2}$: Manage cooperation during its realisation.	$DP_{2.2}$: 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 (see "Relationship duration" in Table 6.3).	$PV_{2.2.1}$: 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 (see "Frequency of meetings to review progress and competencies" in Table 6.3).	$PV_{2.2.2}$: The methods to support the competencies revision: meetings, problem reporting, problem solving, etc.
RM_3 *Cooperation termination*	$FR_{2.3}$: 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.
RM_4 *Cooperation monitoring*	$FR_{2.4}$: 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.
RM_5 *Roles and responsibilities*	$FR_{2.5}$: Assign actors to business activities.	$DP_{2.5}$: The identification of role assignments and its level of adequacy and possible existence of responsibility gaps (see "Levels of roles and responsibilities definitions" in Table 6.3).	$PV_{2.5}$: Description of buyer and supplier role assignment.
RM_6 *Conflict and risk management*	$FR_{2.6}$: 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 (e.g. communication disruption, supply disruption, etc.).
RM_7 *Governance distribution*	$FR_{2.7}$: Distribute governance in the dyad.	$DP_{2.7}$: The definition of a governing firm, or the equal distribution of power on the dyad (see "Levels of power distribution" in Table 6.3).	$PV_{2.7}$: Description of how decision-making process is taken place and how it affects the dyad.
RM_8 *Manage knowledge*	$FR_{2.8}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.8}$: The partner skills for cooperation (see "Levels of partner knowledge skills" in Table 6.3).	$PV_{2.8}$: The competences description, implemented training programs and other measures to ensure adequate skills for cooperation and cooperation scale-up.

- **Rules interoperability**

"To applicable laws or applicable business rules, address the compatibility of those ones and the way firms reconciled them".

Table 6.13 details the laws and business rules confrontation mapped to the methods to sustain legal cooperation.

Table 6.13. Suggested lateral decomposition for each business objective on the RI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
RI_1 *Rules compatibility*	FR_3: Reconcile applicable laws (national and cross-borders) and business rules.	DP_3: The harmonisation of rules for business set-up (see "Levels of rules compatibility" in Table 6.4).	PV_3: Applicable laws and business rules and the method to sustain legal cooperation (policies, ethics, litigations, resolve disputes, etc.).

- **Process interoperability**

"For each interaction of the SCOR operations, address PID and PIA in relation to internal and interface processes".

PI is achieved by "managing internal and interface processes" (FR_4) through the achievement "seamless collaborative business processes" (DP_4). To each interaction, internal processes are addressed by PI_1, PI_2 and PI_3 criteria, while the interface is addressed on PI_4. Table 6.14 presents the mapping of the BI conditions from conceptual to process levels of design.

Table 6.14. Suggested lateral decomposition for each business objective on the PI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
PI_1 *Process sequencing*	$FR_{4.1}$: Model the process sequence.	$DP_{4.1}$: The sequence approach (e.g. sequential, conditional, iterative, etc.) and the business process models (BPM) that choreographs the sequence.	$PV_{4.1}$: The work methods that enable process flow and resources (human and technical) that performs them.
PI_2 *Organisational alignment*	$FR_{4.2}$: Align internal processes with the firms' organisational structures.	$DP_{4.2}$: The organisational alignment solution (see "Levels of organisational alignment" in Table 6.5) BPM and DSM representations.	$PV_{4.2}$: Description of the responsibility assignment.
PI_3 *Process monitoring*	$FR_{4.3}$: Select metrics to monitor internal/interface processes.	$DP_{4.3}$: Operational SCM and interoperability performance metrics.	$PV_{4.3}$: Metrics measurement.
PI_4 *Process alignment*	$FR_{4.4}$: Align companies' internal processes.	$DP_{4.4}$: The internal processes reconciliation (see "Levels of process alignment" in Table 6.5) and the collaborative business process model.	$PV_{4.4}$: Work methods, communication procedures and resources implemented to interact with partner.

- **Data interoperability**

"To each data flow in the considered business processes (internal and interface), address DID and DIA issues".

With regards to DI, the highest FR can be stated as "manage data exchange" (FR_5), which is accomplished by the "data flows between firms" (DP_5). Though, data exchange is a feature inherent to internal and interface business processes. Hence, the parent FR can be suppressed, and the DI features incorporated in the adequate processes whereas occur: communication between partners, data incompatibility, semantic alignment, database heterogeneity, and the need to maintain data and communication quality. In Table 6.15 are presented the suggested FRs, DPs and PVs to address those situations.

Table 6.15. Suggested lateral decomposition for each business objective on the DI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
DI_1 *Communication paths*	$FR_{5.1}$: Manage the communication path for interface processes.	$DP_{5.1}$: The depth of communication paths definition (see "Levels of contact points definition" in Table 6.6).	$PV_{5.1}$: The communication procedure, the users and the ICT implemented for data exchange.
DI_2 *Contact points*	$FR_{5.2}$: Assign employees to interface processes.	$DP_{5.2}$: The contact points definition (see "Levels of contact points definition" in Table 6.6).	$PV_{5.2}$: If contact points were defined, identify the users and respective processes where is performed the contact between firms.
DI_3 *Data formats compatibility*	$FR_{5.3}$: Manage compatibility between exchanged data formats.	$DP_{5.3}$: Solution for data compatibility (e.g. shared/integrated databases, automated data exchange/entry, software conversion or manual data entry).	$PV_{5.3}$: The procedure to enable data formats compatibility.
DI_4 *Semantic conversion*	$FR_{5.4}$: 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 (e.g. normal and urgent orders).
DI_5 *Database heterogeneity*	$FR_{5.5}$: Manage data exchange.	$DP_{5.5}$: The data exchange approach (see "Levels of data exchange" in The contact points definition in Table 6.6).	$PV_{5.5}$: The methods to handle the data exchange solution.
DI_6 *Communication quality*	$FR_{5.6}$: Ensure quality in communications.	$DP_{5.6}$: The approach to maintain data quality in communications.	$PV_{5.6}$: Semantic agreements, required data, etc.
DI_7 *Information quality*	$FR_{5.7}$: 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**

"For each system used in the business processes, address SSID and SSIA aspects".

SSI is addressed in each business process whereas is used a software or services to interact, process and exchange data. Hence, the main requirement is to "manage software and systems interoperability" on the dyad (FR_6) where is achieved by "compatible systems" (DP_6). In business processes that encompasses the interaction between applications, the use of security services, IT management and legacy systems, the decompositions from Table 6.16 are advised.

Table 6.16. Suggested lateral decomposition for each business objective on the SSI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
SSI_1 *Application interoperability*	$FR_{6.1}$: Manage compatibility between interface software.	$DP_{6.1}$: The software solution for interacting/complementary processes (see "Levels of services/software compatibility" in Table 6.7).	$PV_{6.1}$: The users, the procedures and conversions (software or manual) to use data from different or similar software.
SSI_2 *Security*	$FR_{6.3}$: Manage information systems security.	$DP_{6.3}$: The IT security approach (see "Levels of security services in dyad" in Table 6.7).	$PV_{6.3}$: The procedures, agreements, protocols, etc. used to support the security approach.
SSI_3 *IT management*	$FR_{6.4}$: Manage information systems to support the dyad interaction.	$DP_{6.4}$: The IT management solution (see "Evaluation of the IT management" in Table 6.7).	$PV_{6.4}$: The activities to support interface information systems.
SSI_4 *Legacy systems*	$FR_{6.5}$: Maintain compatibility to required legacy systems.	$DP_{6.5}$: Solution to deal with legacy systems (see "Levels of services/software compatibility in Table 6.7).	$PV_{6.5}$: 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**

"In each activity requiring the use of physical hardware that has impact on subsequent processes and data flows on the interface, address the type of interaction and the hardware compatibility".

OHI is addressed by the main requirement "manage internal hardware used in internal processes that have influence on the dyad's interaction" (FR_7), which is achieved by "Hardware solution for seamless data integration" (DP_7). In every process that uses physical hardware (e.g. barcode scanner, label printers, RFID, etc.), the type of interaction and the compatibility of hardware are the two subjects suggested to detail OHI (see Table 6.17).

Table 6.17. Suggested lateral decomposition for each business objective on the OHI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
OHI_1 *Type of interaction*	$FR_{7.1}$: 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).
OHI_2 *Hardware compatibility*	$FR_{7.2}$: Ensure compatibility of physical devices and internal systems.	$DP_{7.2}$: The hardware compatibility approach (see "Levels of hardware compatibility" in Table 6.8).	$PV_{7.2}$: The methods to enable hardware connectivity with other systems (automated or user-based).

- **Human resources**

"In every process that depends on a user, address employees motivation and competencies".

"Manage users that use information systems internally and when interacting with partner" (FR_8), fulfilled by the "methods to ensure motivation, efficiency and adequate competencies for cooperation" (DP_8).

Table 6.18. Suggested lateral decomposition for each business objective on the HR perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
HR_1 *Motivation*	$FR_{8.1}$: Ensure employees motivation.	$DP_{8.1}$: The approach to keep employees motivated (e.g. reward systems, team-building programs, etc.).	$PV_{8.1}$: The form of implementation of the motivational programs.
HR_2 *SC competencies*	$FR_{8.2}$: Ensure adequate knowledge for SC activities.	$DP_{8.2}$: The depth of employee selection and the management of knowledge and skills (see "Levels of SC competencies" in Table 6.9).	$PV_{8.2}$: The description of the adequate knowledge skills for employees to perform activities; the implementation of training programs, etc.
HR_3 *IT competencies*	$FR_{8.3}$: Ensure adequate IT competencies.	$DP_{8.3}$: The depth of employee selection and the management of knowledge and skills (see "Levels of SC competencies" in Table 6.9).	$PV_{8.3}$: The description of adequate IT skills; implementation of training programs, etc.

- **Cultural interoperability**

"In each human-to-human interaction between the dyad's firms, consider the CI aspects".

In interface processes whereas human interaction occurs, one has to "manage the cultural differences on the dyad's interface" (FR_9) by "Methods to harmonize culture and to solve linguistic barriers"

(DP_9). To address this issue, in Table 6.19 is suggested the decomposition for cultural harmonization and language barriers.

Table 6.19. Suggested lateral decomposition for each business objective on the CI perspective.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
CI_1 *Cultural harmonization*	$FR_{9.1}$: Harmonize cultural differences between companies and interacting employees.	$DP_{9.1}$: The methods implemented to avoid cultural differences (e.g. implementation of cross-organisational teams, meetings with partners to fortify relationship, adoption of another cultures, creation of a multicultural work environment, etc.).	$PV_{9.1}$: The description of the method and the form it is implemented.
CI_2 *Language barriers*	$FR_{9.2}$: Avoid linguistic barriers on companies' communication.	$DP_{9.2}$: The method to avoid linguistic barriers (e.g. contact point speaking the same language as the partner, implementation of a secondary language for communication, contract requirement that obligates partners to speak the focal firm language, etc.).	$PV_{9.2}$: 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. FRs are set on the basis of the BI criteria for each BI perspective. The mapping from FR to DP corresponds to the firms' decisions that match the levels of interoperability from the A+D stages. For instance, with regards to BS, in the PVs are referred the attributes of the contract and the form to proceed in response to the form the agreement was set. In this case, failure to duly communicate the terms of the agreement (mapped in $DP_{1.2}$) may require the establishment of liabilities ($PV_{1.2}$) to manage occurring conflicts. In opposition, the comprehensive review of competencies ($DP_{1.2}$) may be enforced by the by the study in depth of partners' capabilities ($PV_{1.2}$), which will result in a mutual advantage environment for the business set up.

6.2.3.2. The procedure to register interoperability problems on design matrices

The design matrices have the purpose of mapping the dependencies FRs-DPs and DPs-PVs. 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 organisational, 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”). Despite the many problems of interoperation that a dyad may have, it will always be considered interoperable. An example is the communication between firms; even if companies use different applications, or an ICT that doesn’t permit the direct integration of data on the receiver’s system, additional activities will enable interoperation by converting the data or insert it manually on the receiver’s systems. A coupled design would mean that it is impossible for that information to be transferred or used. Hence, coupled matrices are a possibility to have on the first conception of a dyad that will be established. For an existing interoperating dyad, AD has to represent how the dyad interoperates and where it presents problems in interoperation.
In Table 6.20 are resumed the types of coupling and the expected interoperability result.

Table 6.20. 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

For decompositions based on criteria from A stages, 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 6.21 and equation (6.1)).

Table 6.21. 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.

$$\begin{bmatrix} FR_{1.1} \\ FR_{1.2} \\ FR_{1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} DP_{1.1} \\ DP_{1.2} \\ DP_{1.3} \end{bmatrix} \tag{6.1}$$

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.

Descriptive criteria (associated with the D stages) correspond to aspects that give detail to BI conditions, but don't refer to a specific level of interoperability. Hence, registering dependencies on the matrix is a sign of how an interoperability solution may affect the execution of another one. For instance, if the buyer changes the ICT to place an order, that would interfere with the supplier's system to receive and manage orders. Those are solutions to different requirements that can be, for the buyer, "establish and ICT to place an order", and, for the supplier, "establish an information system to manage orders". Though, due to existing physical interaction between those, changing one implies the change in the other. Otherwise an interoperability problem (in this case, incompatibility) must be registered on the matrix.

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 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.

6.2.4. Modelling the implications of interoperability (D stages)

The modelling of physical processes is performed after the A stages and alongside to the dyad's design. In the ADADOP method framework (see Figure 6.3) a two-way arrow remarks the link between the dyad's design and the modelling implications. The reason is the complementary nature of both procedures. While design addresses the identified BI conditions from the dyad, mapping them from conceptual to physical and process levels, process modelling acts on those physical and process levels representing the dyad graphically and mathematically. Therefore, the combination of these three procedures is what permits to link the BI conditions to the impact on the physical buyer-supplier dyad.

The A stages, and subsequent mapping in the AD framework, set the implications of BI conditions that have impact at the physical and process levels of the dyad. As mentioned earlier, the procedure is centred on the physical processes of the buyer-supplier dyad. Business set-up and management decisions (BS, RM and RI) have impact on how the companies' processes were established and are addressed on their daily execution. Interoperability problems can be mapped to the executed processes. For instance, the lack of strategy alignment with regards to product quality is traduced on the products received by the buyer. The delivery interaction is remarked with faulty materials that require additional procedures to handle those non-conforming items. The lack of objective alignment may result in additional complaint procedures, implementation of quality verifications on the buyer side or legal action to penalise the supplier. In opposition, the adequate alignment of the strategy would result on implementation of quality systems on the supplier and/or the implementation of a reverse logistics flows to act on eventual non-conforming products.

Besides the BS, RM and RI business set-up conditions, DI, SSI, OHI, HR and CI are addressed as resources to processes. Those refer to data flows, systems, hardware and users required to enable the business processes. They are addressed as part of the modelling procedure described in the next section.

The process decomposition refers to the modelling of the interoperability implications on the physical system. It is a result of the D stages RMD, PID, HRD, OHID and SSID, described in the A+D stages (see section 6.2.1), and a complement to the AD mappings. Business process modelling notation (BPMN), design structure matrix (DSM) and discrete event simulation (DES) are the proposed approaches to deal with the interoperability implications in modelling. The three techniques aim at different levels of modelling: BPMN represents the dyad's internal and interface business processes; DSM represents process logic and resources, by using matrices; and computer simulation allows modelling the considered business processes, input the variables, and obtaining outputs that permit to infer about the business processes performance.

To detail the processes inherent to the buyer-supplier dyad, the following steps are proposed:

1. Identify the SCOR operations involved in design objectives (CNs);
2. Identify the processes and assign responsibilities to actors;
3. Detail the sequence and alignment of internal and interface processes;
4. Link resources to each process.

1. Identify the SCOR operations involved in design objectives (CNs):

For the objectives set for the dyad's design (CNs), identify the SCOR operations related to the buyer-supplier interactions. Generically, the possible SC operations are represented in Figure 6.6.

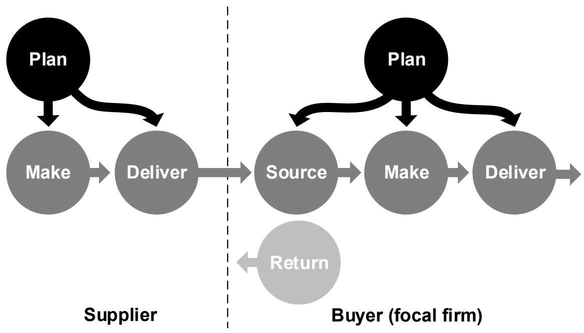


Figure 6.6. Buyer-supplier dyad's SC operations (interacting macro processes).

2. Identify the processes and assign responsibilities to actors

Process identification is performed according to the matching SC operations in Figure 6.6. Responsibility assignment defines which of those processes each actor performs. Though, interface areas require attention. Through the assessment of this criterion in the RMA stage, the adequacy of role assignments is addressed and responsibility gaps are identified. In the modelling perspective, RMD addresses the roles assigned to each actor, and the identification of those processes with ill-defined responsibilities. As consequence, in optimisation stages, new scenarios regarding responsibility assignments should be studied.

For instance, considering the quality shifting noticed on some purchasing strategies, buyers push quality responsibilities to suppliers with the objective of increasing final product quality. In turn, that results in dislocating or adding new quality operations to suppliers (e.g. cross-functional teams or supplier visits to buyer's plants). In opposition to the strategic motivation, responsibility gaps in this matter would affect final product quality. This procedure aims at identifying these boundaries of responsibility, and studies their impact on dyad's performance by representing those processes and study alternative scenarios.

3. Detail the sequence and alignment of internal and interface processes

To each identified SC operation, processes and activities are set in place to permit the accomplishment of dyad's objectives. For instance, the sourcing operation starts on the order placement and validation, delivery scheduling, reception, storage, invoice reception and ends with the payment. The process arrangement depends on companies' decisions. The use of SCOR reference model and the identification of implemented SCM's practices helps to track the decisions performed by the companies. Those decisions contribute to the dyad's design solution space, and impact the way processes are approached. To address those decisions, is suggested the procedure in Figure 6.7.

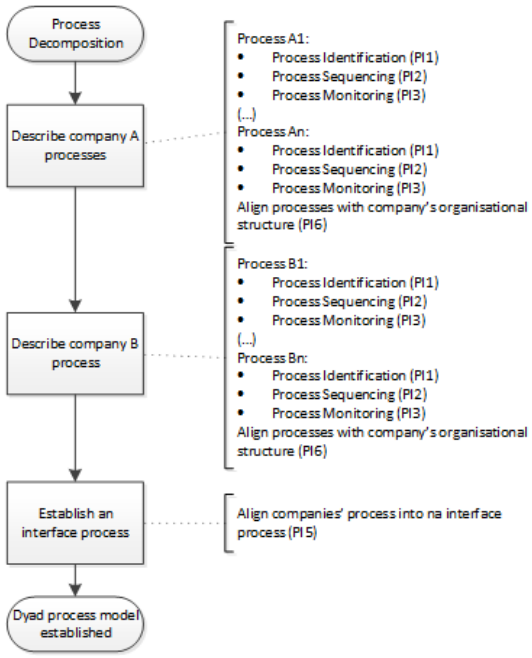


Figure 6.7. Process interoperability decomposition logic.

The internal and interface processes are distinguished and addressed systematically through identification, sequencing and alignment with organisational sections and with regards to interface. Process logic and interactions are emphasized through a DSM diagram. In Figure 6.8, an example of an ordering-selling interaction is presented. In this one, sourcing and delivery operations are detailed into the numbered activities shown on the left of the diagram. The internal process sequence is demonstrated with regards to each actor and the main interactions are highlighted in grey.

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Company B ordering process	Check MRP	1	■																			
	Send order schedule	2	x	■																		
	Order confirmation	3		x	■										x						x	
	Order confirmed	4			x	■																
	Materials reception	5				x	■												x			
	Invoice reception	6				x		■								x						
	Payment	7					x	x	■													
	Order fulfilled	8							x	■												
	Apply penalty	9			x						■											
	Close order	10			x						x	■										
Company A sales process	Order received	11		x									■									
	Inventory verification	12											x	■								
	Confirm order	13												x	■							
	Send invoice	14													x	■						
	Funds received	15							x							x	■					
	Schedule delivery	16													x			■				
	Deliver materials	17																x	■			
	Order fulfilled	18															x		x	■		
	Reject order	19												x							■	
	Order closed	20																			x	■

Figure 6.8. Representation of process logic and interactions between a buyer and a supplier on a order-sell interface (Espadinha-Cruz, Mourão, Gonçalves-Coelho, & Grilo, 2014).

Internal processes are detailed according to the process sequence criterion (PI_1) as presented in the AD framework (see PI_1 in Table 6.14). The DSM serves to represent the sequence and, through the application of algorithms, the sequence may be rearranged for new scenarios. The detail of the sequence is accomplished by BPMN. Based on the same example, a BPMN for the supplier (company A) is presented in Figure 6.9.

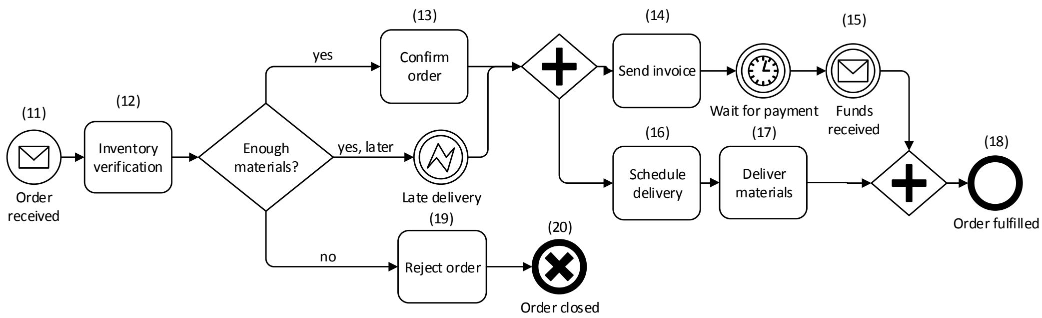


Figure 6.9. Supplier's sales business process model (Espadinha-Cruz, Mourão, Gonçalves-Coelho, & Grilo, 2014).

The distinction between the two representations is that DSM can be re-arranged dynamically without losing the process logic. In the other hand, BPMN provides notation that emphasizes the flows, events, activities, connections, data objects and gateways required to give the context to the business processes.

Still in the perspective of internal processes, organisational alignment (PI_2) addresses the process distribution with the companies' sections. This one is assessed in the PIA stage. In the modelling perspective, the organisational structure is represented through the BPMN's pool lanes. Nevertheless, organisational structures modelling are a limitation of BPMN. For that reason, the procedure to provide new process distribution is performed using DSM's clustering and partitioning algorithms. Considering the required interactions between sections, new activities sequencing and aggregations may be suggested and, in turn, studied using simulation.

The last aspect to model is the process alignment (PI_4), where the individual companies' processes are joined together into collaborative business process. Those contain the interactions highlighted in grey on Figure 6.8. They correspond to the interface between material, data, and currency flows. The business process choreography enables the interaction between the buyer and supplier (see example in Figure 6.10). The work distribution is addressed in the interface in the same manner as the organisational alignment using DSM to study possible alternatives to the current alignment.

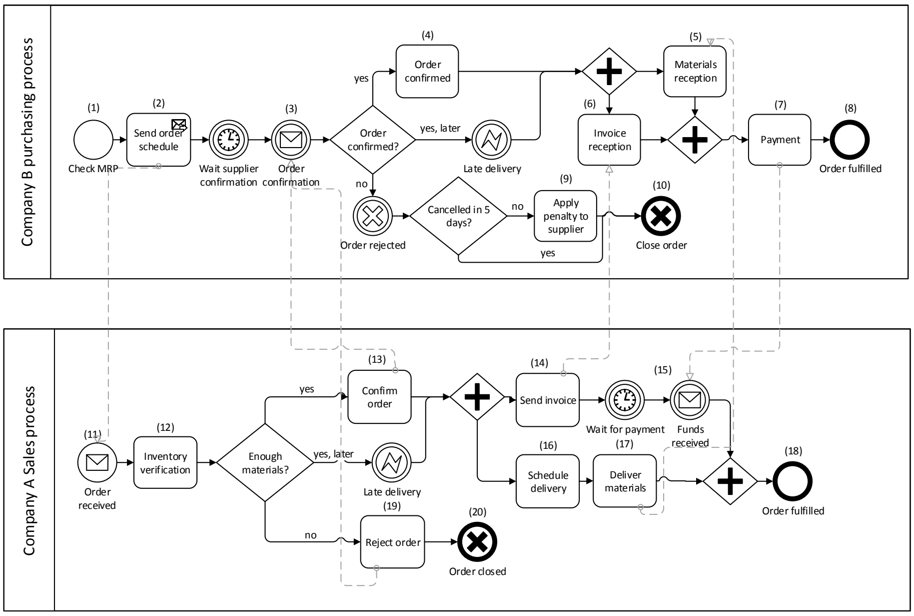


Figure 6.10. The collaborative business process for the purchasing interaction (Espadinha-Cruz, Mourão, Gonçalves-Coelho, & Grilo, 2014).

4. Address data flows and resources on the processes

DI, SSI, OHI and HR give a secondary level of detail to address processes, focusing on the activities whereas systems, hardware and users are required to process and exchange data. The accomplishment of that detail is made by implementing the D stages presented in section 6.2.1, and through the assessment of using the levels of interoperability from the respective A stages from section 6.2.2.

With regards to modelling, the detail on DI, SSI, OHI and HR is registered in the AD framework with regards to the activities and flows present in the considered BPMN and DSM models. Hence, to connect these aspects to processes is proposed to address each one of the issues with regards to processes they belong to. For instance, considering the previous example of the collaborative business process for purchasing interaction (see Figure 6.10 (collaborative business process for purchasing interaction), the detail of DI and SSI on the order placement interaction (between processes (2)-(11)), can be arranged according to the AD design in Table 6.22.

Table 6.22. Purchasing interface design.

BI perspective/criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
PI *Process interoperability*	FR_1: Manage the order placement procedure.	DP_1: Features of the order placement.	
DI_2 *Contact points*	$FR_{1.1}$: Assign employee's to order placement/receive interface.	$DP_{1.1}$: Contact points defined.	$PV_{1.1}$: Both companies have assigned employees to communicate with the partner.
SSI_1 *Application interoperability*	$FR_{1.2}$: Manage the compatibility between buyer's ordering system and suppliers order management system.	$DP_{1.2}$: Order received by e-mail and converted manually for processing in SAP system.	$PV_{1.2}$: Supplier's user inserts data manually on SAP.

The four explained steps help to guide through the determination of the buyer-supplier dyad's BI conditions, by assisting in represent the BI implications on business processes implemented to accomplish the dyad's interactions. Their implementation presupposes the parallel design through AD. I.e., after the BI conditions are qualified in the A stages, AD maps those conditions to physical and process levels. In turn, BI conditions assigned to the physical representation (D stages) are modelled in support to the design elements they belong to. The final product is an AD design, containing the FRs derived from the BI conditions, the interoperability solutions (DPs) matching the companies' decisions, the PVs that operationalize those decisions, and the physical model representing the DPs, which depends on the PVs for execution.

6.2.5. Optimization procedure (OP stages)

Being the higher aim of the buyer-supplier dyad to achieve optimal interoperability, the optimization procedure is set on the notion that solving interoperability problems on the dyad one can accomplish higher performance and increase value added to the final customer. So far, the dyad's conditions were mapped from conceptual to physical and process levels, having represented the essence of the dyad through an AD framework and by process models. The AD framework sets the interoperability requirements and respective solutions and PVs, while process models represent how the interactions are set to accomplish the dyads objectives. The optimization procedure points at linking the mapped conditions with the performance and value creation. On the performance perspective, the procedure aims to find the interoperability solutions and/or adequate PVs that ensure higher performance. In turn, on the value perspective, solving interoperability problems is defended as means to increase value added for the final customer.

Looking at the SC as a whole, value added (VA) activities are the ones that add value to the final product, which can be the manufacturing processes, product design, marketing, etc. In the BI point-of-view, the organisational and IT infrastructures support the execution of the SCOR operations, contributing to the SC flows in the buyer-supplier dyad. Though, at the operational level, interoperability problems result in additional non-value added (NVA) activities. Those interoperability NVA activities are reflected in over-processing, miscommunications, need for data conversion, processes repeated or iterated, etc. In turn, they have impact on the buyer-supplier dyad reflected in delays, additional costs or excessive use of resources (technical and human), which consume the degrees of liberty necessary to employ on the product or service. Interoperability problem identification and solution encompasses the determination of adequate conditions or solutions that deliver higher interoperability in terms of dyad's performance. Those solutions act at the physical processes performed by the dyad's firms. Implementation of solutions where interoperability is promoted (for instance, technology scale-up in the maturity levels, use of compatible systems, adequate process alignment, etc.) has impact in the reduction or elimination of additional interoperability NVA activities. Consequently, VA activities have more degrees of liberty to increase value of the product or service delivered to the final customer.

To achieve the optimally interoperable buyer-supplier dyad, the following steps are proposed to come from the determined BI conditions (“as-is”) to the optimal interoperability scenario (“to-be”):

1. **Build simulation model** - from the developed process and business process models in the previous phase, a simulation model must be built to represent those processes and the associated PVs.
2. **Select metrics** – for each business process (internal and collaborative) select the adequate metrics;
3. **Collect data** - in order to operate the simulation model, data must be collected regarding the processes addressed in the AD framework and represented on the BPMN diagrams as well as the SC processes that, although doesn’t fit the interoperability scope, represent the core SC activities (e.g. order placement records, production rate, transport time, etc.).
4. **Simulate and measure performance** – the first run of the model will provide the “as-is” performance metrics values to compare with new scenarios.
5. **Establish new scenarios** - through identification of interoperability problems in the AD framework, and by studying alternative values inherent to the PVs, new design solutions (DPs) or configurations (PVs) will be proposed, respectively.
6. **Test scenarios** – the second and subsequent runs of the model that permits to obtain performance metrics values for each of the new scenarios. Those values are compared to the “as-is” scenario.
7. **Select best scenario** – The optimal “to-be” scenario is the one that has better performance values when compared with the “as-is” conditions.

Based on the determined BI conditions, the 1st step corresponds to the set-up of the simulation model. According to the addressed business processes, in step 2 metrics are selected both through verification of which metrics the firms implement, addressed in the AD framework as cooperation and process monitoring (see section 6.2.3), and the adequate SCM and interoperability metrics, as will be explained in the next section. Data collection refers to data that supports and characterizes the processes involved in the addressed SCOR operations and the record of metrics for the simulation model’s validation.

The steps from 4 to 7 correspond to the use of the simulation model to determine the best solutions and configurations for the interoperable dyad. First, the “as-is” performance values are determined. Then, iteration between steps 5 and 6 is performed until obtaining the best results. This depends on the creation of new scenarios, supported by the AD framework and business process models, and the testing of each one of those. Last, the final step is to decide which scenario is the best to achieve optimal interoperability on the buyer-supplier dyad.

On the next two sections, performance measurement (section 6.2.5.1) and new scenario generation (section 6.2.5.2) are explained. In the first, interoperability and SCM performance metrics are suggested, and is explained the procedure to select metrics. And, in the last, is described how the interoperability problems are identified and how problem solving affects the BI conditions, the dyad's design and the business process and simulation models.

6.2.5.1. Interoperability performance measurement (IPM)

The interoperability performance measurement (IPM) supports the design and the modelling during the implementation of the method. In the first instance, IPM addresses firms' decisions in the relationship set-up ("as-is") and, in the subsequent scenarios, accompanies the mappings from BI conditions to the physical processes. Each measurement is inherently associated to a specific set of BI conditions that match conceptual, physical and process designs, and a specific set of business processes and variables. This makes possible to track down the BI conditions, the interoperability solutions and the PVs that deliver a certain value of a performance metric. The optimal interoperable buyer-supplier dyad results on the implementation of the determined conditions matching the best results for the performance metrics.

The determined BI conditions, accomplished through A+D stages, AD framework and process models, attain the SCM business-context and the interoperability factors that rule interaction. Similarly, the selected metrics should capture the essence of this business context and interoperability, reflecting the impact of BI in the buyer-supplier dyad. Still, both SCM and BI BoKs have limitations with regards to the collaborative performance measurement. SCPM addresses operative, tactical and strategic levels, proposing metrics that act on BS, RM, PI and DI interoperability perspectives. In the other hand, interoperability BoK proposes metrics that address DI, SSI and OHI aspects. Exploring the gaps of both BoK, in Figure 6.11 is proposed the framework that combines SCM metrics with interoperability metrics.

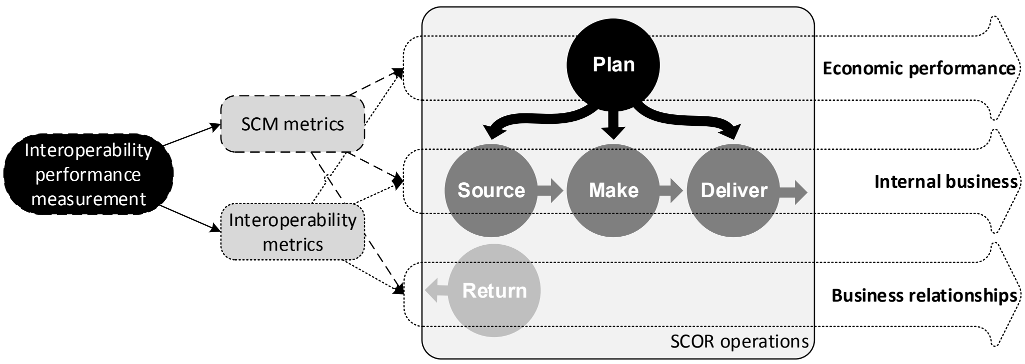


Figure 6.11. IPM framework.

The IPM framework covers the SCOR operations in economic, internal business and business relationships performance perspectives. The objective is to provide the adequate metrics for the addressed business-context. So, for the considered interactions of the buyer-supplier dyad, in Table

6.23 performance metrics are proposed to address each of the SCOR operations at strategic, tactical and operational levels.

The performance measuring is addressed in three levels of the model: in the detailing of RM, addressed by cooperation monitoring (RM_4), in the decomposition of processes (PID), by describing the process monitoring (PI_3), and in the optimization procedure. During the application of the A+D stages to determine the dyad's conditions, RM_4 addresses implemented metrics at strategic and tactical levels, and PI_3 addresses metrics at operational level. The determination of those serves the purpose of determining what efforts the firms are making to monitor partnership, and if they are fit to address interoperability in the SC relationship. Existing adequate metrics help in the optimization procedure, because one can use the firm's performance data to aid in the development of the simulation model.

During the application of the optimization procedure additional metrics may be required to support the model. New scenarios may provide different interoperability solutions that can be better measured with a new set of performance metrics. Hence, when determining the "to-be" conditions, the implementation procedure may include the employment of new metrics to monitor processes (individually and on the interface) and to monitor the partnership.

Table 6.23. Proposed performance metrics to address interoperable buyer-supplier dyads.

SCOR operation	Perspective/process	Metrics	SCM metrics	Interoperability metrics
Strategic				
Plan	Economic performance	Total cost of interoperation		x
		Total cost of information exchange (communications)		x
		Information processing cost	x	x
		Total cost with information conversion		x
	Internal business	Order lead-time	x	
		Total cycle time	x	
		Accuracy of documentation	x	
		Accuracy of operations	x	
		Total time of interoperation		x
		Total time in information treatment		x
		Wasted time in information conversion		x
	Business relationships	Consistency of supplier information (trust)	x	x
		Level of collaboration	x	
		Level of strategy alignment	x	
		Supplier evaluation	x	
		Total time spent in communications		x
Deliver	Internal business	Effectiveness of enterprise distribution planning schedule	x	
	Business relationships	On-time delivery	x	
		Order fill rate	x	
		Overall supplier quality of interoperation		x
Tactical				
Plan	Business relationships	Customer query time/information preparation and return time	x	x
		Quality of data exchange		x
		Conformity		x
		Contact points connectivity		x
	Internal business	Order entry methods	x	
		Human resource productivity	x	
		Time of interoperation		x

SCOR operation	Perspective/process	Metrics	SCM metrics	Interoperability metrics
		Quality of use		x
		Quality of interoperation		x
Source	Business relationships	Supplier delivery performance	x	
		Supplier lead-time against norm	x	
		Promised lead-time	x	
		Supplier booking procedures	x	
		Quality of use of customer data		x
		Conformity of customer data		x
		Supplier delay in order confirmation		x
	Internal business	Efficiency of purchase order cycle time	x	
		Accurate orders	x	
Deliver	Internal business	Effectiveness of enterprise distribution planning schedule	x	
		Effectiveness of delivery invoice methods	x	
	Business relationships	Flexibility of service system to meet customer needs	x	
		Flexibility for urgent orders	x	
		Customer complaints	x	
		Customer order path	x	
		Delivery reliability performance	x	
		Information preparation and return time to customer orders		x
Return	Business relationships	Supplier ability to respond quality problems	x	
		Supplier delay in return response time		x
Operational				
Plan	Internal business	Order entry methods	x	
		Human resource productivity	x	
		Cost of interoperation in Logistics		x
		Time of use of order information to plan production and deliveries		x
		Quality of use of order information to plan production and deliveries		x
		Conformity of order information to plan production and deliveries		x
		Human resources consistency (trust)		x
		HR Efficiency		x
		HR Efficiency using IT		x
		Number of database interactions		x
		Database capacity		x
		Database connectivity		x
		Systems utilization/interactions		x
		Systems capacity		x
		System overload		x
		Underutilization		x
		Undercapacity		x
		HR frequency of absence		x
	Economic performance	Information processing cost	x	
		Cost of interoperation in logistics		x
Source	Internal business	Efficiency of purchase order cycle time	x	
		Accurate orders	x	
	Business relationships	Time of interoperation in purchasing		x
		Time of interoperation in invoice reception and payment		x
		Time spent in information conversion		x
		Time of interoperation to make complaints		x
		Supplier delays in order confirmation/shipment notice		x
	Economic performance	Cost of interoperation in Purchasing		x
		Cost of interoperation to information request/exceptions handling		x

SCOR operation	Perspective/process	Metrics	SCM metrics	Interoperability metrics
Make	Internal business	Human resource productivity	x	
Deliver	Internal business	Effectiveness of delivery invoice methods	x	
		Number of faultless delivery notes invoiced	x	
		Time spent in information conversion		x
	Business relationships	On-time delivery	x	
		Percentage of urgent deliveries	x	
		Information richness carrying out delivery	x	
		Delivery reliability performance	x	
		Time of interoperation in order reception		x
		Time of interoperation to send invoice and receive payments		x
		Customer delays in payment		x
		Time of interoperation in handling complaints		x
	Economic performance	Cost of interoperation in Sales, Delivery and Accounts		x
		Cost of interoperation for exceptions handling		x
Return	Internal business	Quality of use of return information		x
	Business relationships	Time of interoperation in handling complaints		x
		Time of interoperation to make complains		x
		Quality of conformity of return information		x
		Quality of data exchange in return		x
	Economic performance	Cost of interoperation to receive complain and work on solutions		x
		Cost of interoperability to make complain and wait for solutions (w/ or w/o return)		x

6.2.5.2. New scenario generation

The new scenario generation acts on the steps 4 to 7 of the optimization procedure. Having selected the adequate performance metrics for the interoperable buyer-supplier dyad, the procedure of optimization starts with the first run of the simulation model. This first step complements the determined dyad's BI conditions with the performance values that characterize it. After that, the new scenario generation task is the one that determines if interoperability is achieved conceptually and in terms of performance. Hence, there are two optimization possibilities: improving the existing interoperable solutions or providing a new interoperable solution for the dyad (represented in Figure 6.3 in section 6.2 by the arrows "reconfiguration" and "another interoperable solution", respectively). Those possibilities culminate in several scenarios, and, on the threshold of the best performance results, the selected "to-be" scenario permits to achieve optimal interoperability.

In the creation of alternative scenarios to the "as-is", the proposed method aims at identifying conceptually, interoperability problems, and measuring performance of new scenarios. On the first instance, the 1st axiom (independence axiom) is applied. The identification and solving of couplings in designs permits to identify interoperability problems in the interoperable solution space (DPs), and in the PVs associated to those solutions. Solving the couplings requires either new DPs and/or new PVs.

On the second instance, performance measurement addresses the implications of new DPs and PVs. While the 1st axiom streamlines the design decisions, the performance measurement commits those decisions with values that tell if the design is near or far from optimal interoperability.

Nevertheless, the application of 1st axiom and simulation occur in a complementary fashion. Despite those act at different levels (conceptual and process), the study of DPs and/or PVs through computer simulation may either confirm or disprove the couplings on the design matrices. For example, consider the design in Table 6.24 referring to the internal processes of a firm. If we consider the mapping between DPs and PVs, to accomplish process A and B (DP_1 and DP_2) a certain quantity of resources is used (PV_1 and PV_2). Though, the resource distribution (PV_3) to execute the organisational alignment solution (DP_3) requires that the same employee perform both of them. Conceptually, couplings on the matrix can be registered because when the employee is busy in activity A, he won't be available for activity B, and vice-versa. Simulating those processes is possible to determine if the resource quantity is sufficient (PV_1 and PV_2) and/or the resource distribution (PV_3) is adequate. If the results match the PVs, the design matrix should be uncoupled. In other cases, new PVs should be provided to solve the couplings.

Table 6.24. Example of firm's internal process design.

Parent criterion	Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
PI_1 *Process sequencing*	FR_1: Model process A.	DP_1: Business process model for process A.	PV_1: 1 employee performs process A.
	FR_2: Model process B.	DP_2: Business process model for process B.	PV_2: 1 employee performs process B.
PI_2 *Organisational alignment*	FR_3: Align process A and process B with the organisational structures.	DP_3: 1 firm's section to perform process A and process B.	PV_3: The same employee performs process A and B.

As mentioned earlier, there are two optimization possibilities: the improvement of existing interoperability solutions (A) and the providing of new interoperable solutions (B). Both approaches have distinct methods of application. In the next sections both approaches are explained.

A - Improvement of existing interoperability solutions

"Keep DPs constant and re-work the PVs".

The first optimization hypothesis represents the decision of keeping the same interoperability solutions (DPs), and working on the actions or required assets or resources that enable those solutions (the PVs that satisfy them). To improve existing conditions, one has to: apply the first axiom application for DPs-PVs matrices – solving couplings inside business conditions (BS, RM, RI), couplings between business set-up conditions and processes and resources (PI, DI, SSI, OHI, HR and CI), and couplings inside processes and resources –, and propose new PVs for each existing DP to improve performance, maintaining the compliance with 1st axiom.

For the business set-up conditions addressed in the A stages (BSA, RMA and RIA), couplings between DPs and PVs are reflected on the agreement specifications, policies, partnership approaches, etc. (see PVs in Table 6.11, Table 6.12 and Table 6.13). Nevertheless, although couplings between those DPs and PVs may be identified and solved, they cannot be tested on the present simulation model.

However, in business set-up conditions mapped to process, one can determine if the processes or resources DPs are affected or constrained by inadequate business set-up PVs.

Still on the business set-up conditions, the PVs associated with the RMD criteria have impact on the processes and resources PVs. Those ones act in specific conditions and couplings referring to improper PVs specifications or values remark lack of interoperability. For example, if an inspection procedure is implemented as a means to avoid non-conforming components received from supplier (DP for RM_6), the PV may be the description of the inspection procedure. The reception process (DP for PI_1) depends on the work procedure of unloading the truck and store components performed by a certain quantity of employees and the use of a determined system (PV). Additionally, the same process has to deal with the inspection procedure. The compatibilization of inspection and regular procedures could depend on the adequate quantity of resources (e.g. employees), or on the implementation of sampling methods to determine when the inspection procedure should be performed. Using simulation, one can verify if the inspection procedure constrains the regular procedure of reception or, in opposition, determine the adequate value for the PVs (e.g. the number of employees or the study of a sampling method).

With regards to processes and associated resources (PI, DI, SSI, OHI, HR and CI), couplings between DPs and PVs require changes with regards to work methods, communication procedures, work distribution, resources (users, systems and hardware) and resource distribution. Dependencies in those can be tested using simulation model (e.g. the study of the resource utilization to verify if resources are well distributed in several processes).

The improvement of existing interoperability solutions may continue beyond the identification of interoperability problems on the matrices couplings. Even if no couplings are found between DPs and PVs, better performance results can be achieved through the proposal of new PVs (e.g. the increase or decrease of resource quantity in a specific process). Though, one has to obey to the 1st axiom. Proposal of new PVs may result in couplings (e.g. the proposal of resource share in several processes may result in process inefficiency).

B - New interoperability solutions

“Provide new DPs and PVs”.

In the second optimization alternative, new interoperability solutions (DPs) are provided to improve interoperability. To create scenarios according to this alternative, one has to: implement the first axiom between FRs and DPs – couplings inside business set-up conditions, inside processes and resources, and couplings between those two –, propose new DPs for BI aspects in A stages; propose new DPs for BI aspects in D stages; and determine optimal values for PVs associated with new DPs.

Couplings in business set-up conditions represent the issues raised in the A stages (see section 6.2.2) due failing to complying the different solutions with subsequent interoperability requirements. For instance, ill-defined objectives have impact on business strategy clarity, occurring failures in cooperation. Suggestions of new DPs to solve those couplings may include the scale-up or scale-down in terms of the interoperability levels. Still, DPs' proposal at this level cannot be tested in simulation.

Business set-up issues mapped to processes and resource levels reflect the impact that the strategy negotiation, the measures to maintain cooperation and the alignment of rules have on processes and resources definition. For instance, considering the earlier example where a contingency plan was set in place to avoid non-conforming components (DP for RM_6), in the modelling of the reception procedure (FR for PI_1), in addition to providing a BPM to satisfy this FR, the same BPM should include the business processes associated with the component inspection. The coupling exists if the inspection BPM affects the normal execution of the reception BPM. The simulation helps in testing this coupling and in supporting the definition of a BPM that makes both procedures compatible.

Couplings between processes and resources reflect areas where the boundaries for interoperability requirements were crossed. Solving them require providing new solutions for BPM, data flows, implemented systems, hardware and users. An example is the incompatibility of software (SSI_1) used in both firms that may require the use manual or automated conversion of data (DI_3). The implementation of compatible software in both firms would result in compatible data formats that can be used in both systems.

Regarding the criteria addressed in A stages, the proposal of new interoperability solutions may be a result of selecting another DPs that fit the levels of interoperability in section 6.2.2. This alternative may imply the scale-up or scale-down in terms of interoperability levels (e.g. selection of compatible software).

In opposition to DPs associated with criteria from A stages, interoperability solutions regarding to conditions addressed in the D stages are less structured. Proposed alternatives require further study of the impact they bring to the dyad's performance. Though, in Table 6.25 are presented the possible interoperability solutions to D stages criteria, and the BI perspectives that may be affected.

Table 6.25. Alternative interoperability solutions to D stages criteria.

BI perspective	Criterion	Possible interoperability solutions	May impact
RM	**RM_4** *Cooperation monitoring*	New methods to assess cooperation (e.g. audits, inspections, metric record, etc.).	PI
	RM_5 *Roles and responsibilities*	Shift responsibility.	PI
	RM_6 *Conflict and risk management*	New contingency/mitigation plans.	PI, SSI, OHI
PI	**PI_1** *Process sequencing*	New process sequence (provide new BPM or use DSM sequencing algorithms to redistribute activities).	SSI, OHI, HR
	PI_2 *Organisational alignment*	New process alignment with company's organisational structure (provide new BPM or use DSM clustering and partitioning algorithms to redistribute business processes).	SSI, OHI, HR
	PI_3 *Process monitoring*	New PMS or another measuring method.	PI
	PI_4 *Process alignment*	New interface process (provide new BPM for collaborative process).	SSI, OHI, HR
DI	**DI_1** *Communication paths*	Provide new communication paths.	SSI, HR
	DI_2 *Contact points*	Assign different employees to inter-firm communication.	SSI, HR
	DI_3 *Data formats*	Select different conversion or data integration method.	SSI, OHI, HR
	DI_4 *Semantic conversion*	New semantic conversion method.	PI, SSI, HR
SSI	**SSI_1** *Application interoperability*	Select another software or system.	PI, SSI, HR
OHI	**OHI_1** *Type of interaction*	Select different device.	PI, SSI, HR

For each proposed scenario (DP), adequate PVs should be provided to permit achieving optimal performance values. Those are determined in a similar manner as in the improvement of existing conditions (A).

After all the consider scenarios are simulated, the method ends with selection of the "to-be" scenario. The selection of this scenario can be performed by comparison of performance measurements of each scenario, or through the implementation of optimisation methods as Design of Experiments (DOE) or Taguchi. The final "to-be" scenario is the one that delivers better performance values and, in turn, grants the buyer-supplier dyad optimal interoperability.

The ADADOP method allows to accompanying systematically the procedure from the determination of the dyad's BI conditions to the optimization procedure. All the improvements are registered in the AD framework, and represented in the BPMs. Upon the identification of the "to-be" scenario, the buyer and supplier have the required information to implement changes physically on respective firms, and on the interface.

Chapter 7 - Case Studies

The ADADOP method and the theoretical frameworks proposed in the previous chapter are tested here in a case study approach. First are exposed early application scenarios that contributed to test the method and the main propositions are discussed. Afterwards, is made a description of the actors involved in the case studies and, then, the case studies are presented. Last, an analysis and interpretation of results is presented and discussed.

7.1. Application scenarios

The application of the ADADOP method in a real industrial context depended on several developments accomplished through application scenarios. In these ones, several propositions were explored that shaped the final method to apply using case studies (see Table 7.1).

Table 7.1. Summary of elaborated application scenarios

Application scenario	Industrial context in study	Studied propositions	Annex
1	Implementation of the reverse logistics (RL) SCM practice in a buyer-supplier automotive dyad.	The use of MCDM combined with AD to analyse and re-design the buyer-supplier dyad. Customer need is the improvement of interoperability in SCM practices implementation.	A
2	Implementation of the reverse logistics (RL) SCM practice in a buyer-supplier automotive dyad.	The use of AD to analyse and re-design the buyer-supplier dyad. Customer need is the improvement of interoperability in SCM practices implementation.	B
3	Design of purchasing-selling interaction of a buyer-supplier dyad.	Proposes BPMN and DSM to aid in process interoperability decomposition and in the generation of new scenarios. Customer need is the improvement of interoperability in SCOR interactions.	C
4	Simulation of interoperable buyer-supplier dyads.	Proposes simulation to study the impact of BI in the dyads' performance. Uses SCM metrics combined with interoperability metrics to measure the impact of BI in buyer-supplier dyads' performance.	D

Application scenarios 1 and 2 were generated based on data gathered during a previous project (LARGeSCM) related to the author's MSc thesis. In the application scenario 1 was studied the hypothesis of incorporating multi-criteria decision-making (MCDM) (in this case, a Fuzzy sets model) in the method as a form to analyse quantitatively interoperability in practices implementation before the re-design of the dyad's interaction. This proposition was discarded during the testing of the second scenario, where a similar approach to the RL implementation was demonstrated, and the interoperability problems were identified through the application of the Axiomatic Design theory (AD). In this application scenario, the design of the automotive dyad was presented and, through the application of the 1st axiom (independence axiom), couplings in the design matrices were identified reflecting the interoperability problems in the dyad. Although the Fuzzy sets models in application scenario 1 provides a general view of interoperability conditions, being the main aim of the research identify and solve interoperability by means of re-design, the use of AD replaced the need for an MCDM model. The application of 1st axiom provides a more detailed perspective on the interoperability perspectives and the way are approached on the industry-context, by illustrating the decision-making between the interoperability requirements (FRs) and the interoperable solutions (DPs) companies apply. Additionally, the solving of coupled matrices permits to devise new solutions that comply with 1st axiom. The AD was considered fit both to address the analysis and solving of interoperability problems, by implementing the 1st axiom.

An early conception of the method assumed the main customer need (CN) as the improvement of interoperability in the implementation of supply chain management (SCM) practices. This proposition was replaced by the improvement of interoperability in SCOR interactions. Despite SCM practices portray an important part in the effective and efficient management of the SC, practices can be seen the solution space that aims at better management of SC and, consequently, can also be seen as a solution to some interoperability problems. The SCM practices and constructs presented in (in section 2.2.2) and aligned with the BI perspectives in Chapter 6 (in section 6.1), convey the idea that those are aligned with the advocated drivers of interoperability. SCM practices provide a management solution to SC and the context of application, which can be understood under the BI perspectives. For a specific interoperability requirement, the underlying SC context may require the implementation of a SCM practice that delivers higher interoperability or, in case of that one proves inadequate to solve the interoperability problem, new interoperability practices (represented in the DPs' solution space) may be formulated adding to previous knowledge both in BI and in SCM.

The application scenario 3 acknowledged the previous findings, and advanced to the implementation of the method at the physical level. So far, the method was developed to map interoperability conditions from conceptual to physical level, in terms of FRs and DPs. The proposition of using the modelling techniques business process modelling notation (BPMN) and design structure matrix (DSM) served the purpose of representing the mappings in terms of buyer-supplier dyads' operations and processes. The combination of both modelling techniques contributed to the decomposition process introduced in section 6.2.4 and to the generation of new scenarios in section 6.2.5.2.

In the 4th application scenario was proposed the integration of discrete-event simulation to study the impact of BI in buyer-supplier dyad's performance. The model is based on a set of BI conditions that were modelled using BPMN and translated to a simulation model. The application of SCM and interoperability metrics is also proposed to measure the impact of BI in the dyad's performance. The model allowed the testing of different scenarios, that refer to alternative interoperability conditions, where was confirmed that is possible to study interoperability improvements. This approach is incorporated as part of the optimisation procedure presented in section 6.2.5.

7.2. Case study design/preparation

After having finished the ADADOP method, and previously tested it in application scenario, the case studies were designed. At this point, some considerations were made considering the case selection, the characterization of the unit of analysis, choosing the number of cases, the selected data collection methods and the implementation procedure.

Case selection

The unit of analysis in this case is the buyer-supplier dyad operating upstream the SC. The case selection was performed by reviewing the companies from the rating provided in (Jornal EXPRESSO, 2013). Companies were selected on the automotive industry, contacting manufacturers and suppliers on the electronic automotive industry and electronic industry. The contacts were established by e-mail, phone and directly with known employees. To the effect, companies were first contacted by e-mail, sending a document were the scope of the research was explained (see Annex A). The follow-up as made by phone, using a communication protocol to explain the project and determine the interest on participating on the research project. Last, for the companies who agreed, a description of the case study with the necessary data to be collected was sent (see Annex F), and a personal meeting was set-up to discuss the implementation of the cases.

From the contacts established early, a firm agreed to participate in the research as the buyer (focal firm), showing available to introduce the suppliers upstream that would compose the dyad (due to non-disclosure agreements, the firm wasn't allow to reveal data regarding customers nor their participation). On the second stage, the selection of suppliers was made by questionnaire to the buyer (see Annex G). In this one, the firm was inquired to fill up to 10 companies, to select the most relevant supplier for the case. On the second stage, the author of this thesis presented the research in the buyer's installation during a meeting with suppliers to introduce to method, the case study implementation procedure and required data.

In the supplier selection process, despite the interest of three firms in the participation, and although data was collected regarding these companies, due to time constrains and the difficulty to collect more data from two firms outside Portugal the preferred approach was 4 in-depth case studies from 4 interaction contexts, centred on a buyer-supplier dyad consisting of the buyer and the selected supplier. The objective in this approach was to address different perspectives of the SCOR operations to test the full scope of the ADADOP method.

Companies' description

The selected companies are presented as follows:

- **First supplier (FS)** – The focal firm (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 few with plants in Portugal.

- **Second supplier (SS_1)** – $SS_1$is a company located in Portugal, which produces copper wire for automotive and communications industries. The relationship with FS is to provide copper wire in order for this one produce injection coils. The product has high specificity due to the complexity of the final product. The copper wire is ultra-fine and requires an enamel coating to insulate the copper. In turn, this one must permit to glue with the external case by using a resin applied at high temperature. The fulfilment of these requirements is of high relevance to FS, having established a long-term strategic partnership with SS_1.

  SS has high integration in the development and conception of its products. They acquire raw materials and produce copper wires, the enamel used for coating, the machines to produce enamel and also the machines to winding wire. 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.

Upon the agreements to cooperate with the present research, both companies solicited confidentiality in of the collected data and in the results of the case studies, displaying no intention in revealing their companies' names in the present thesis and publications.
Table 7.2 makes the characterization of the dyad's companies.

Table 7.2. Dyad's companies profile

Company	FS (Buyer)	SS (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

Implementation procedure and data collection

The implementation of the case studies was made using the proposed A+D stages (see section 6.2.1) according to the diagram presented on Figure 7.1.

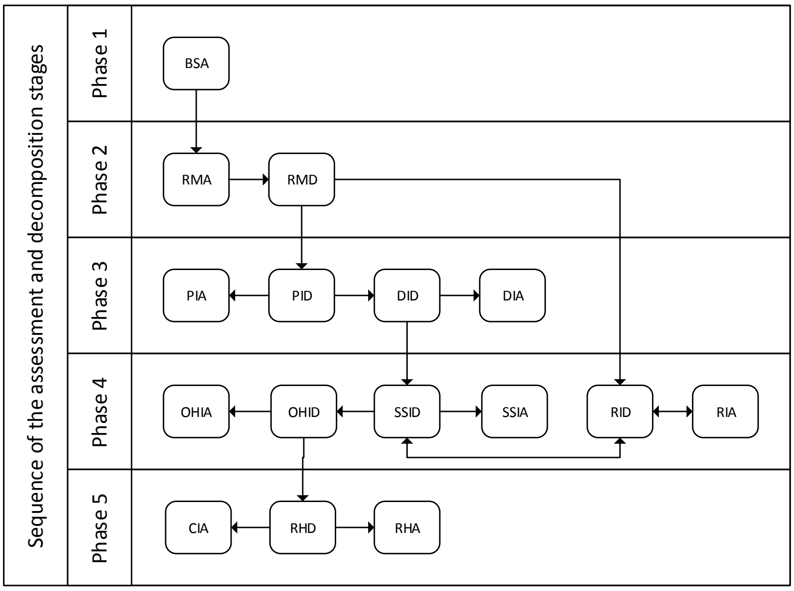


Figure 7.1. Case studies implementation procedure.

The data was collected in 5 phases, where different aspects of business interoperability (BI) were addressed according to the sequence in the presented figure. The data collection methods used during those phases was a combination of interviews, questionnaires, analysis of firm's documentation and direct observation.

Prior to the implementation of the A+D stages, were performed the following preparations:

- First meeting with FS's to gather general information regarding implemented processes.
- A tour inside FS's plant to observe manufacturing processes and another sections.
- The soliciting of FS's documentation.
- Selection of FS's suppliers for case study.
- Presentation of the research project to suppliers.
- The soliciting of supplier's documentation.
- Companies' documentation and early collected data during meetings were analysed and the subsequent questionnaires for the next phases were elaborated.
- Based on the same data, early drafts of the AD framework and BPMs were made.

Then, the A+D stages were applied:

1. **Phases 1 and 2:** in the next meetings in FS, based on the standard contracts available by the companies, were discussed the agreements' specifics. The first questionnaire corresponding to phases 1 and 2 was implemented. Additional notes were gathered to validate previous data, and to complement information beyond the questionnaire. On SS_1, the questionnaire was answered by mail.

2. **Phase 3:** Previously drafted BPMs were validated in interviews with FS, and by e-mails exchanged with SS. Additional data was collected referring to processes (e.g. production time, lead-time, etc.) to support the simulation model.
3. **Phase 4:** After representing the business processes, in phase 4, software, systems and hardware were addressed. The analysis of companies' documentation permitted to determine which systems were implemented and a prior questionnaire allowed to infer about how companies qualify interoperation in those aspects. The main issues regarding the use of systems and devices were discussed with the firms personally (with FS) and by phone (with SS_1).
4. **Phase 5:** In the last stage was addressed the users associated to previously modelled processes. Data was collected regarding HRA through adapted questionnaire featuring the processes were users are involved. Additionally, some processes in FS were observed and recorded in order to obtain parameters for simulation. On the impossibility to measure all the processes, data was requested having the firms made available the parameters they consider to reflect the processes and activities execution.

The applied questionnaires during those phases are following:

- Phases 1 and 2 questionnaires (see Annex H).
- Phases 3, 4 and 5 questionnaires (see Annex I).

To ensure the validity and reliability of the case study, some methods were implemented:

- The use of different sources (interviews, questionnaires, analysis of companies' documentation and direct observation).
- The keeping of a chain of evidence through systematic record keeping of interviews, questionnaires, direct observation timing, and the recurrent validation the collected data (e.g. verification of BPMs with interviewees) between interviews. The chain of evidenced was maintained in hard copies (paper) and digital storage in database created for case studies and computer files.
- The use of protocols and questionnaires to support interviews.
- The use of different interviewees.
- The gathering of the same information in the different perspectives of the interaction (i.e. the dyad's actors view of the same subject).

7.3. Case studies description – the dyad's business set-up conditions

As mentioned before, the performed case studies address the same buyer-supplier dyad ($FS\text{-}SS_1$) in four different perspectives (the buyer-seller interaction, the delivery-reception interaction, the faulty orders handling and the global view of the dyad). The early stages of the ADADOP method were performed jointly, addressing the business set-up conditions (BS and RM) that set the same basis for subsequent processes, inherent to each one of the case studies.

The main customer need (CN) for the dyad was established as to "achieve optimal interoperability in the interactions of the $FS\text{-}SS_1$ dyad". Specific CNs for each case study will be addressed, although they fit under the scope of the main CN. To achieve this CN, it is proposed that one has to 'ensure high levels of interoperability in the dyad interactions' (FR_0) through a 'systematic design of the dyad' (DP_0).

Business strategy

Through interviews, questionnaires and analysis of firms' documentation, the main agreements that characterize business strategy (BS) perspective of interoperability were analysed. Among those, two were distinguished as the basis for the addressed perspectives:

- The purchasing and selling conditions (specifying roles, delivery agreements, planning horizon, delivery locations, liabilities and penalties);
- Liabilities for delivery failures.

The first aspect refers to regular interaction in sourcing and delivery operations, and the associated interactions. The second refers to special context of that interaction. Those were distinguished due to different approaching with regards to the impact on subsequent processes, which are explored in the case studies.

The first condition to assess in the dyad is business strategy (BS). The establishment of the cooperation goals (FR_1) and the settlement of an agreement on the beginning of their relationship characterize BS. By negotiating the conditions and ground rules for business (DP_1), companies accomplish FR_1. Based on firms' assessment, through the analysis of BS (i.e. BSA) during data collection, was possible to determine the interoperability level in terms of Business goals definition (BS_1), clarity of strategic goals (BS_2), and business strategy alignment (BS_3). Those conditions were mapped using AD from conceptual to physical and processes levels (see Table 7.3).

Table 7.3. Dyad's BS interoperability conditions.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process variables (PVs)
$FR_{1.1}$: 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.	$PV_{1.1.1}$: The delivery lead-time allotted to the purchase orders is 7 days (5 working days).
$FR_{1.1.2}$: 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.	$PV_{1.1.2}$: Negotiate penalties in case of failure to the commitments.
$FR_{1.1.3}$: Ensure a clear business strategy for both actors.	$DP_{1.1.3}$: Occasional failures in cooperation.	$PV_{1.1.3}$: Follow the cooperation objectives specified in the contract.
$FR_{1.2}$: 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.	$PV_{1.2.1}$: Contingencies: in case of delays, the supplier must arrange an alternative transport supporting its costs; in case of order failure, supplier supports the total costs.
$FR_{1.2.2}$: Reconcile liabilities for delivery failures with the individual strategy.	$DP_{1.2.2}$: The objectives are fully aligned.	$PV_{1.2.2}$: FS has a procedure to identify and give response to delays; SS has an after-sales department to deal with delays, failures and returns.
$FR_{1.2.3}$: Ensure clarity in liabilities for both actors.	$DP_{1.2.3}$: Occasional failures.	$PV_{1.2.3}$: In case of delays or order failure, solve the problem on an ad-hoc approach and negotiate penalties.

The corresponding design matrices for FRs-DPs and DPs-PVs is given in Figure 7.2.

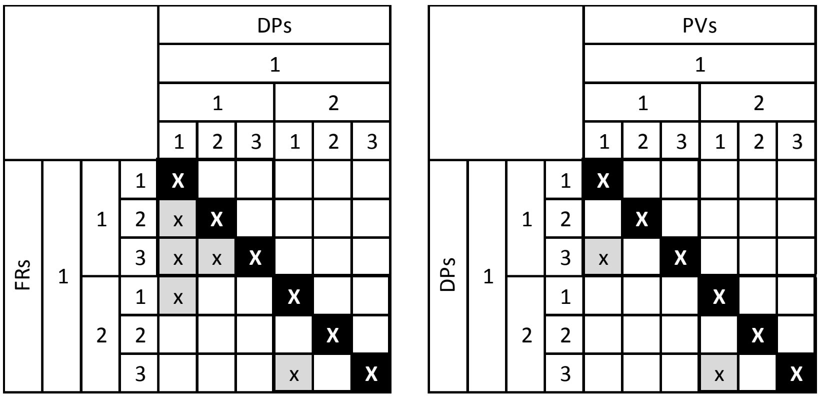


Figure 7.2. Design of dyad's business strategy.

With regards to the first agreement, the establishment of purchasing and selling conditions (FR1.1), there is lack of interoperability in some issues registered in the design matrix. 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_1 presented a different opinion with regards to the strategy defined for the collaboration. The objectives were strongly imposed by FS, not completely aligned with individual objectives, being remarked with occasional failures in cooperation. The resulting design matrix is given by equation (7.1).

$$\begin{bmatrix} FR_{1.1.1} \\ FR_{1.1.2} \\ FR_{1.1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} DP_{1.1.1} \\ DP_{1.1.2} \\ DP_{1.1.3} \end{bmatrix} \tag{7.1}$$

The couplings on the matrix are due the lack of proper negotiation, alignment and clear communication of strategic objectives. In practice, the approach to those issues is address by the DPs (see Table 7.3). The misalignment of objectives and the inability to clearly communicate what are the objectives for cooperation, leads to couplings that require that the contract conditions being constantly checked and applied in interaction. Proof of that, is the procedure to place orders between companies. When an order is placed, FS accompanies the order schedule with the terms and conditions for the specific part they are purchasing. When delivering the parts, SS accompanies the order with the selling conditions. Upon occurrence of conflicts, the strict negotiation of contract conditions occur prior to the conflict, instead of being adequately negotiated in the dyad's set-up. At the process level, the DPs are executed by the PVs in Table 7.3. $PV_{1.1.1}$ defines the conditions for the agreement (in this case, was emphasized the lead-time, despite another agreements took place). The lack of alignment of BS is approached by negotiating the penalties when failure to commitments occurs ($PV_{1.1.2}$). And, last companies have to follow the cooperation objectives specified in contract ($PV_{1.1.3}$) in order to maintain the objectives clear for both partners when cooperating.

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.

The second agreement remarks the same issues regarding objectives negotiation and their clear communication. Both firms disagreed in terms of the objectives negotiation, being, once again, remarked as a contract signing with impositions from FS, and the occurrence of conflicts. Nevertheless, the alignment of this agreement with individual objectives was performed adequately. At the process level, PVs characterize the approach to the BS definition (see Table 7.3). Contingencies were set in place by FS that affect SS when order failures occur ($PV_{1.2.1}$), and problem solving on an ad-hoc basis is executed when conflicts occur ($PV_{1.2.3}$), where the liabilities specified on the contract are analysed and set in place by negotiation. Though, as mentioned, the alignment of the objective with individual strategy was adequately defined. That is operationalized by $PV_{1.2.2}$, where both companies incorporated the means to solve delivery failures. FS implements a procedure to handle delays or incomplete orders, and SS has an after-sales department to quickly solve delays, incomplete orders or returns.

Relationship management

RM was the second addressed aspect referring to the business set-up conditions. In this one, the stages RMA and RMD were implemented to qualify interoperability and to determine what measures the companies devised to maintain partnership collaboration, or to cope with abrupt termination. The interoperability requirement (FR_2) for this aspect is to "manage cooperation" (FR_2) by implementing "measures to maintain cooperation" (DP_2). The existing conditions were mapped and are presented in Table 7.4.

Table 7.4 Dyad's RM interoperability conditions.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{2.1}$: Distribute governance in the dyad.	$DP_{2.1}$: Unilateral power distribution.	$PV_{2.1}$: FS is the governing firm and all decisions affect directly SS.
$FR_{2.2}$: 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.	$PV_{2.2.1}$: SS is responsible for receiving orders from the focal firm, produce, pack and deliver the goods in the specified times and supporting all the costs.
$FR_{2.2.2}$: Assign responsibilities to the focal firm.	$DP_{2.2.2}$: Well-defined. The responsibility and roles assignment is not an issue.	$PV_{2.2.2}$: FS places orders, delivers the production schedules and forecasts, manages the relationship by monitoring it onsite, receives the goods, labels, inspects and performs the payments.
$FR_{2.3}$: Manage cooperation in its initiation.	$DP_{2.3}$: Selection of a certified supplier.	$PV_{2.3}$: SS was selected according to the FS corporate group rating and evaluations.
$FR_{2.4}$: Monitor cooperation.	$DP_{2.4}$: Record of partnership metrics and audits.	$PV_{2.4}$: Implemented strategic internal business, business relationships and customer service dimensions and tactical performance metrics.
$FR_{2.5}$: Manage cooperation during its realisation.	$DP_{2.5}$: 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.	$PV_{2.5.1}$: SS is classified as strategic partner having established a long-term relationship that has endured more than 10 years.
$FR_{2.5.2}$: Assess and review cooperation progress during the cooperation.	$DP_{2.5.2}$: Annual meetings to review partnership performance.	$PV_{2.5.2}$: Cooperation problems are solved in a case-by-case approach. An IT platform was created in order to report problems. So far, no revision period was specified for this relationship.
$FR_{2.5.3}$: Establish a mechanism to deal with premature cooperation breakdown.	$DP_{2.5.3}$: Preventive contract condition to keep the steady supply after cooperation breakdown.	$PV_{2.5.3}$: The focal firm may extend the contract for one more year until finding a new supplier.
$FR_{2.6}$: Establish a risk management system.	$DP_{2.6}$: The mitigation and contingency plans for disturbances	

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
	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.	$PV_{2.6.1}$: FS may: (a) acquire the goods from another source; (b) oblige the SS_1 to provide the existing goods (from inventory); (c) oblige the SS_1 to provide work in progress materials (d) oblige the SS_1 to provide the useful raw materials.
$FR_{2.6.2}$: Contingency plan for delays in information transmission/communication	$DP_{2.6.2}$: Alternative procedure for communication.	$PV_{2.6.2}$: In case of the normal communication setting fails, e-mail and phone is used as a parallel procedure that happens frequently. For instance, to reinforce the order placement, an additional call or e-mail may be performed.
$FR_{2.6.3}$: 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.	$PV_{2.6.3}$: Orders are checked on a model based on ABC sampling. In case of missing parts in the order, the supplier is contacted to send additional parts, and to correct the invoice.
$FR_{2.7}$: Ensure the partners have the adequate skills to perform SC activities.	$DP_{2.7}$: Appropriate skills for cooperation.	$PV_{2.7}$: The training and competences are a requirement assessed during the sourcing and supplier selection phase.

Symbols: RM_1 - Partner selection; RM_2 – cooperation realisation management; RM_3 – cooperation termination; RM_4 – cooperation monitoring; RM_5 – Roles and responsibilities; RM_6 – conflict and risk management; RM_7 – governance distribution; RM_8 – knowledge management.

The RM conditions were mapped internally and with relation to the prior BS conditions. Hence, the design matrices for RM are presented in Figure 7.3 and in Figure 7.4.

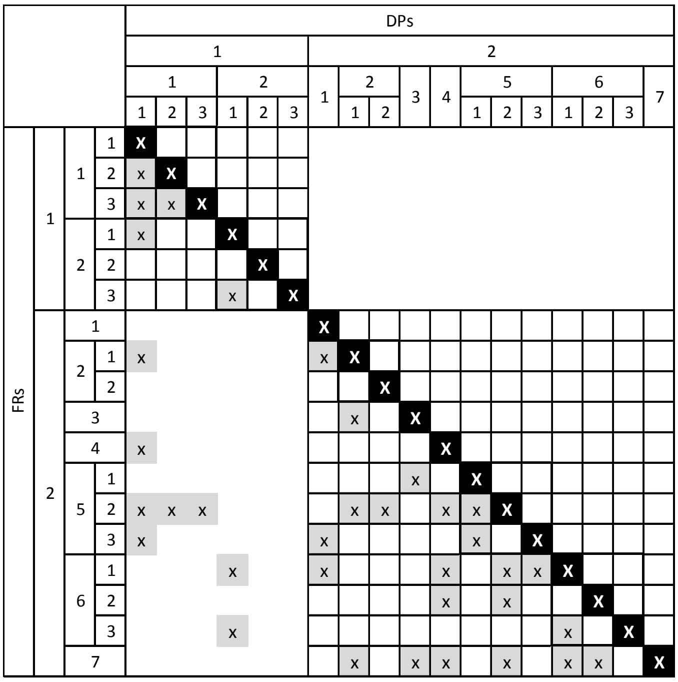


Figure 7.3. Design matrix of dyad's BS and RM conditions (mapping between FRs and DPs).

			PVs																	
			1						2											
			1			2			1	2		3	4	5			6			7
			1	2	3	1	2	3		1	2			1	2	3	1	2	3	
DPs 1	1	1	X																	
		2		X																
		3	x		X															
	2	1				X														
		2					X													
		3				x		X												
DPs 2	1								X											
	2	1							x	X										
		2									X									
	3								x			X								
	4												X							
	5	1												X						
		2											x		X					
		3							x							X				
	6	1							x								X			
		2																X		
		3																	X	
	7									x		x								X

Figure 7.4. Design matrix of dyad's BS and RM conditions (mapping between DPs and PVs).

Interoperability conditions within RM

Regarding dyad governance ($FR_{2.1}$), FS is notably the governing firm. Both companies agree that whatever decisions FS takes will affect SS_1, agreeing in the same interoperability level for this aspect. This has particular impact on the responsibility assignment and in implementing changes in SS_1 production. FS strictly imposes the business model implemented in the dyad.

Responsibility assignment is an issue reflected on $FR_{2.2}$. This issue affects directly the process distribution internally and on the interface processes (addressed in FR_3). The assessment for this issue is the highest level of interoperability, considering that there are no responsibility gaps and the role assignment is adequate. However, role assignment is closely related with the power distribution on the dyad. Overtime, FS pursues the adequate responsibility assignment, trying to push non-added value activities to ease the product reception and coordination of receptions with other supplier products.

The partner selection refers to the management of the dyad before a contract ($FR_{2.3}$). SS_1 was selected according to a pre-selection of the FS corporate group companies ($PV_{2.3}$). To select the partner a certificated supplier ($DP_{2.3}$) was chosen, rather than the broad assessment of the competences performed by FS.

With regards to partnership monitoring ($FR_{2.4}$), the firms didn't disclose metrics they currently implement. Though, the approach for this aspect is made by keeping record of partners' performance and audits ($DP_{2.4}$). Based on the nature of the studied interactions, is suggested the implementation of strategic and tactical performance measures.

The 5th sub-FR of FR_2 refers to the management of cooperation during its realisation. This one is achieved by the relationship measures that ensure the cooperation duration and adequacy to the dyad needs ($DP_{2.5}$). The relationship between FS and SS is considered by FS as a strategic long-term partnership ($DP_{2.5.1}$), which has endured for almost 10 years. The relevance of SS_1 for FS is high, because the supplied materials are present in every component built in FS. As a consequence, $FR_{2.5.2}$ and $FR_{2.5.3}$ depend on $DP_{2.5.1}$, leading to the establishment of this measures that permit to accompany the relationship and prevent it from breaking down. Partnership assessment and review ($FR_{2.5.2}$) is performed by annual meeting to review the partnership performance ($DP_{2.5.2}$). Regarding this aspect, FS arguments that this number of meetings is sufficient to keep track of the partnership. Contract impositions keep the relationship tight in $FR_{2.5.3}$. In the event of the collaboration breakdown, $DP_{2.5.3}$ obliges SS_1 to continuing supplying products. In practice, FS may extend the contract one year more until finding a new supplier ($PV_{2.5.3}$).

Concerning the risks companies are subject due to lack, or momentary lack, of interoperability, the companies from dyad 1 have established a risk management system ($FR_{2.6}$) by implementing mitigation and contingency plans ($DP_{2.6}$). Like in the case of $FR_{2.5.3}$, $FR_{2.6.1}$ is accomplished by contract obligations and, also, the implementation of a secondary supplier for the same product when delays in delivery occur. Regarding delays in information transmission/communication, both companies use an alternative procedure for communication ($DP_{2.6.2}$). If the normal communication fails, e-mail and phone are used as a parallel procedure ($PV_{2.6.2}$). Though, this procedure is being used more often than in the case of communication problems. Last, the third risk that is managed is the occurrence missing items in the received orders ($FR_{2.6.3}$). To deal with this situations, FS implements a standard procedure of verification upon material and components reception, and an exceptional procedure to deal with the contact with SS_1 (and other suppliers) to solve the situation ($DP_{2.6.3}$ and $PV_{2.6.3}$). This one is decoupled due to the dependency of $FR_{2.6.3}$ from $DP_{2.6.1}$. The execution of the procedures to solve the identification of missing parts in orders is similar to a delay. There are contract obligations for this cases and SS_1 still needs to arrange an alternative (express) transport to quickly deliver the missing parts.

The last FR of relationship management refers to the knowledge management in the dyad. Both actors consider that each one possesses the appropriate skills for cooperation ($DP_{2.7}$). It was also remarked that never occurred a problem due to lack of training or capacity to perform the tasks on the dyad interaction.

The impact of BS in RM

On the mapping between FRs and DPs (see Figure 7.3), it is evident the influence of the BS aspects on RM. Contract impositions and the occurrence of failures in cooperation are evidenced in most of the RM's FRs. For instance, the definition of the SS_1's roles in cooperation ($FR_{2.2.1}$), the partnership monitoring ($FR_{2.4}$), the revision of competencies during cooperation ($FR_{2.5.2}$) and the mechanisms to prevent cooperation breakdown ($FR_{2.5.3}$) are strongly influenced and conditioned by the signed contract ($FR_{1.1.1}$). This influence reinforces the need to keep track of partnership progress in order to implement the adequate measures to avoid prejudice of the business activities. The existing failures in cooperation, remarked on the decomposition of $FR_{1.1}$, are the motive for the partners review the cooperation progress. However, this cooperation revision is not accompanied regularly (only once per year ($PV_{2.5.2}$). Preventive measures for cooperation breakdown established by contract ($DP_{2.5.3}$) is the FS's solution to deal with failures in the cooperation ($FR_{2.5.3}$). This measure leads to ad-hoc problem solving, involving legal issues and disputes instead of an open discussion.

The mapping between DPs and PVs demonstrate the practical implementation of FRs and DPs. The power distribution on the dyad ($FR_{2.1}$), is achieved by the unilateral power distribution (DP) that is, in turn, achieved by $PV_{2.1}$, which states that FS is the governing firm. This has particular influence in the RM aspects of the dyad. Namely, the fulfilment of $DP_{2.2.1}$, $DP_{2.3}$ and $DP_{2.5.3}$ are performed having in consideration that FS imposes power and conditions on the fulfilment of RM activities.

The next stage in the application of ADADOP method was to address the internal and interface processes in the dyad. Here is where the case studies diverged and, hence, are addressed in separate sections. The first step to address process interoperability was to identify the processes involved in the firms' interaction (see Figure 7.5).

				FS									SS				
				dD1	dP2	dP1	dS1	dS2	dS3	dM	dR	dD2	xD1	xP	xM	xD2	xD3
Dyad operations	FS	Sales	dD1	X													
		Purchasing planning	dP2	x	X	x											
		Production planning	dP1	x	x	X		x									
		Purchasing	dS1		x		X	x	x				i3				
		Reception	dS2				x	X		x	x						i2
		Payments	dS3					x	X		x					i	
		Production	dM			x		x		X							
		Return	dR					x		x	X						
		Delivery	dD2							x		X					
	SS	Sales	xD1				i1						X	x			x
		Plan	xP										x	X			
		Production	xM											x	X		
		Accounts	xD2					i					x			X	
		Pack and Deliver	xD3										x		x		X

Figure 7.5. DSM illustration of the dyad's processes.

The FS's processes range from plan, source, make, deliver and return operations, and SS_1's operations feature the deliver, plan, make and return operations. The FS's internal processes encompass the supply chain operations since the customers demand received in the sales (dD1) process, ending with the delivery (dD2) of the final product (injection coil) to the customers. In this dyad, the implementation of reverse logistics (RL) is not an issue raised by FS. The reverse flow of materials is

based on the purchase of scrap. Therefore, the return operation is not addressed in this dyad. Hence, sourcing operations dS1 and dS3 are the considered FS's operations. The first processes in FS (dD1, dP2 and dP1) are only considered to initialize the simulation model with the customers' demand data. Although the payment operations (dS2) were noted as low interoperable by the two companies, the procedure is imposed by the FS's corporate group and distributed along 3 FS's partners and 2 datacentres. Hence, for the current dyad the studied interactions are the following: buyer-seller interaction (i1), expedition-reception interaction (i2) and faulty orders handling (i3).
From full scope of the dyad's operations, four perspectives were selected for the case studies:

- **Case study 1 (D1CS1)** – Buyer-seller interaction.
- **Case study 2 (D1CS2)** – Expedition-reception interaction.
- **Case study 3 (D1CS3)** – Faulty orders handling.
- **Case study 4 (D1CS4)** – Full sourcing-delivery operations.

Case studies 1, 2 and 3 address the dyad's interaction individually. Case study 4 studies the dyad as a whole, approaching interoperability improvement in all the three interactions.

7.4. Case study 1

The objective of this case study is to improve interoperability in the buyer-selling interaction (i1) of the FS-SS_1 dyad. The CN for this case is to "achieve optimal interoperability in the buyer-selling interaction of the FS-SS_1 dyad".

7.4.1. Interoperability characterization and modelling of processes and resources

Having determined the business set-up conditions for the dyad's interaction, the subsequent steps in the application of the ADADOP method refer to the identification, modelling and interoperability assessment of processes and the associated resources. The arrangement of interoperability perspectives in the AD framework follows a process-centred approach, where the resources are addressed with regards to the processes they are associated.

The FR for this interaction is to "model and manage the buyer-seller interaction" ($FR_{3.1}$), which is accomplished by the "features of FS's and SS_1's procedures to handle orders, since order placement to fulfilment" ($DP_{3.1}$).

Figure 7.6 represents the main processes involved in the interaction. Responsibility assignment was addressed in the business set-up conditions (see $FR_{2.2}$ in Table 7.4). The processes involved in i1 start on the FS's purchasing process (dS1), where the order is placed, and the interaction ends when the copper wire rods are delivered, fulfilling the order.

				FS		SS_1			
				dS1	dS2	xD1	xP	xM	xD3
Dyad operations	FS	Purchasing	dS1	X					
		Reception	dS2		X				x
	SS_1	Sales	xD1	i1		X	x		x
		Plan	xP			x	X		
		Production	xM				x	X	
		Pack and Deliver	xD3			x		x	X

Figure 7.6. Supply chain operations involved in the purchasing-selling interaction.

The implementation of the A+D stages permitted the identification, decomposition and assessment of processes and resources associated to the processes required to perform i1. The design of this interaction is presented on Figure 7.5.

Table 7.5. The “as-is” design of the buyer-seller interaction.

Interoperability Requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.1}$: 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 Figure 7.9).	
$FR_{3.1.1.1}$: Model the process sequence of FS processes.	$DP_{3.1.1.1}$: Sequential procedures with low interaction dependency.	$PV_{3.1.1.1}$: Purchasing and reception procedures occur independently. One user performs the inventory planning and the parts ordering.
$FR_{3.1.1.2}$: 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.	$PV_{3.1.1.2}$: One user from inventory planning and parts ordering section checks MRP on SAP and prepare e-mail with the order scheduling.
$FR_{3.1.1.3}$: Align purchasing and reception with FS organisationalPI_2 structure.	$DP_{3.1.1.3}$: Functional process distribution by matching a process to a section (see Figure 7.9).	$PV_{3.1.1.3}$: Parts ordering section for orders placement and validation activities and reception section for the material arrivals. The user in parts ordering section resources is shared with previous processes of planning.
$FR_{3.1.2}$: Model and manage SS_1’s sales processes.	$DP_{3.1.2}$: SS_1 actual business process model for order reception (see Figure 7.10), order treatment (see Figure 7.11), production and delivery.	
$FR_{3.1.2.1}$: 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.	$PV_{3.1.2.1}$: Sales procedure starts the processes and interacts directly with production planning. One user performs the selling and procurement procedures and three users perform the MPS.
$FR_{3.1.2.2}$: 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.	$PV_{3.1.2.2}$: One user checks the e-mail queue and inserts the orders manually in the SAP system.
$FR_{3.1.2.3}$: Align SS_1 processes with organisational 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 7.12).	$PV_{3.1.2.3}$: Sales section employee performs selling, logistics planning and procurement activities. Production planning, production and expedition activities have dedicated sections.
$FR_{3.1.3}$: Align companies' internal processes.	$DP_{3.1.3}$: The collaborative business process model (see Figure 7.13).	
$FR_{3.1.3.1}$: 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.	$PV_{3.1.3.1.1}$: The user from parts ordering is dedicated to deal with the component ordering and contact with the user from sales and logistics section, which is responsible for FS's orders.
$FR_{3.1.3.1.2}$: 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.	$PV_{3.1.3.1.2}$: Manual entry of order data on logistics department.
$FR_{3.1.3.1.3}$: Manage the communication path to place orders.	$DP_{3.1.3.1.3}$: Standard procedure defined to communicate orders.	$PV_{3.1.3.1.3}$: One user from parts ordering (FS) sends the order and soft order data by e-mail. 1 user from sales and logistics section (SS_1) receives and processes the orders.
$FR_{3.1.3.2}$: Manage the order confirmation procedure.	$DP_{3.1.3.2}$: Features of order confirmation.	

Interoperability Requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.1.3.2.1}$: Manage the communication path to confirm orders.	$DP_{3.1.3.2.1}$: Standard procedure defined to communicate orders.	$PV_{3.1.3.2.1}$: The user from sales and logistics section confirms orders by EDI sending an ASN.
$FR_{3.1.3.2.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.1.3.2.2}$: ASN is integrated directly on SAP system.	$PV_{3.1.3.2.2}$: User from parts ordering review daily the order confirmations in order to prepare for component reception.
$FR_{3.1.3.3}$: Establish a delivery process for material flow.	$DP_{3.1.3.3}$: 3rd party freight forwarder to retrieve components from SS_1 and deliver them to FS.	$PV_{3.1.3.3}$: Delivery is agreed between SS1 and a third party freight forwarder and the components are delivered to FS in 2-3 days.
$FR_{3.1.4}$: Select metrics to monitor interface processes.	$DP_{3.1.3}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.1.3}$: Measure: order lead-time, time of interoperation for purchasing and time spent in information conversion on sales.
Symbols: PI_1 – process sequencing; PI_2 – organisational alignment; SSI_1 – application interoperability; DI_1 – communication paths; DI_2 – contact points.		

In Figure 7.7 and Figure 7.8 the corresponding design matrices are presented, and the dependencies of the addresses processes and resources with prior business set-up conditions (BS and RM) are registered.

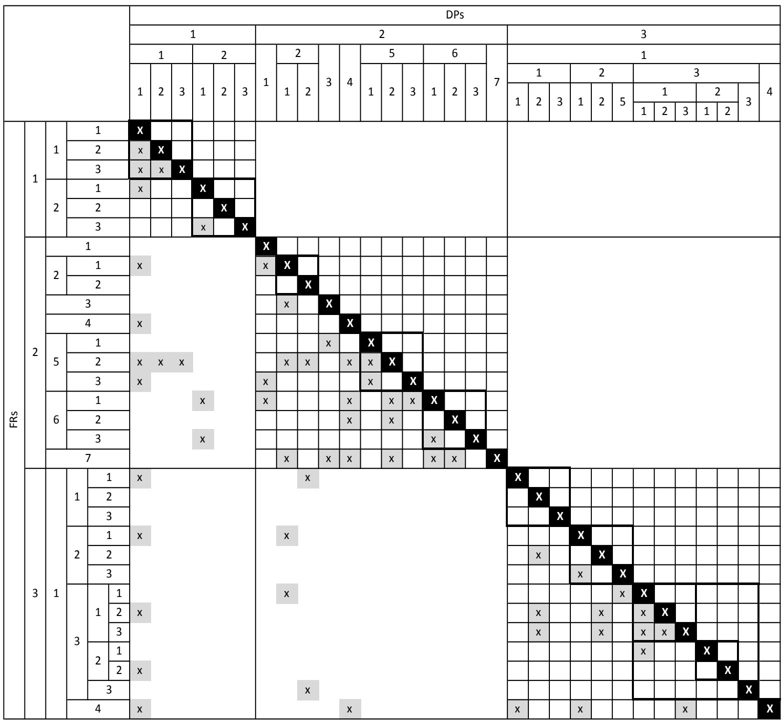


Figure 7.7. Design matrix for the "as-is" design of the buyer-seller interaction (mapping between FRs and DPs).

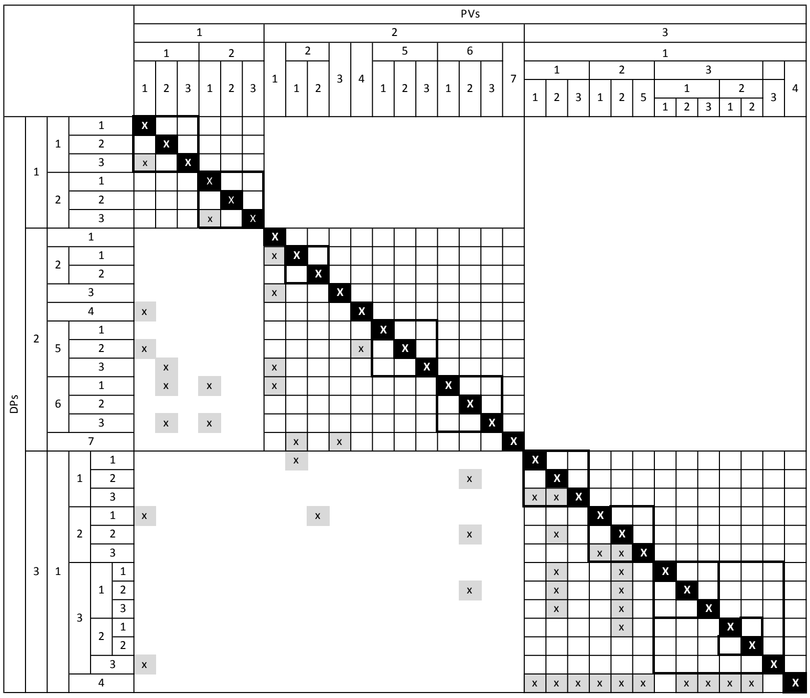


Figure 7.8. Design matrix for the “as-is” design of the buyer-seller interaction (mapping between DPs and PVs).

FS’s internal processes

The FS’s internal processes are presented in Figure 7.9. The processes are sequential, with low interaction dependency ($DP_{3.1.1.1}$) and distributed functionally each one to a specific organisational section ($DP_{3.1.1.3}$).

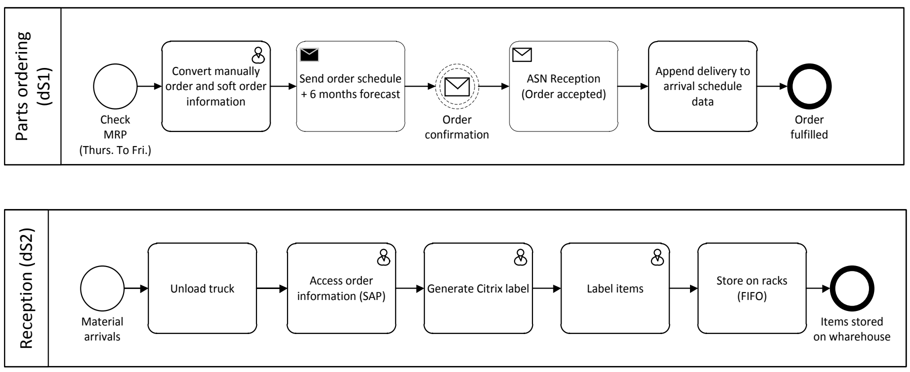


Figure 7.9. Functional assignment of purchasing and reception processes to parts ordering and reception sections, respectively.

In the analysis of the design matrix regarding FR’s internal processes (decomposition of $FR_{3.1.1}$), the matrix is uncoupled, complying with the 1st axiom. Though, the design equation for the mapping between DPs and PVs (see (7.2)) is decoupled. The motive is the sharing of resources with inventory planning activities, which occur previous to the order placement.

$$\begin{bmatrix} DP_{3.1.1.1} \\ DP_{3.1.1.2} \\ DP_{3.1.1.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} PV_{3.1.1.1} \\ PV_{3.1.1.2} \\ PV_{3.1.1.3} \end{bmatrix} \tag{7.2}$$

SS_1's internal processes

On SS_1, the processes encompass plan, delivery and make supply chain operations, accompanying the order since reception until component delivery. A coupling exists in the decomposition of $FR_{3.2.1}$ (see equation (7.3)).

$$\begin{bmatrix} FR_{3.1.2.1} \\ FR_{3.1.2.2} \\ FR_{3.1.2.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ x & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.1.2.1} \\ DP_{3.1.2.2} \\ DP_{3.1.2.3} \end{bmatrix} \tag{7.3}$$

The sequencing of activities ($FR_{3.1.2.1}$) is accomplished by a cooperative procedure between logistics planning and production planning activities ($DP_{3.1.2.1}$). In the sales and logistics business processes (see Figure 7.10) the orders are received and, in case of insufficient inventory, a production request is sent.

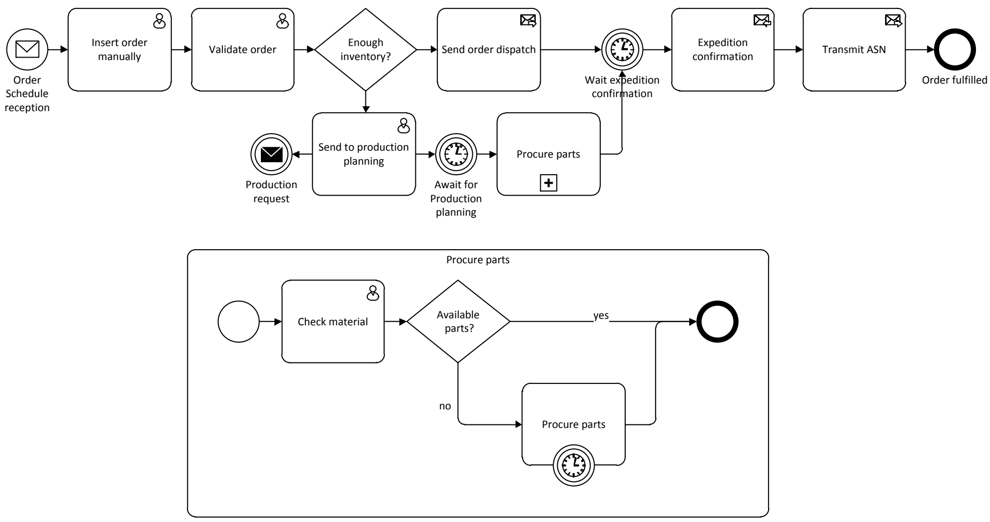


Figure 7.10. SS_1's sales and logistics business process.

In turn, the production planning process (see Figure 7.11) receives the production requests and prepares the master production schedule (MPS) that requires the validation by the sales and logistics section. This means that two different business processes depend on one another to be performed. This leads to the existence of loops on the procedures that may generate delays in their execution.

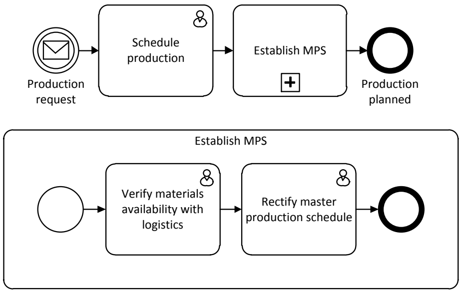


Figure 7.11. SS_1 production planning process.

On the alignment of both business processes with the organisational structures ($FR_{3.1.2.3}$), the existence of such process dependency concentrates many tasks on the same section ($PV_{3.1.2.3}$). Namely, the sales and logistics section that has to deal with order reception, and also has to validate the master production schedule (MPS) from the production planning section (see Figure 7.12).

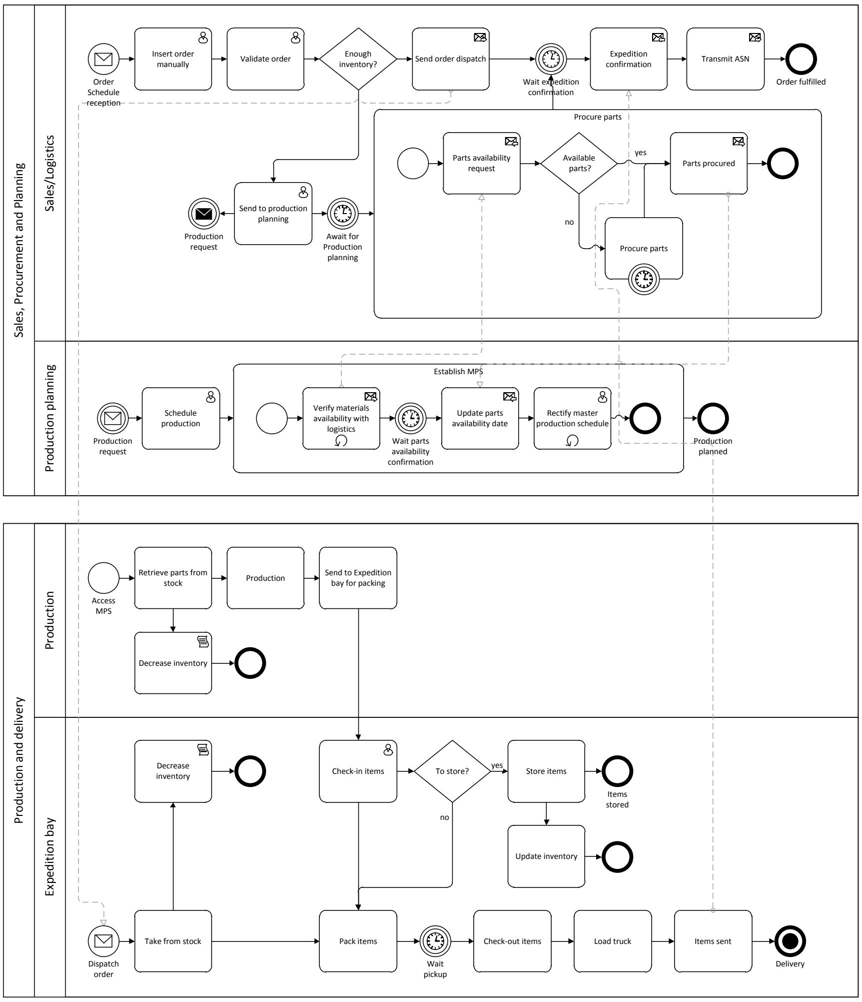


Figure 7.12. SS_1 internal processes.

With regards to the mapping between DPs and PVs for the SS_1's internal processes, a coupling was registered on the matrix (see (7.4)).

$$\begin{bmatrix} DP_{3.1.2.1} \\ DP_{3.1.2.2} \\ DP_{3.1.2.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ x & x & x \end{bmatrix} \begin{bmatrix} PV_{3.1.2.1} \\ PV_{3.1.2.2} \\ PV_{3.1.2.3} \end{bmatrix} \tag{7.4}$$

Resource quantity and distribution limit the execution of the sales/logistics and production planning processes. One user performs all the sales and logistics tasks, interacting directly with FS to receive orders, and treating the procurement of the parts required to fulfil the order. Another three users, working on production schedule section, perform only the production planning business processes but for all the company and for all the customers orders. Resource quantity and distribution should be studied through DSM and simulation.

In the performance of the sales business process, an incompatibility problem occurs due to the orders are received in an incompatible format to import in the order management system (SAP). The management of compatibility between the ICT and the SAP ($FR_{3.1.2.2}$) depends on the manual conversion that occurs in the ordering process of FS ($DP_{3.1.1.2}$). The orders are received by e-mail in pdf format, which cannot be imported directly into SAP, requiring the manual entry of information ($DP_{3.1.2.2}$). This incompatibility leads to the existence of a conversion process that, in this case, is performed by the user in sales and logistics section.

Interface processes

To establish an interface, one has to "align companies' internal processes" ($FR_{3.1.3}$) by establishing "the collaborative business process model" ($DP_{3.1.3}$) (see Figure 7.13).

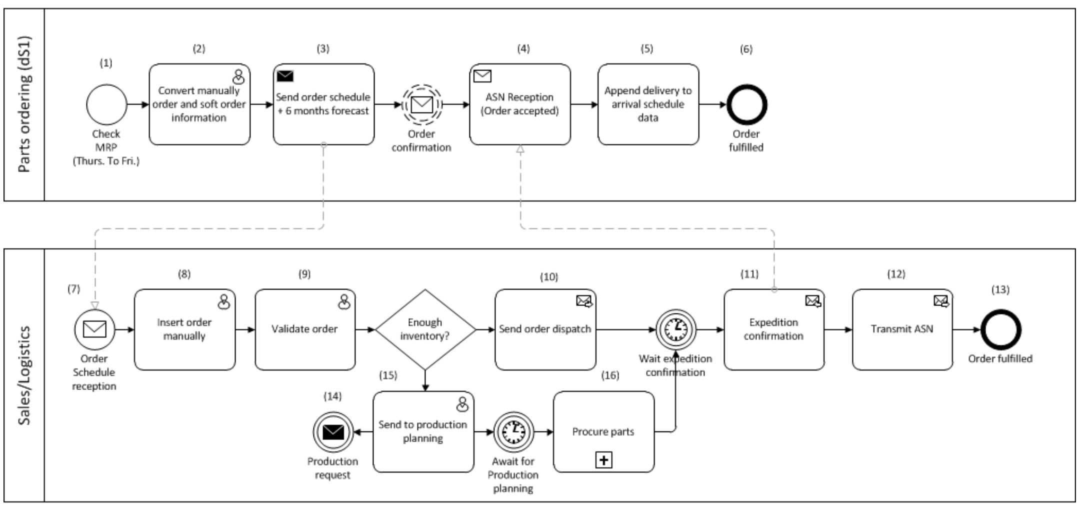


Figure 7.13. Interface between parts ordering and sales and logistics section.

The interface processes are composed by: 2 communications ($FR_{3.1.3.1}$ and $FR_{3.1.3.2}$) and 1 material flow ($FR_{3.1.3.3}$). The first interaction is performed between parts ordering and sales and logistics section.

In the first interaction, companies need to manage the order placement procedure ($FR_{3.1.3.1}$). Hence three aspects are raised: contact points' definition; systems compatibility and the communication path. In the first one, $FR_{3.1.3.1.1}$ refers to the assignment of employees to the interface for order placement/reception. In both companies, the contact points were defined. FS remarked that the contact points are, indeed, defined, but the performance is very low because there is no margin for urgent orders neither procedure to change delivery dates. Also, only one employee performs the SS_1's sales and logistics tasks (see $DP_{3.1.2.3}$).

In terms of systems compatibility on the interface ($FR_{3.1.3.1.2}$), like it was referred on $FR_{3.1.2.2}$, 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. SS_1 has to send an ASN[19], which is integrated directly on the SAP system by using an EDI ($DP_{3.1.3.2.2}$) and the procedure is well defined ($DP_{3.1.3.2.1}$).

On the analysis of the design matrices for this aspect, the design matrix referent to the decomposition of order placement procedure is uncoupled (see the decomposition of $FR_{3.1.3.1}$ in Figure 7.7). This is due to contact point definition that has impact on the interface to exchange order and soft order that, and in the communication path to send a receive the orders. The contact point assigned by SS_1 is shared with another business activities, instead of working exclusively with order reception and treatment.

In the case of the order confirmation procedure, an automated process was implemented. 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 (see the decomposition of $FR_{3.1.3.2}$ on Figure 7.7) is uncoupled.

7.4.2. Optimization procedure

After determining the existing interoperability conditions, and main conceptual problems, the next stage is to simulate scenarios that correspond to alternative solutions to "as-is" and compare them in

[19] ASN – Advanced shipment notice

order to find the scenario that delivers best performance values and, consequently, permits achieving optimal interoperability. Hence, based on the business process models elaborated for the present interaction, a simulation model was built in Arena software in order to study the different scenarios. To support the optimization procedure, performance metrics were selected fitting the business processes and operations of the interaction:

- Order lead-time (OLT);
- Total time of interoperation
- Time of interoperation for purchasing (TIP) - time spent since order placement and ASN reception.
- Time of use to plan orders (TUP) – time spent by SS_1 in order planning.
- Total time of interoperation = TIP + TUP.
- Conversion time in FS (Cv-FS) – time spent converting SAP's order data to pdf.
- Conversion time in SS_1 (Cv-SS_1) – time spent inserting orders manually on SAP.
- Total conversion time (Cv) = Cv-FS + Cv_SS

The study of alternative scenarios

From the identified interoperability problems, new scenarios can be proposed to solve the problems. As explained in section 6.2.5 (optimisation procedure), the problem solving is made in two possibilities: the improvement of existing conditions (A); and the proposal of new interoperability solutions (B). According to the enounced problems in the "as-is" design, the two possibilities will address those problems according to Table 7.6.

Table 7.6. Proposed solutions to identified interoperability problems according to A and B optimisation possibilities.

Optimisation approach	Identified problems	Proposed solutions	Impact on
A	- The use of one user to several processes in parts ordering section.	- Study a new resource quantity and distribution in activities "convert manually order and soft order data" and "append delivery to arrival schedule" (see the BPM in Figure 7.9).	FS's internal processes
	- The process sequence of sales/logistics processes and production planning processes and respective alignment. - Human resources quantity and distribution in the same processes.	- Study a new sequence and alignment. - Study the adequate number of resources for "as-is" and new sequence and alignment.	SS_1's internal processes
	- Incompatibility of order data with SS_1's SAP system.	- Study new resource distribution and quantity in sales and logistics processes.	SS_1's internal processes
B	- Data format incompatibility between ICT and FS's and SS_1's SAP systems	- Implementation of a WebEDI - Implementation of an EDI.	FS's internal processes SS_1's internal processes

A. Improvement of the existing interoperability conditions

Modifications in FS's internal processes

To improve the existing conditions in FS, is proposed the study of human resource distribution on the purchasing activities. In the purchasing business process, there are two user-based activities: "convert manually order and soft order information" and "append delivery to arrival schedule data". Currently these activities are performed by one of the three users that make the purchase planning that deals with SS_1, and other assigned suppliers. The suggestion is to study if this procedure should be done using the existing three users from the purchase planning or if FS should contract new employees to perform the purchasing activities. Also, is proposed the study if the increase of employees should be implemented across the purchasing activities or if it should aim at the manual conversion.

The suggested scenarios for FS's internal processes are presented in Table 7.7.

Table 7.7. Proposed scenarios for FS.

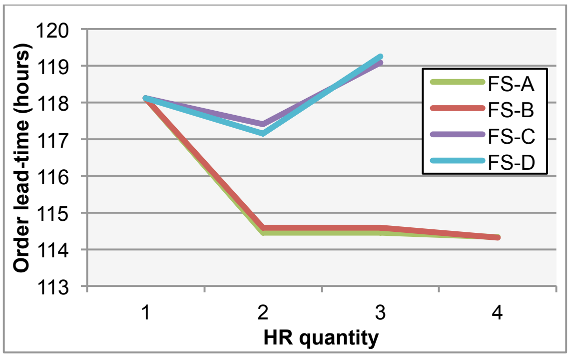
Scenarios	Changes	Employee quantity by process			
		Convert manually order and soft order data		Append delivery to arrival schedule data	
		Existing	New	Existing	New
FS-A	Maintain process distribution and add new employees.	1	[0,1,2,3]	1	[0,1,2,3]
FS-B	New users perform "convert manually order and soft order data" exclusively.	0	[1,2,3]	1	0
FS-C	Use existing users from inventory planning in parts ordering processes.	[1,2,3]	0	1	0
FS-D	Use existing users from inventory planning in "convert order and soft order data".	[1,2,3]	0	[1,2,3]	0

The simulation results for each scenario are presented in Table 7.8.

Table 7.8. Simulation results for FS's scenarios.

Scenarios	Number of employees	Order lead-time (OLT)	Time of interoperation			Conversion time (Cv)		
			Total	Time of interoperation for purchasing (TIP)	Time of use to plan (TUP)	Total	FS	SS_1
		(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-A	1	118,120	113,577	70,177	43,400	48,30	31,62	16,68
	2	114,445	104,151	66,438	37,713	48,36	31,68	16,68
	3	114,445	104,151	66,438	37,713	48,36	31,68	16,68
	4	114,327	103,932	66,324	37,608	48,36	31,68	16,68
FS-B	1	118,120	113,577	70,177	43,400	48,3	31,62	16,68
	2	114,593	104,658	66,601	38,057	48,36	31,68	16,68
	3	114,585	104,761	66,582	38,179	48,36	31,68	16,68
	4	114,317	104,015	66,345	37,670	48,36	31,68	16,68
FS-C	1	118,120	113,577	70,177	43,400	48,3	31,62	16,68
	2	117,407	111,503	69,430	42,073	48,36	31,68	16,68
	3	119,081	116,341	71,097	45,244	48,36	31,68	16,68
FS-D	1	118,120	113,577	70,177	43,400	48,3	31,62	16,68
	2	117,149	110,826	69,190	41,636	48,36	31,68	16,68
	3	119,261	116,524	71,250	45,274	48,36	31,68	16,68

The graphics presented in Figure 7.14 show the variation in terms of the selected metrics: OLT, Cv and TI, respectively.



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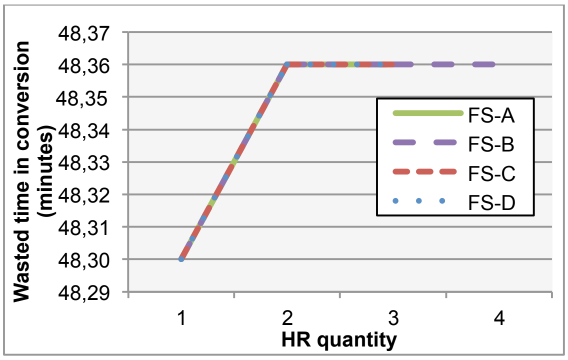

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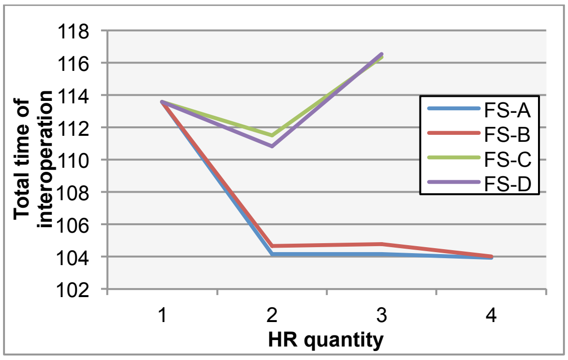


(3)

Figure 7.14. The influence of purchasing's human resource distribution in: (1) - order lead-time (OLT), (2) - wasted time in conversion (Cv); and (3) - time of interoperation (TI).

According to the selected metrics, the best solution is to contract a new employee that aids the existing employee in order conversion and schedule creation: scenario FS-A with 2 employees. Superior HR quantity doesn't increase the performance. Though, every scenario increased the value of the wasted time in conversion, but this value is of low significance (3,6 seconds per order).

Modifications in SS_1's internal processes

On SS_1, the current design approach for sequencing SS_1's process lead to cooperation between sales and logistics section and production planning section (see Figure 7.15).

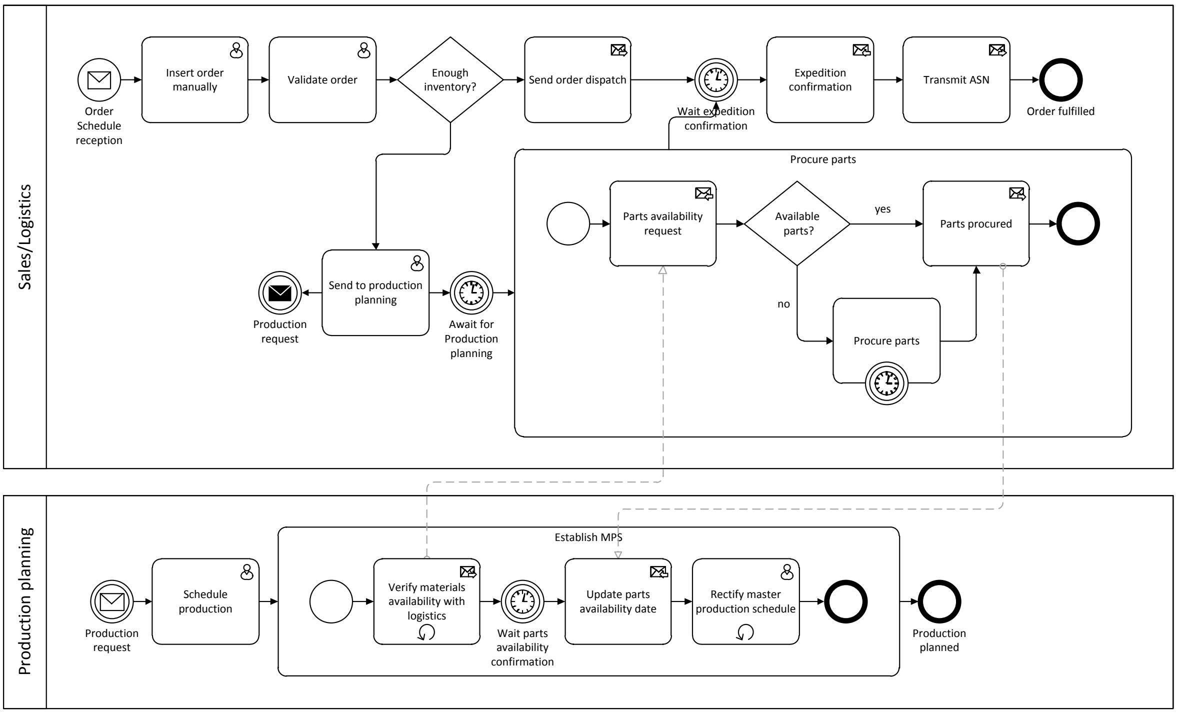


Figure 7.15. Collaboration between sales/logistics processes and production planning processes.

Although this design appears logical and functional in terms of work distribution, the existence of loops on the procedures may generate delays in their execution. To design another process sequence, DSM may be applied to reduce the loops and re-aggregate the processes in order to optimize the workflow. The processes presented in Figure 7.15 may be represented as follows (see Figure 7.16).

				Sales and logistics (xD1)						Production planning (xP)			
							Procurement				Establish MPS		
				1	2	3	4	5	6	7	8	9	10
Sales and logistics (xD1)		1	Insert order manually	X									
		2	Validate order	x	X								
		3	Send to production planning		x	X							
	Procurement	4	Check materials/parts availability request				X				x		
		5	Procure parts				x	X					
		6	Parts procured				x	x	X				
Production planning (xP)		7	Schedule production			x				X			
	Establish MPS	8	Verify materials availability with logistics							x	X		
		9	Update parts availability date						x			X	
		10	Rectify master production schedule									x	X

Figure 7.16. SS collaboration DSM for sales and production planning interactions.

The dark grey clusters on Figure 7.16 represent the pool lanes of the BPMN from Figure 7.15; and the light grey clusters correspond to the sub-models on the same figure ("procure parts" and "Establish MPS").

The first observation regarding the DSM representation in Figure 7.16 is the existence of coupled blocks. These blocks correspond to a functional division work, rather than emphasizing on the interaction itself. There are three interactions outside the boundaries of the dark grey clusters (pool-lanes on the BPMN). The first interaction is the communication between company's sections to inform that an order should be planned. The second and the third interactions correspond to a loop between the two sections. Production planning needs the sales/logistics section to inform them when the parts will be available in order to finalize the MPS. On the other hand, sales and logistics section requires information about the master production plan in order to establish the requirements in terms of quantity and date.
Applying the path searching method based on ((Steward, 1981) cited by (Eppinger & Browning, 2012; Harmel, Bonjour, & Dulmet, 2006)), the existing activities may be re-sequenced into a new process model. First, the clusters were flattened, ignoring the functional lanes and the sub-processes (see Figure 7.17).

		1	2	3	7	8	4	5	6	9	10
1	Insert order manually	X									
2	Validate order	x	X								
3	Send to production planning		x	X							
7	Schedule production			x	X						
8	Verify materials availability with logistics				x	X					
4	Check materials/parts availability request					x	X				
5	Procure parts						x	X			
6	Parts procured						x	x	X		
9	Update parts availability date								x	X	
10	Rectify master production schedule									x	X

Figure 7.17. Flattened DSM.

Applying the sequencing algorithm, the activity representation is almost linear. The activity of checking materials is conditional, which may depend on the existence of the sufficient amount of materials to fulfil the order. However, in opposition to the "as-is" design (Figure 7.15), no coupled activities were found according to the existing process decomposition. However, a constraint was found in the resource distribution of these processes. All the sales and logistics activities are performed by only one user, which is responsible for the FS's orders ($PV_{3.1.2.1}$). The production planning is performed by three users, which are responsible for planning the production for all the costumers' orders. This HR's distribution leads to a poorly sequenced activity. The users from production planning need to wait for the sales user to start and finish the materials procurement in order to close the MPS. This generates delays in order fulfilment and the users from production planning are forced to wait for the required information. Also, the physical separation between the two interacting departments leads to additional communications and un-modelled cooperation to occur. The appropriate aggregation of activities would presuppose that the people who need the most to interact, to actually work together, leading to the clustering of the closest interactions.

Representing the processes and the users on and MDM matrix, in the as-is diagram (see Figure 7.18) is evident that the work division is due to the use of the same employee for several tasks.

				Processes										Human Resources			
				Sales and logistics (xD1)						Production planning (xP)				xD1	xP		
							Procurement				Establish MPS						
				1	2	3	4	5	6	7	8	9	10	User 1	User 1	User 2	User 3
Processes	Sales and logistics (xD1)	1	Insert order manually	X													
		2	Validate order	x	X												
		3	Send to production planning		x	X											
	Procurement	4	Check materials/parts availability				X				x						
		5	Procure parts				x	X									
		6	Parts procured				x	x	X								
	Production planning (xP)	7	Schedule production			x				X							
	Establish MPS	8	Verify materials availability with lo							x	X						
		9	Update parts availability date						x			X					
		10	Rectify master production schedul									x	X				
Human Resources	xD1		User1	x	x	x	x	x	x					X	x	x	x
	xP		User1							x	x	x	x	x	X	x	x
			User2							x	x	x	x	x	x	X	x
			User3							x	x	x	x	x	x	x	X

Figure 7.18. MDM matrix of SS_1's collaboration and the human resource distribution.

Solutions for this issue may encompass a new process sequence/organization and another resource distribution. One alternative PV for $FR_{3.2.1}$, may be making the existing sales/logistics employee work exclusively on logistics planning directly with production planning - scenario SS_1-A. To ensure the sales activities, another worker may be needed. This solution is illustrated in Figure 7.19.

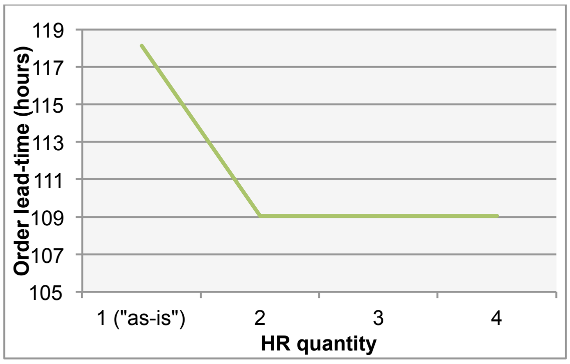
				Processes										Human Resources				
				Sales			Production and Logistics planning							xD1	Ex	xP		
				1	2	3	7	8	4	5	6	9	10	U1	E1	U1	U2	U3
Processes	Sales	1	Insert order manually	X														
		2	Validate order	x	X													
		3	Send to production planning		x	X												
	Production and Logistics planning	7	Schedule production			x	X											
		8	Verify materials availability with logist				x	X										
		4	Check materials/parts availability requ					x	X									
		5	Procure parts						x	X								
		6	Parts procured						x	x	X							
		9	Update parts availability date								x	X						
		10	Rectify master production schedule									x	X					
Human Resources	xD1		User1						x	x	x			X		x	x	x
	External		External1	x	x	x									X			
	xP		User1				x	x				x	x	x	x	X	x	x
			User2				x	x				x	x	x	x	x	X	x
			User3				x	x				x	x	x	x	x	x	X

Figure 7.19. MDM matrix of SS_1's collaboration with another employee to fulfil the sales activities.

To infer about this cooperation performance, a simulation model was used to study the influence of the current process sequence in the performance of both sections. The results are presented in Table 7.9 and Figure 7.20.

Table 7.9. Simulation results regarding "as-is" and SS_1-A scenario.

Scenario	Number of employees	Order Lead-time (OLT) (hours)	Total time of interoperation (TI) (hours)	Wasted time in conversion (Cv) (minutes)
"as-is"	1	118,12	113,577	48,3
SS_1-A	2	109,05	87,487	48,3
	3	109,05	88,487	48,3
	4	109,05	87,487	48,3



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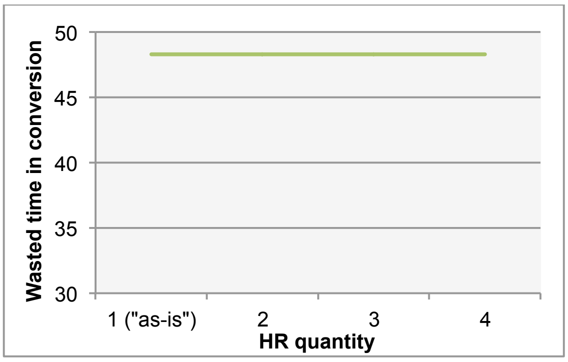

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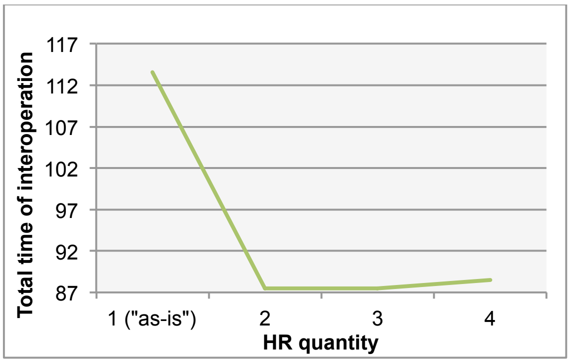


Figure 7.20. Influence of HR quantity on SS1's sales and logistics processes for SS_1-A scenario.

According to the obtained results, the contracting of an external employee to perform the sales activities in exclusive provides a better solution than the "as-is" situation. OLT decreases in 9 hours and the TI decreases 26 hours, if we contract one or two new employees.

However, this solution may interfere with $DP_{3.1.2.2}$. The resulting design matrix is given by the equation (7.5).

$$\begin{bmatrix} DP_{3.1.2.1} \\ DP_{3.1.2.2} \\ DP_{3.1.2.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ x & x & 0 \\ 0 & 0 & x \end{bmatrix} \begin{bmatrix} PV_{3.1.2.1} \\ PV_{3.1.2.2} \\ PV_{3.1.2.3} \end{bmatrix} \tag{7.5}$$

Solutions to mitigate the conversion problem may consist in providing a new design approach for the systems compatibility (i.e., a new DP) or adding new employees to the sales and logistics activities (i.e. a new PV), which can work with the existing employee or perform the conversion in exclusive. However, implementing the proposed solution for $FR_{3.1.2.1}$, one needs to take into account the new process sequence. Though, other alternatives may be considered are presented in Table 7.10.

Table 7.10. Proposed scenarios for SS_1.

Scenarios	Description	Employee quantity by process					
		Insert order manually		Validate order		Procurement	
SS_1-B	Add external employees to "insert order manually" and "validate order" activities.	1	[0,1,2]	1	[0,1,2]	1	0
SS_1-C	Add external employees to all activities.	1	[0,1,2]	1	[0,1,2]	1	[0,1,2]
SS_1-D	New employees do "insert order manually" activity, exclusively.	0	[1,2,3]	1	0	1	0
SS_1-E	Add external employees to "insert order manually" activity.	1	[0,1,2]	1	0	1	0

The simulation results for each scenario are presented in Table 7.11.

Table 7.11. Simulation results for SS_1 scenarios.

Scenarios	Number of employees	Order lead-time (OLT)	Time of interoperation			Conversion time (Cv)		
			Total	Time of interoperation for purchasing (TIP)	Time of use to plan (TUP)	Total	FS	SS_1
		(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
SS_1-B	1	118,120	113,577	70,177	43,400	48,30	16,68	31,62
	2	116,159	106,420	68,209	38,211	48,36	16,62	31,74
	3	116,201	106,607	68,252	38,355	48,36	16,62	31,74
SS_1-C	1	118,120	113,577	70,177	43,400	48,30	16,68	31,62
	2	118,057	113,43	70,112	43,318	48,30	16,68	31,62
	3	115,438	104,095	67,490	36,605	48,36	16,68	31,68
SS_1-D	1	118,128	110,412	70,117	40,295	48,30	18,68	31,62
	2	108,399	83,889	60,446	23,443	48,30	16,68	31,62
	3	108,399	83,889	60,446	23,443	48,30	16,68	31,62
SS_1-E	1	118,128	110,412	70,117	40,295	48,30	16,62	31,68
	2	119,872	114,674	71,921	42,753	48,30	16,62	31,68
	3	120,085	115,223	72,127	43,096	48,30	16,62	31,68

The graphics presented in Figure 7.21 present the variation in terms of OLT, Cv and TI by scenario varying with the increase of employees.

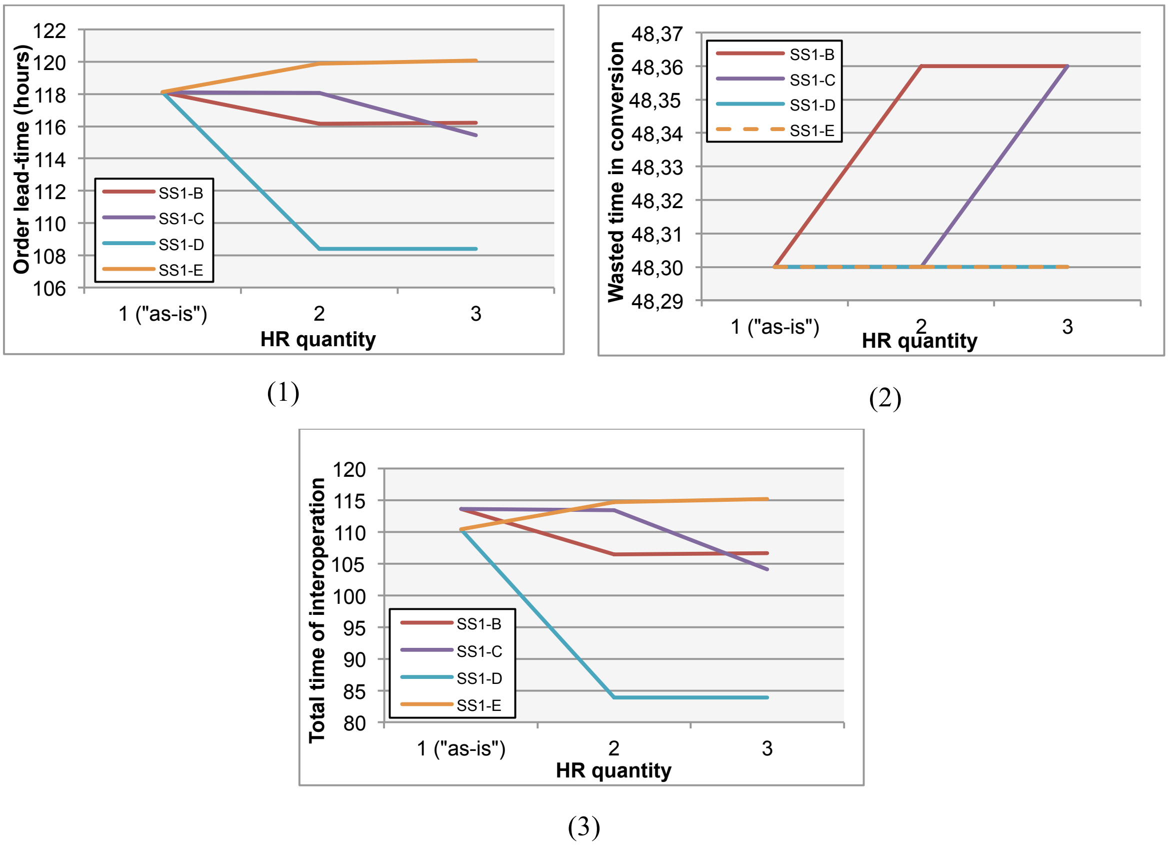


Figure 7.21. Influence of HR quantity on SS1's sales and logistics processes for each scenario.

Increasing the number of employees in all the alternatives leads to better results in "SS_1-B" and "SS_1-D". For these scenarios, the OLT values stabilize from 2 employees working on sales and logistics. However, the best result is achieved in scenario "SS_1-D", where an employee is contracted to perform only the manual insertion of orders on SAP. This contradicts the alternative proposed for $FR_{3.1.2.1}$ (SS_1-A), because leads to better results in terms of OLT and TI, and the same values for Cv. Hence, in terms of process sequence, SS_1 must use the current $DP_{3.1.2.1}$. In $FR_{3.1.2.2}$, the DP remains the same because the system incompatibility wasn't solved. However, the procedure to handle the incompatibility changed to:

$PV_{3.1.2.2}$: One user checks the e-mail queue and inserts the orders manually in the SAP system. Another user validates the orders and performs procurement.

This solution may be represented in terms of MDM (see Figure 7.22).

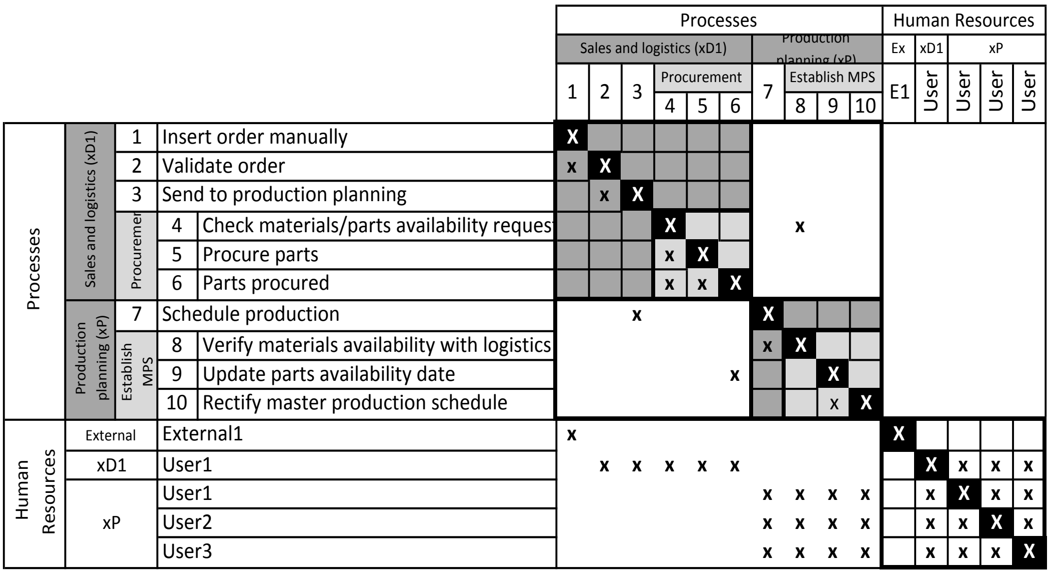


Figure 7.22. Final MDM considering the performance improvement by SS_1's scenarios.

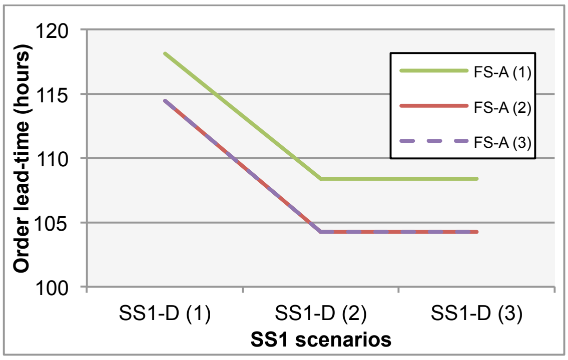
Due to the dependency of $FR_{3.1.2.2}$ from $DP_{3.1.1.2}$, and $DP_{3.1.2.2}$ from $PV_{3.1.1.2}$, it is needed to study the combined solutions for the manual conversions. The results were obtained in Table 7.12 and graphics in Figure 7.23.

Table 7.12. Combined scenarios for the improvement of "as-is" conditions.

Number of employees		Order lead-time (OLT)	Time of interoperation: Total	Time of interoperation: Time of interoperation for purchasing (TIP)	Time of interoperation: Time of use to plan (TUP)	Conversion time (Cv): Total	Conversion time (Cv): FS	Conversion time (Cv): SS_1
		(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-A (1)	SS_1-D (1)	118,120	113,577	70,177	43,400	48,30	16,68	31,62
	SS_1-D (2)	108,399	83,889	60,446	23,443	48,30	16,68	31,62
	SS_1-D (3)	108,399	83,889	60,446	23,443	48,30	16,68	31,62
FS-A (2)	SS_1-D (1)	114,445	104,151	66,438	37,713	48,36	16,68	31,68
	SS_1-D (2)	104,246	76,021	56,32	19,701	48,30	16,68	31,62
	SS_1-D (3)	104,246	76,021	56,32	19,701	48,30	16,68	31,62
FS-A (3)	SS_1-D (1)	114,445	104,151	66,438	37,713	48,36	16,68	31,68
	SS_1-D (2)	104,246	76,021	56,32	19,701	48,30	16,68	31,62
	SS_1-D (3)	104,255	76,075	56,327	19,748	48,30	16,68	31,62

In each graphic is displayed the evolution of the metrics with the addition of new employees to FS's parts ordering, and the contracting of new employees to perform exclusively the manual insertion of orders in SS_1's sales and logistics section – represented in abscissas.

The best solution to improve the existing conditions in the dyad, without acquiring new information systems, is the contracting of a new employee to FS's parts ordering section - FS-A (2) scenario -, and a new employee to perform the manual conversion in SS_1's sales and logistics section – SS_1-D (2) scenario.



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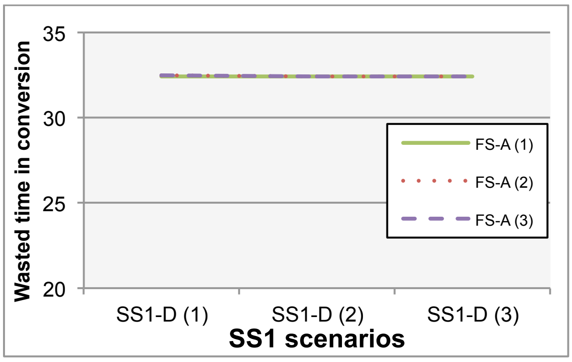

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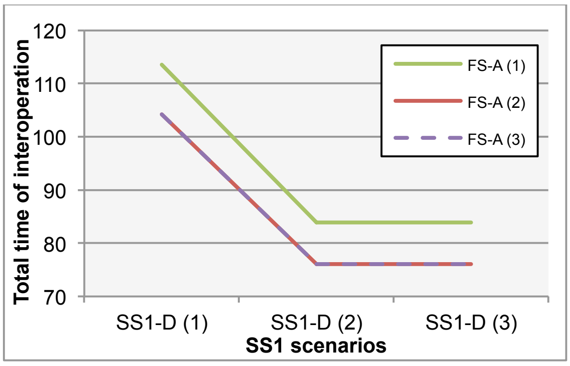


(3)

Figure 7.23. Influence of the combined scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – total time of interoperation (TI).

B. Proposal of new interoperability solutions

B.1. The implementation of a WebEDI

The WebEDI solution is already implemented by FS as a secondary communication channel that, actually, is not used by any of the suppliers. It is a passive communication system that requires suppliers' users to login on the FS's WebEDI website to get access to the orders. This alternative was applied to overcome the manual process of extraction purchase order information from SAP and other inventory management software manually and send it by e-mail.

The implications of this design alternative affect FS internal processes, SS_1 internal processes and the interface alignment.

Modifications in FS's internal processes

So, the first alteration to the current FS processes is the business process model ($DP_{3.1.1}$) (see Figure 7.24). Instead of exporting manually the order data from SAP, users now only have to generate the purchase order that is uploaded to WebEDI service. In this procedure there is no direct communication. Purchase orders are created and uploaded to the web service.

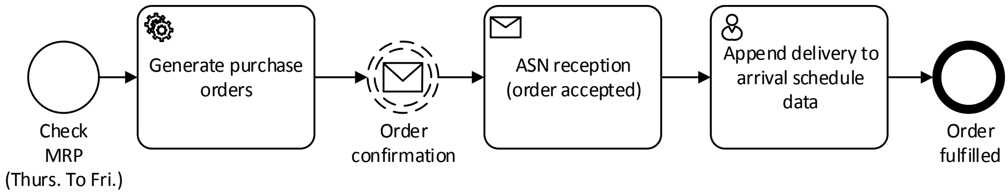


Figure 7.24. FS purchasing process with WebEDI implementation.

The applications are still different, but are compatible and fully integrated. The data flow is seamless in the FS perspective and no additional NVA processes are required to place an order.

Regarding SS_1, this alternative implies some changes in terms of business processes. Instead of receiving orders by e-mail, the users should login to customer's WebEDI to get access to the PO's. The new business process is presented in Figure 7.25.

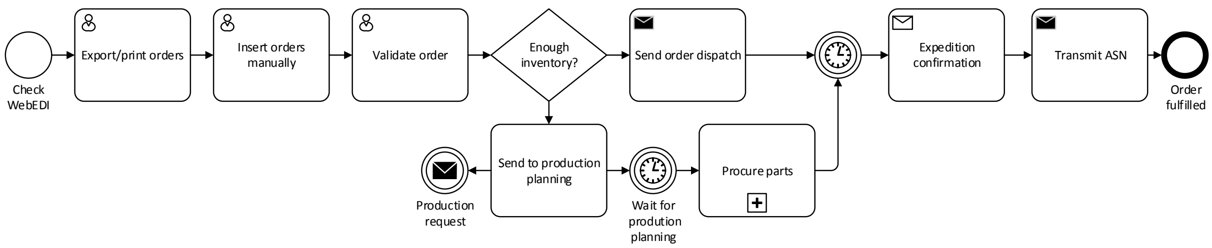


Figure 7.25. SS_1 sales process changes after FS's WebEDI implementation ($DP_{3.1.2}$).

The interface between this web-service and the SS_1's SAP is not interoperable ($DP_{3.1.2.2}$). The users on sales need to print or export the order data to another format and insert the orders manually ($PV_{3.1.2.2}$). Comparing to the as-is situation, the consequences of the FS's WebEDI is the creation of NVA processes and a new work method to verify orders.

On the interface, there is no apparent change in terms of interoperability gain. Although the ICT was changed, the order data is not compatible with SS_1's SAP ($DP_{3.1.3.1.2}$). The users still have to introduce data manually.

In terms of communication paths, the procedure to place and receive orders has been changed. In the "as-is" situation, FS had implemented WebEDI in the past years but it is still using the e-mail and the phone instead of the WebEDI. The reason for that is because WebEDI is not a standard communication and is not integrated with the data reception ERP's.

Modifications in SS's internal processes

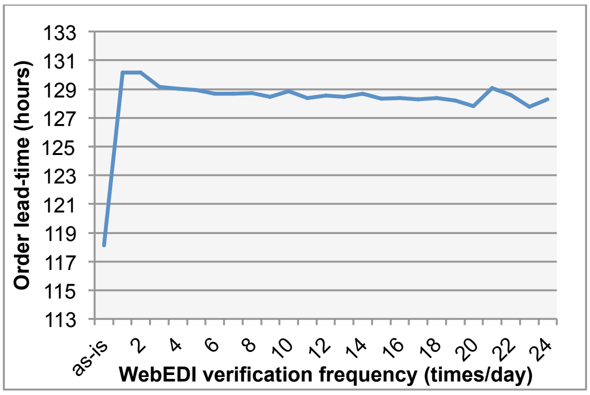
The scenarios to test using simulation for the WebEDI implementation, are the following:

(a) Determination of the time interval to check WebEDI server;

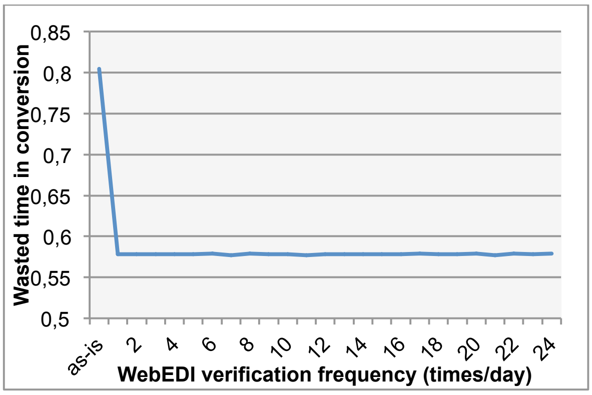
(b) Determination of the appropriate human resources quantity and distribution in FS's purchasing and SS_1's sales.

(a) Determination of the time interval to check WebEDI server:

To work with the FS's WebEDI server, users in SS_1 have to access the web-platform to verify if orders were received. The first step to study the use of WebEDI in dyad 1 was to determine the number of times a user should check the WebEDI server in each day. The graphics in Figure 7.26 present the number of WebEDI verifications by day and its influence in the metrics.



(1)



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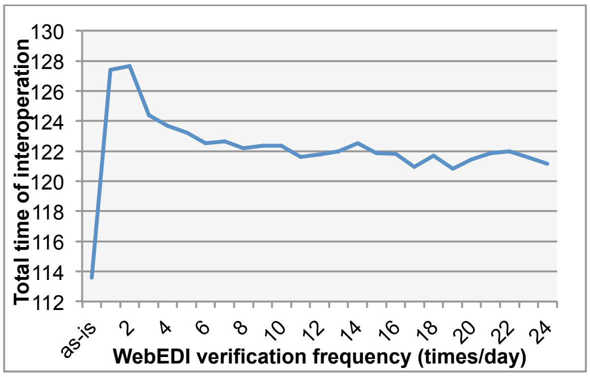


(3)

Figure 7.26. Influence of WebEDI verification frequency in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

The lowest values of OLT and TI are obtained if workers from SS_1's sales check the WebEDI server 8 or more times each day. After that value, both OLT and Cv don't go below 127 and 120 hours, respectively. This value is worse than the as-is situation without implementing WebEDI. Though, in terms of Cv, the conversion time decreases in about 15 minutes in each order.

(b) *Determination of the appropriate human resources quantity and distribution in FS's purchasing and SS_1's sales:*

To determine the adequate number of human resources in FS's parts ordering and SS_1's sales sections, was applied a similar approach as in the improvement of the "as-is" scenario. Therefore, the resource arrangement was the same as the best configurations for the "as-is". I.e., in FS was studied the influence of additional employees added to all the parts ordering's processes (see Table 7.13); in SS_1 was studied the influence of having employees performing the manual conversion of order data in exclusive (see Table 7.14). The results are presented in Table 7.15.

Table 7.13. Proposed scenarios the implementation of WebEDI in FS.

Scenarios	Changes	Employee quantity by process			
		Generate purchase order		Append delivery to arrival schedule data	
		Existing	New	Existing	New
FS-E	Maintain process distribution and add new employees.	1	[0,1,2,3]	1	[0,1,2,3]

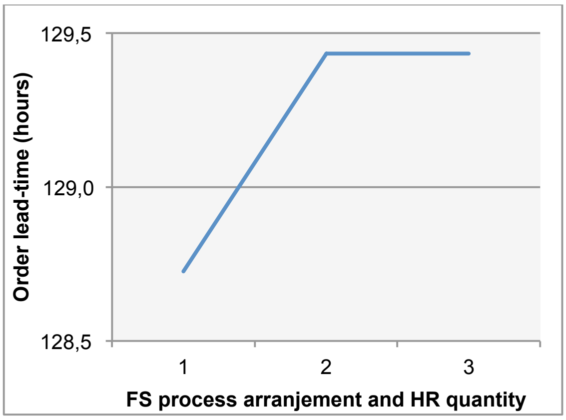
Table 7.14. Proposed scenarios the implementation of WebEDI in SS_1.

Scenarios	Description	Employee quantity by process					
		Insert order manually		Validate order		Procurement	
SS_1-F	New employees do "insert order manually" activity, exclusively.	0	[1,2,3]	1	0	1	0

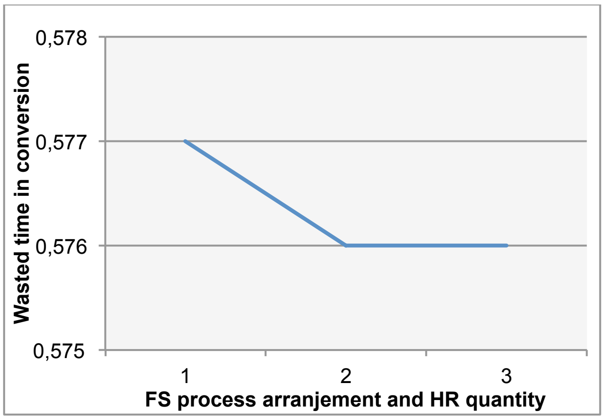
Table 7.15. Simulation results for the study of FS-E scenario.

Scenario	Resource quantity in FS's parts ordering	Order lead-time (OLT)	Conversion time (Cv)			Time of interoperation (TI)			
			Total	SS_1	FS	Total	TUP	TUPO	TUPP
	(employees)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-E	1	128,726	0,577	0,527	0,05	124,809	80,752	44,057	25,935
FS-E	2	129,434	0,576	0,526	0,05	126,700	81,437	45,263	27,003
FS-E	3	129,434	0,576	0,526	0,05	126,700	81,437	45,263	27,003

Graphically, the results are represented in Figure 7.27.



(1)



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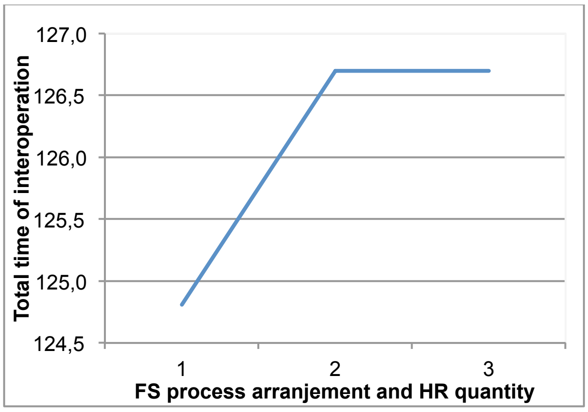


(3)

Figure 7.27. Influence of FS-E scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

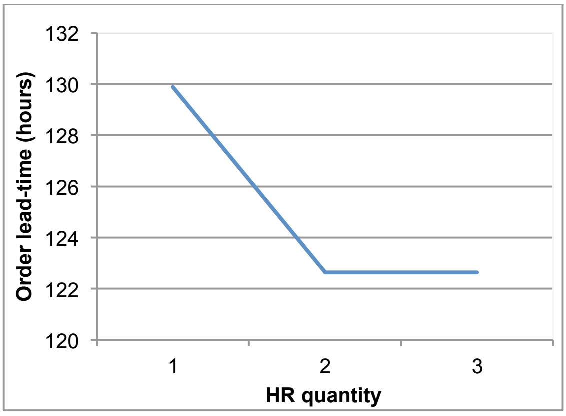
The best resource quantity is to have only the existing employee in FS's parts ordering. However, this result is worse than the "as-is".

In the case of SS_1, the results corresponding to the increase of employees working exclusively in manual insertion process are presented in Table 7.16.

Table 7.16. Simulation results for the study of SS_1-F scenario.

Scenario	Resource quantity in SS_1's sales and logistics	Order lead-time (OLT)	Conversion time (Cv)			Time of interoperation (TI)		
			Total	SS_1	FS	Total	TIP	TUP
	(employees)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
SS_1-F	1	129,885	0,578	0,528	0,05	123,950	81,923	42,027
SS_1-F	2	122,631	0,577	0,527	0,05	103,961	74,779	29,182
SS_1-F	3	122,631	0,577	0,527	0,05	103,961	74,779	29,182

Graphically, the results are illustrated by Figure 7.28.



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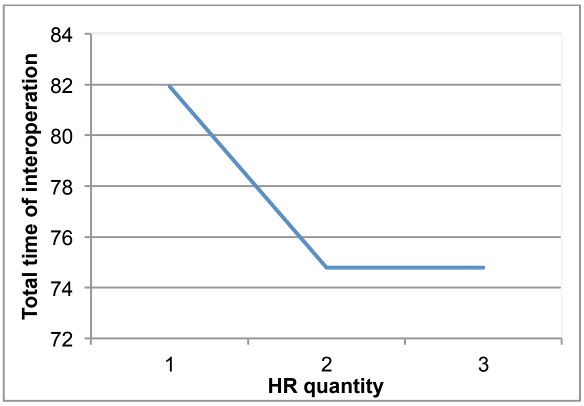


(3)

Figure 7.28. Influence of SS_1-F scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

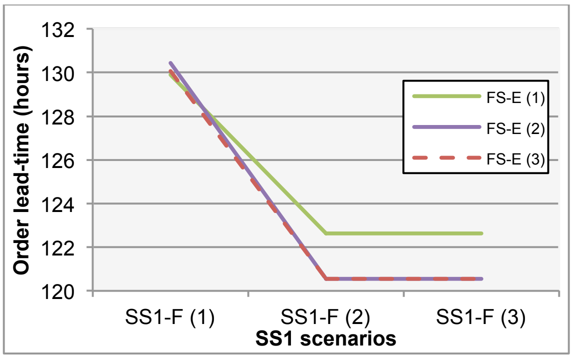
The best results in terms of OLT and TI are obtaining by contracting one additional employee to perform the manual insertion of orders exclusively (2 employees in total).

The dependency of $FR_{3.1.2.2}$ from $DP_{3.1.1.2}$, and $DP_{3.1.2.2}$ from $PV_{3.1.1.2}$ implies that new DPs or PVs have influence upon them. Hence, the combined scenario results are presented in Table 7.17.

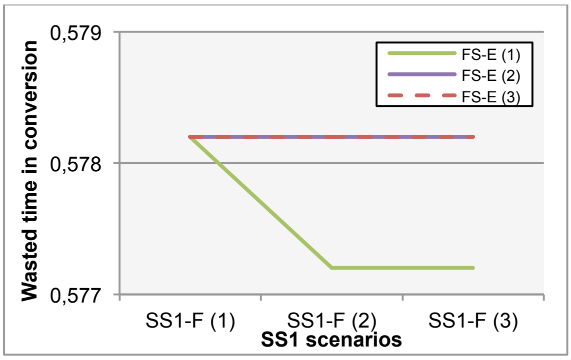
Table 7.17. Simulation results for the study of the influence of FS's scenarios in SS_1's.

Scenarios		Order lead-time (OLT)	Conversion time (Cv)			Time of interoperation (TI)			
			Total	SS_1	FS	Total	TUP	TUPO	TUPP
FS	SS_1	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-E (1)	SS_1-F (1)	129,885	0,578	0,528	0,050	123,950	81,923	42,027	26,357
	SS_1-F (2)	122,631	0,577	0,527	0,050	103,961	74,779	29,182	19,898
	SS_1-F (3)	122,631	0,577	0,527	0,050	103,961	74,779	29,182	19,898
FS-E (2)	SS_1-F (1)	130,433	0,578	0,528	0,050	125,367	82,469	42,898	27,407
	SS_1-F (2)	120,547	0,578	0,528	0,050	99,284	72,699	26,585	18,632
	SS_1-F (3)	120,547	0,578	0,528	0,050	99,284	72,699	26,585	18,632
FS-E (3)	SS_1-F (1)	130,066	0,578	0,528	0,050	124,928	82,113	42,815	27,326
	SS_1-F (2)	120,547	0,578	0,528	0,050	99,284	72,699	26,585	18,632
	SS_1-F (3)	120,547	0,578	0,528	0,050	99,284	72,699	26,585	18,632

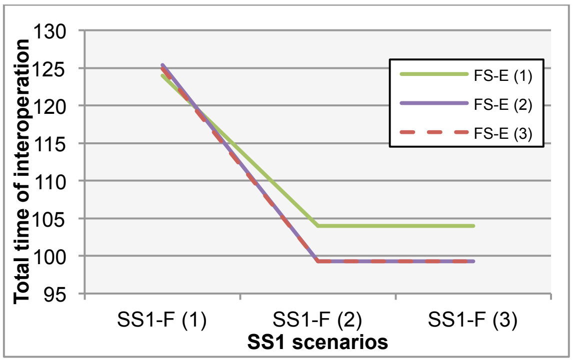
Figure 7.29 illustrates the results for the results of Table 7.17.



(1)



(2)



(3)

Figure 7.29. Influence of combined scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

The scenario combination resulted in best results contracting one additional employee for FS – scenario FS-E (2) -, and two employees to SS_1 – SS_1-F (2). This contradicts the results in Figure 7.27.

B.2. The implementation of an EDI

The EDI is an ICT solution that both companies actually use but not with each other. The barriers to EDI implementation are the costs to establish the connection and maintenance.

Modifications in FS's internal processes

The impact of EDI on FS processes ($FR_{3.1.1}$ and $FR_{3.1.1.2}$) is similar to the implementation of the WebEDI, so Figure 7.24 presents the adequate business process to operate the order placement and the compatibility considerations are the same as WebEDI.

However, data interoperability is different for this case. Like stated before, WebEDI is stored on a web-platform that may be a server or cloud-based (located on-site or on an external provider). For the EDI the business server is the same as the ERP solution (SAP). Implementing an EDI eliminates, partially, the barrier between the purchase order data formats. The user-based conversion mechanisms (manual check, print and data insertion) are eliminated in the both ends of the ICT. Though the SAP integration is not always compatible, requiring in some cases additional conversion mechanisms, in this scenario is assumed perfect data integration between companies.

Modifications in SS_1's internal processes

On the SS_1 perspective, changing the ICT for purchase orders leads to the elimination of the manual entry of order data. The business process arrangement for this solution is presented in Figure 7.30.

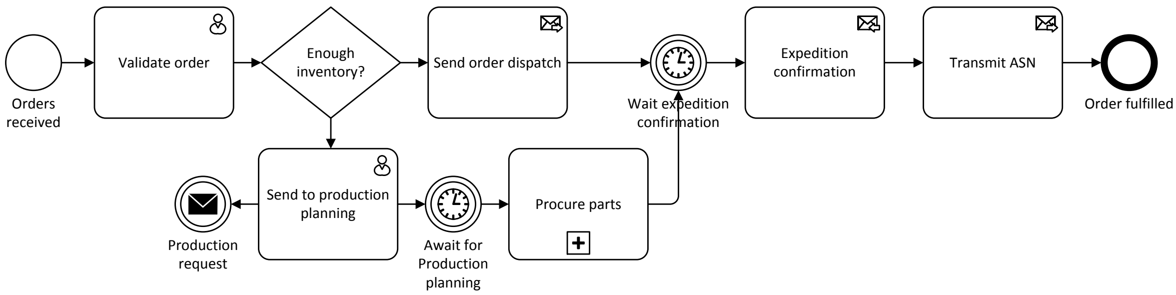


Figure 7.30. SS_1 sales process changes after EDI implementation.

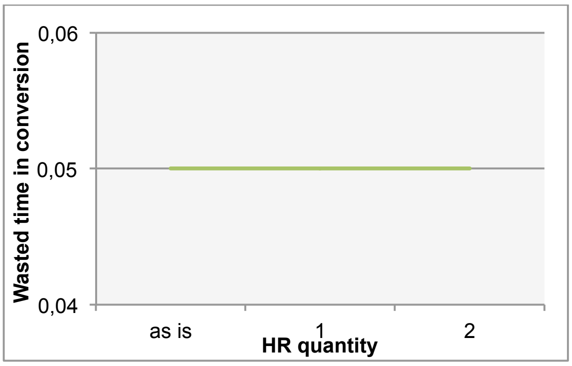
Both companies use the same ERP system, and the EDI enables the data flow between them without relevant issues on data integration that are translated on additional user-based processes. The integration of data makes possible for user to only handle the relevant process workflow that, actually, enable business operation, instead of having to deal with the ICT itself and the manual handling of data. To achieve higher levels of interoperability in terms of communication paths definition, exceptional procedures should be modelled and integrated in this communication path. For instance, an urgent request should be modelled and users from SS_1 should be able to distinguish the context of the order in order to apply a different procedure without resource to additional processes (e.g., e-mail reinforcing orders of phone calls).

The improvements to operationalize the use of EDI to place orders in FS focus in the work methods, resource distribution and quantity. In terms of process sequence and organisational alignment there is nothing to add. Hence, the scenario tested for EDI implementation in FS is similar to the best scenario for the improvement of the "as-is" conditions: maintain the process distribution and add new employees to all processes – FS-F. The obtained results are presented in Table 7.18 and Figure 7.31.

Table 7.18. Simulation results for EDI implementation on FS.

Scenarios	Resource quantity in SS's sales and logistics (employees)	Order lead-time (OLT) (hours)	Conversion time (Cv) Total (hours)	Conversion time (Cv) SS_1 (hours)	Conversion time (Cv) FS (hours)	Time of interoperation (TI) Total (hours)	Time of interoperation (TI) TIP (hours)	Time of interoperation (TI) TUP (hours)
FS-F	1	106,698	0,05	0	0,05	83,049	58,725	24,324
	2	106,599	0,05	0	0,05	82,862	58,651	24,211
	3	106,599	0,05	0	0,05	82,862	58,651	24,211

(1)



(2)

(3)

Figure 7.31. Influence of FS-F in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

Better values for the performance metrics are achieved using an additional employee in all the parts ordering processes. Though, comparing the metrics of using a new employee instead of none leads to an improvement of low significance. Due to the reduction of time to generate purchase orders using SAP and EDI, the resource use is low. Then, it is appropriate to use the parts ordering processes with the existing employee.

Table 7.19 presents the studied scenarios for EDI implementation in SS_1's processes.

Table 7.19. Main improvements to perform in SS's processes in EDI implementation.

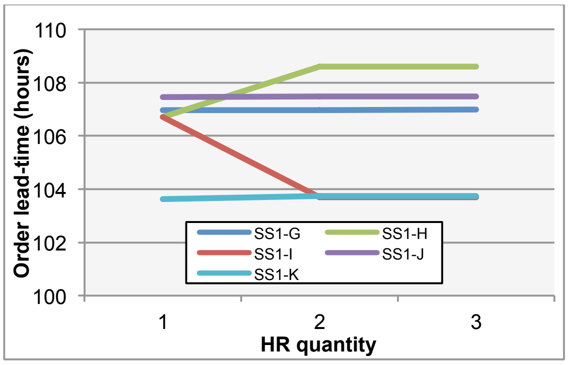
Scenario	Changes	Employee quantity by process			
		Validate order		Procurement	
		Existing	New	Existing	New
SS_1-G	Maintain the process distribution and add new employees to all processes.	1	[0,1,2]	1	[0,1,2]
SS_1-H	Add new employees to "validate order" process.	1	[0,1,2]	1	0
SS_1-I	New employees work exclusively in "validate order" process.	0	[1,2,3]	1	0
SS_1-J	Add new employees to "procurement" process.	1	0	1	[0,1,2]
SS_1-K	New employees work exclusively in "procurement" process.	1	0	0	[1,2,3]

Table 7.20 presents the results for the influence of human resources quantity in the processes performed in parts ordering.

Table 7.20. Simulation results for SS's scenarios for EDI implementation.

Scenarios	Resource quantity in SS's sales and logistics (employees)	Order lead-time (OLT) (hours)	Conversion time (Cv) Total (hours)	Conversion time (Cv) SS_1 (hours)	Conversion time (Cv) FS (hours)	Time of interoperation (TI) Total (hours)	Time of interoperation (TI) TIP (hours)	Time of interoperation (TI) TUP (hours)
SS_1-G	1	106,959	0,05	0	0,05	84,176	58,985	25,191
	2	106,959	0,05	0	0,05	84,176	58,985	25,191
	3	106,979	0,05	0	0,05	83,414	58,992	24,422
SS_1-H	1	106,698	0,05	0	0,05	83,049	58,725	24,324
	2	108,593	0,05	0	0,05	83,452	60,631	22,821
	3	108,593	0,05	0	0,05	83,452	60,631	22,821
SS_1-I	1	106,698	0,05	0	0,05	83,049	58,725	24,324
	2	103,683	0,05	0	0,05	73,584	55,733	17,851
	3	103,683	0,05	0	0,05	73,584	55,733	17,851
SS_1-J	1	107,445	0,05	0	0,05	85,576	59,563	26,013
	2	107,466	0,05	0	0,05	85,523	59,483	26,040
	3	107,466	0,05	0	0,05	85,523	59,483	26,040
SS_1-K	1	103,617	0,05	0	0,05	73,424	55,664	17,760
	2	103,733	0,05	0	0,05	73,718	55,783	17,935
	3	103,733	0,05	0	0,05	73,718	55,783	17,935

Graphically, the results are represented in Figure 7.32.



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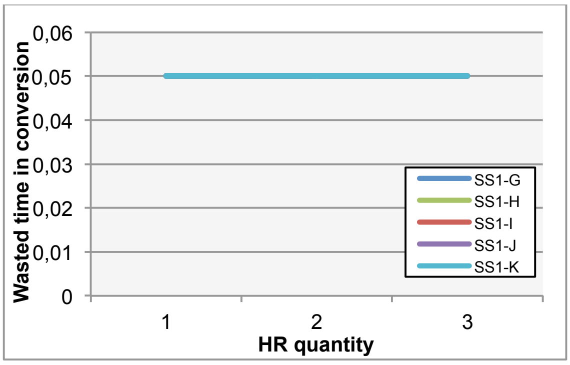

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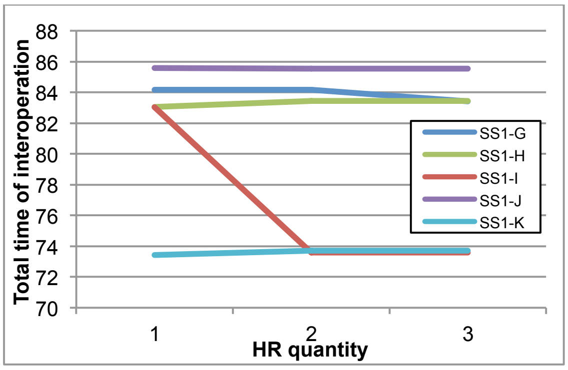


(3)

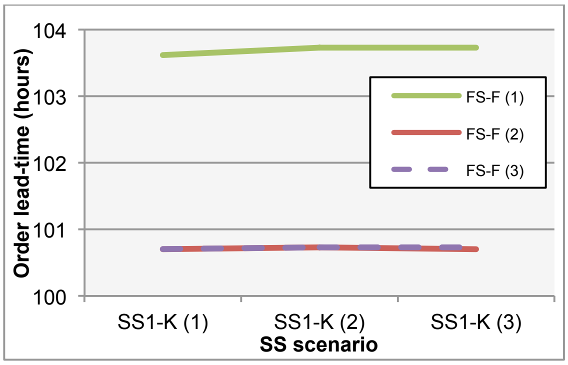
Figure 7.32. Influence of SS's scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

In conclusion, the best alternative is to contract one new employee to perform the procurement processes (scenario SS_1-K).

The dependency of $DP_{3.1.2.2}$ from $PV_{3.1.1.2}$ produces implications in terms of the dyad performance. Hence, the influence of improvements performed in $PV_{3.1.1.2}$ and in $PV_{3.1.2.2}$ was studied. The results are presented in Table 7.21,and Figure 7.33.

Table 7.21. Simulation results for combined scenarios.

Scenarios		Order lead-time (OLT)	Conversion time (Cv)			Time of interoperation (TI)		
			Total	SS_1	FS	Total	TIP	TUP
FS	SS	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-F (1)	SS_1-K (1)	103,617	0,05	0	0,05	73,424	55,664	17,760
	SS_1-K (2)	103,733	0,05	0	0,05	73,718	55,783	17,935
	SS_1-K (3)	103,733	0,05	0	0,05	73,718	55,783	17,935
FS-F (2)	SS_1-K (1)	100,704	0,05	0	0,05	67,918	52,743	15,175
	SS_1-K (2)	100,733	0,05	0	0,05	67,982	52,766	15,216
	SS_1-K (3)	100,698	0,05	0	0,05	67,904	52,737	15,167
FS-F (3)	SS_1-K (1)	100,704	0,05	0	0,05	67,918	52,743	15,175
	SS_1-K (2)	100,733	0,05	0	0,05	67,982	52,766	15,216
	SS_1-K (3)	100,733	0,05	0	0,05	67,982	52,766	15,216



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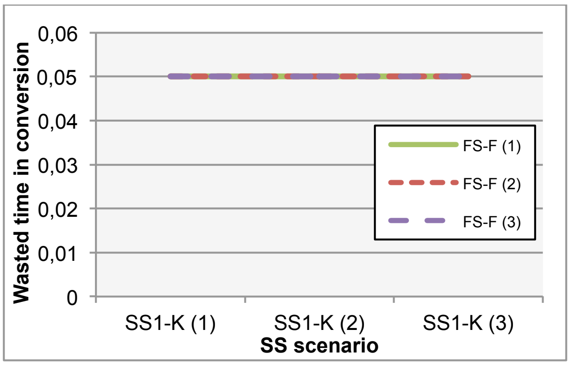

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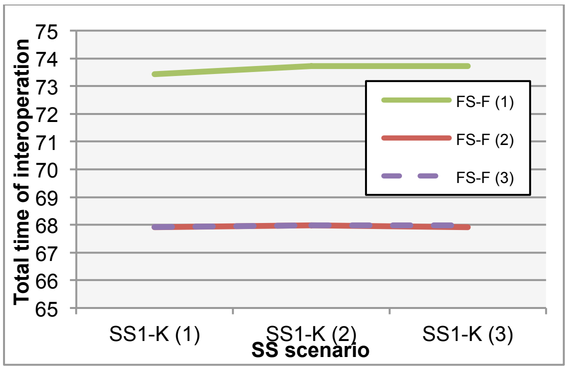


(3)

Figure 7.33. Influence of combined scenarios in: (1) – order lead-time (OLT); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

The solution that delivers the best performance is the contracting of a new employee for all the FS's parts ordering processes – scenario FS-F (2); and the contracting of one new employee for SS_1's procurement processes, performing them exclusively – scenario SS_1-K (1).

7.4.3. Scenario comparison and discussion

The three studied alternatives provide different approaches to the way dyad 1 handle orders. In each alternative, the work methods and resource utilization was studied in order to obtain best results in terms of dyad performance. The best results for each alternative are summarized in Table 7.22 and represented in the graphics of Figure 7.34 and Figure 7.35.

Table 7.22. Alternative comparison for purchase-selling interface.

Alternatives	Order lead-time (OLT)	Conversion time (Cv)	Time of interoperation in purchasing (TI)
	(hours)	(hours)	(hours)
"as-is"	118,12	0,805	113,577
"as-is" improved	104,246	0,805	76,021
WebEDI	120,547	0,578	99,284
EDI	100,704	0,050	67,918

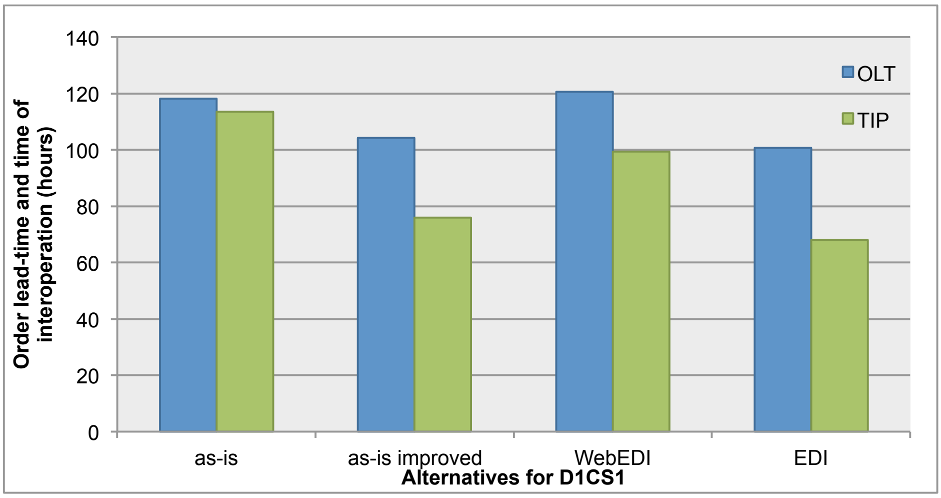


Figure 7.34. Order lead-time and time of interoperation in purchasing values for "as-is" and each improved alternative.

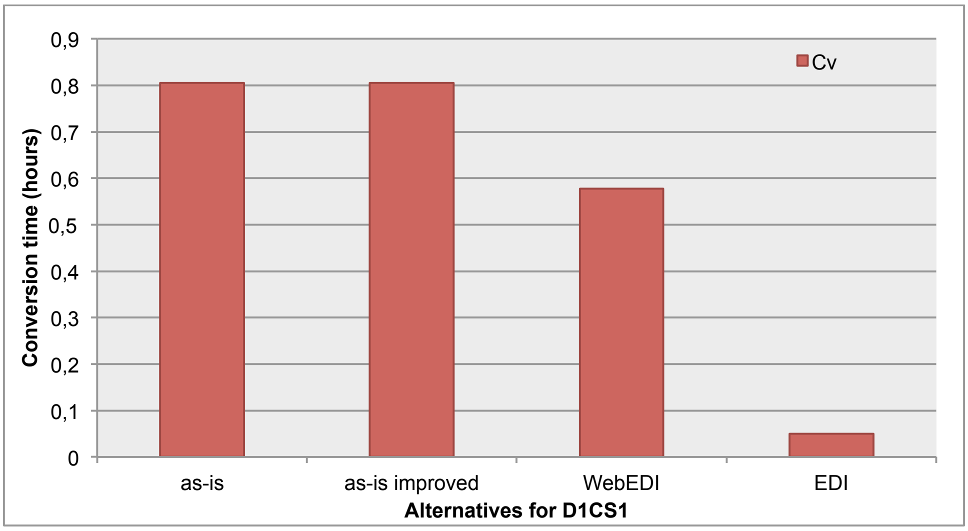


Figure 7.35. Conversion time values for "as-is" and each improved alternative.

The improvement percentage was calculated, for each alternative, according to equation (7.6).

$$Improvement(\%) = \frac{Metric_{as-is} - Metric_{alternative}}{Metric_{as-is}} \times 100 \qquad (7.6)$$

Where $Metric_{as-is}$ is the value of the metrics (OLT, Cv and TIP) for the "as-is" scenario, and $Metric_{alternative}$ is the metrics value for each studied alternative scenario. Therefore, the results are presented in Table 7.23.

Table 7.23. Improvement percentage of each scenario in relation to "as-is" scenario.

Alternative	OLT improvement (%)	Cv improvement (%)	TI Improvement (%)	Total improvement (%)
"as-is" improved	11,75	0,00	33,07	44,82
WebEDI	-2,05	28,20	12,58	41,73
EDI	14,74	93,79	40,20	148,73

Graphically, the improvement percentage results are represented in Figure 7.36.

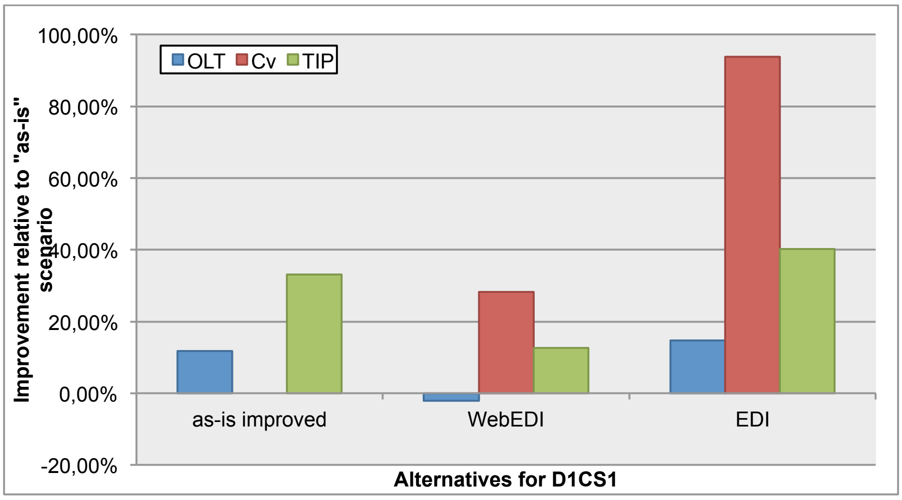


Figure 7.36. Improvement percentage for each alternative.

By analysing the obtained results, is possible to conclude that the best alternative is the implementation of the EDI. This alternative presents the lowest values in terms of OLT, Cv and TIP. The improvement percentage for each one is 15%, 94% and 40 %, respectively.

Implications of the selected alternative in the dyad design – "to-be" scenario

The implications of the modelling and simulation results are presented in the following FRs, DPs and PVs (see Table 7.24) and design matrices (see Figure 7.37 and Figure 7.38).

Table 7.24. The "to-be" design of the buyer-seller interaction.

Interoperability requirements (FRs)	**Interoperability solutions (DPs)**	**Process Variables (PVs)**
$FR_{3.1}$: 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.	**<u>$DP_{3.1.1}$: FS new business process model for purchase and reception (see Figure 7.24 and Figure 7.30).</u>**	
$FR_{3.1.1.1}$: Model the process sequence of FS processes.	$DP_{3.1.1.1}$: Sequential procedures with low interaction dependency.	**<u>$PV_{3.1.1.1}$: Purchasing and reception procedures occur independently without requiring special cooperation modelling. Two users (one from inventory planning and a new one) perform the inventory planning and the parts ordering.</u>**
$FR_{3.1.1.2}$: Manage the interface between the inventory management system and the ordering system.	**<u>$DP_{3.1.1.2}$: Integrated data between SAP and EDI.</u>**	**<u>$PV_{3.1.1.2}$: Two users (one user from inventory planning and parts ordering section and a new one) check MRP on SAP and prepare create purchase orders.</u>**
$FR_{3.1.1.3}$: Align purchasing and reception with FS organisational structure.	**<u>$DP_{3.1.1.3}$: Functional process distribution by matching a process to a section (see Figure 7.39).</u>**	**<u>$PV_{3.1.1.3}$: Parts ordering section for orders placement and validation activities and reception section for the material arrivals. One user from parts ordering is shared with inventory planning and another is dedicated to this section.</u>**

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.1.2}$: Model and manage SS_1's sales processes.	**$DP_{3.1.2}$: SS_1 new business process model for order reception (see Figure 7.30), and actual order treatment (see Figure 7.43), production and delivery (see Figure 7.44) business process models.**	
$FR_{3.1.2.1}$: Model the process sequence of SS_1 processes.	**$DP_{3.1.2.1}$: Sequential procedures triggered by the order reception on sales (see Figure 7.43).**	**$PV_{3.1.2.1}$: Sales procedure occurs independently and triggers the rest of SS_1's procedures. One user performs the selling activities and a new user performs procurement procedures.**
$FR_{3.1.2.2}$: Manage the interface between the ICT for order reception and the order management system.	**$DP_{3.1.2.2}$: Integrated data between EDI and SAP.**	**$PV_{3.1.2.2}$: One user performs order validation after order reception.**
$FR_{3.1.2.3}$: Align SS_1 processes with organisational structure.	**$DP_{3.1.2.3}$: Functional process distribution (see Figure 7.44).**	**$PV_{3.1.2.3}$: Sales section employee performs selling. Inventory and production planning, production and expedition activities have dedicated sections.**
$FR_{3.1.3}$: Align companies' internal processes.	**$DP_{3.1.3}$: The new collaborative business process model (see Figure 7.45).**	
$FR_{3.1.3.1}$: 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.	**$PV_{3.1.3.1.1}$: Two users from parts ordering are dedicated to deal with the component ordering and contact with the user from sales section, which is responsible for FS's orders.**
$FR_{3.1.3.1.2}$: Manage the interface between ICT's used to place/receive orders.	**$DP_{3.1.3.1.2}$: SAP data integrated between the two firms.**	**$PV_{3.1.3.1.2}$: Data seamlessly integrated.**
$FR_{3.1.3.1.3}$: Manage the communication path to place orders.	$DP_{3.1.3.1.3}$: Standard procedure defined to communicate orders.	**$PV_{3.1.3.1.3}$: Two users from parts ordering (FS) generate purchase orders on SAP. one user from sales section (SS_1) checks EDI and processes the 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.	$PV_{3.1.3.2.1}$: The user from sales and logistics section confirms orders by EDI sending an ASN.
$FR_{3.1.3.2.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.1.3.2.2}$: ASN is integrated directly on SAP system.	$PV_{3.1.3.2.2}$: User from parts ordering review daily the order confirmations in order to prepare for component reception.
$FR_{3.1.3.3}$: Establish a delivery process for material flow.	$DP_{3.1.3.3}$: 3rd party freight forwarder to retrieve components from SS_1 and deliver them to FS.	$PV_{3.1.3.3}$: Delivery is agreed between SS1 and a third party freight forwarder and the components are delivered to FS in 2-3 days.
$FR_{3.1.4}$: Select metrics to monitor interface processes.	$DP_{3.1.3}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.1.3}$: Measure: order lead-time, time of interoperation for purchasing and time spent in information conversion on sales.

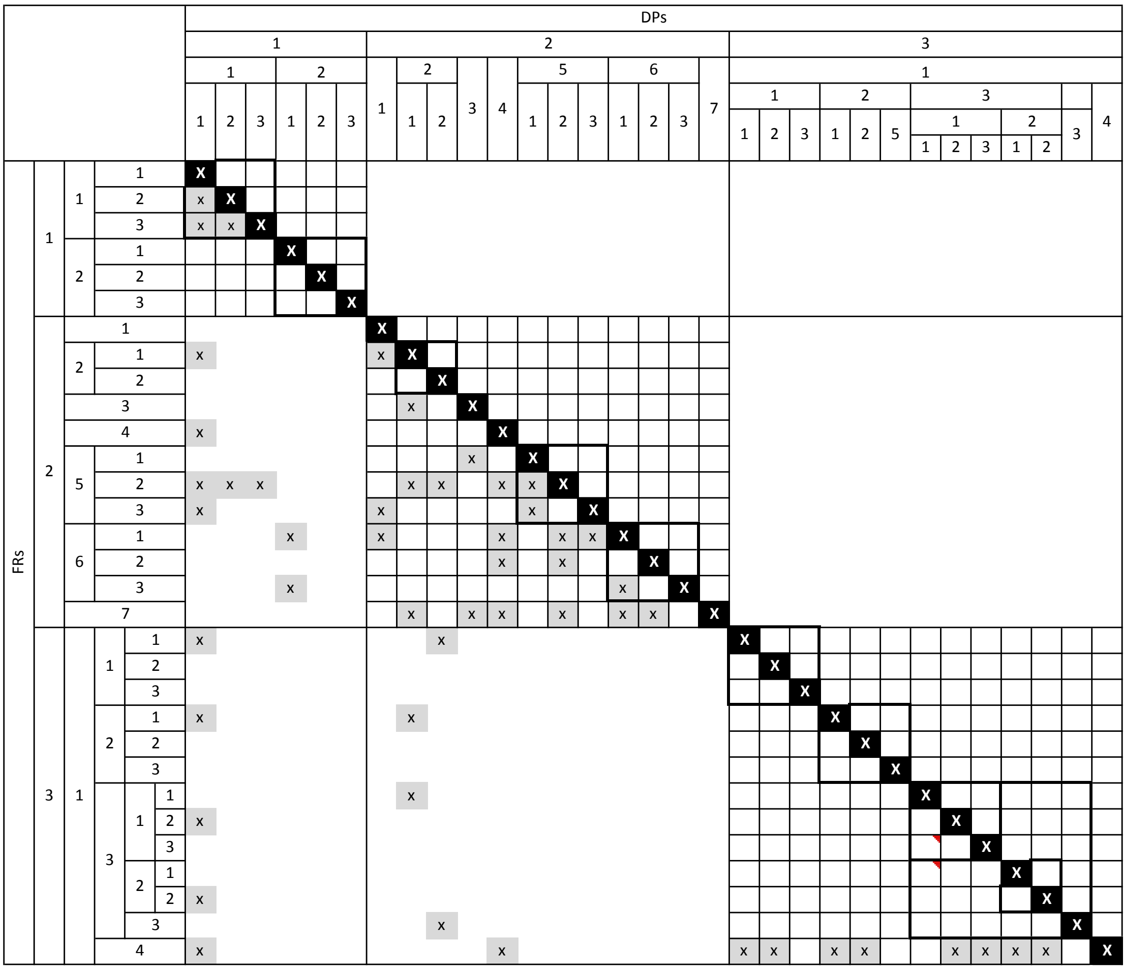


Figure 7.37. Design matrix for the "to-be" design of the buyer-seller interaction (mapping between FRs and DPs).

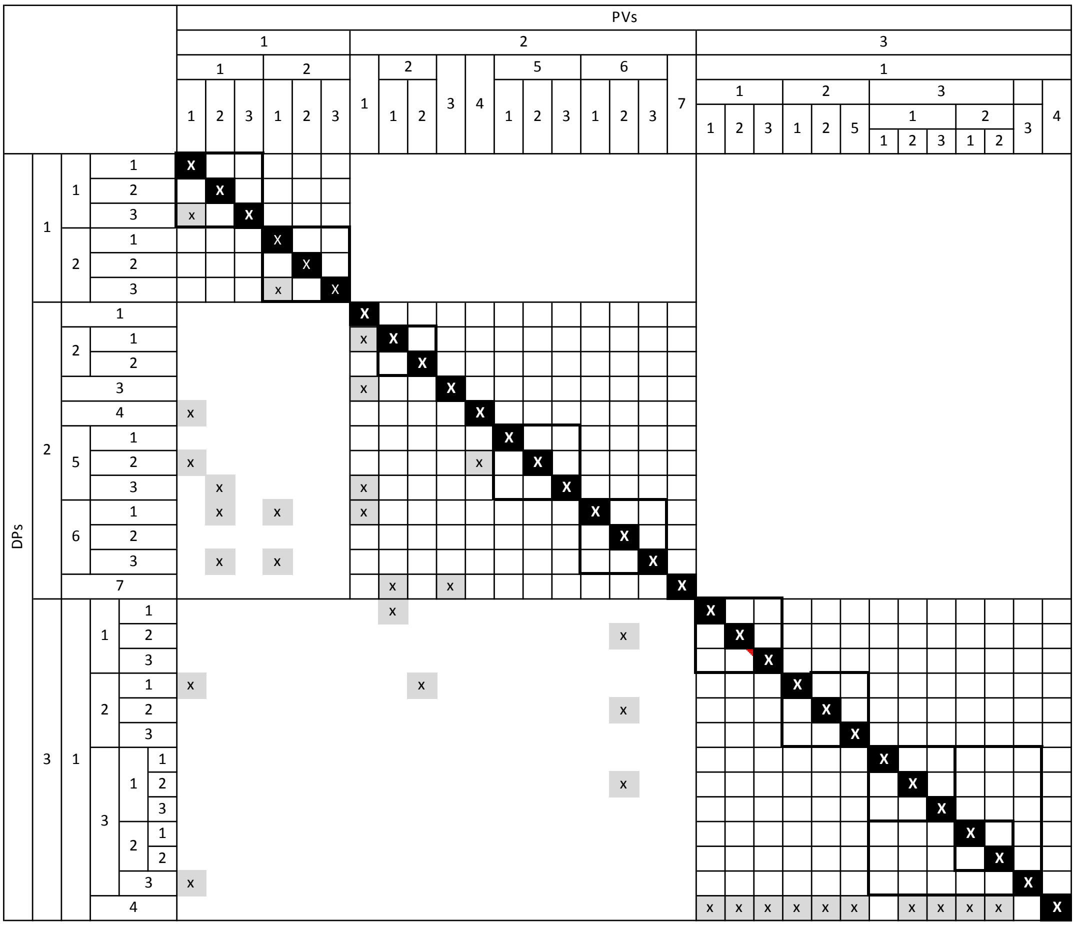


Figure 7.38. Design matrix for the "to-be" design of the buyer-seller interaction (mapping between DPs and PVs).

In FS's internal processes, the couplings on the lower triangular are solved due the new resource distribution. Only one user is shared with another FS's processes, and another one is dedicated to the purchasing activities. This reduces the dependency of this process from the shared resource.

The final BPM for the organisational alignment ($DP_{3.1.1.3}$) is presented in Figure 7.39.

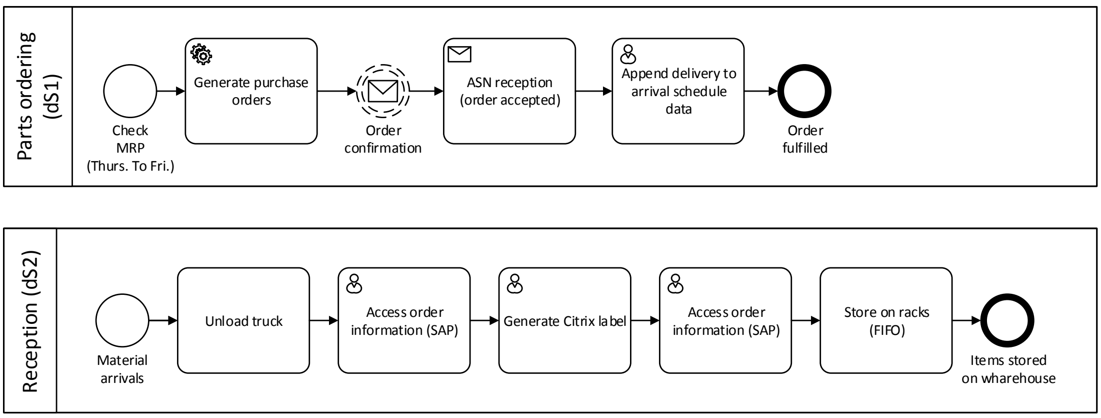


Figure 7.39. Functional alignment of new purchasing processes ("to-be" BPM) and reception to parts ordering and reception sections, respectively.

According to the results simulated for the “to-be” scenario, SS_1 should contract a new employee to perform the procurement activities. Still, there are problems regarding the process sequence and alignment. Using the obtained resource distribution in the simulated scenarios is possible to represent the MDM of SS_1’s selling, procuring and production planning activities (see Figure 7.40).

				Processes									Human Resources				
				Sales and logistics (xD1)					Production planning (xP)				Ex	xD1	xP		
						Procurement				Establish MPS							
				1	2	3	4	5	6	7	8	9	E1	U1	U1	U2	U3
Processes	Sales and logistics (xD1)		1 Validate order	X													
			2 Send to production planning	x	X												
		Procurement	3 Check materials/parts availability request			X				x							
			4 Procure parts			x	X										
			5 Parts procured			x	x	X									
	Production planning (xP)		6 Schedule production		x				X								
		Establish MPS	7 Verify materials availability with logistics						x	X							
			8 Update parts availability date					x			X						
			9 Rectify master production schedule								x	X					
Human Resources	External		External1			x	x	x					X	x			
	xD1		User1	x	x									X	x	x	x
	xP		User1						x	x	x	x	x		X	x	x
			User2						x	x	x	x	x		x	X	x
			User3						x	x	x	x	x		x	x	X

Figure 7.40. MDM matrix for “to-be” SS_1’s collaboration.

According to the MDM matrix, there exists a loop between sales and logistics sections and the production planning section. This loop was due to the resource limitations on sales and logistics section. After flattening the clusters from the SS_1’s processes DSM, a sequencing algorithm was applied a new process sequence was obtained (see Figure 7.41).

			Processes									Human Resources				
												xD1	Ex	xP		
			1	2	6	7	3	4	5	8	9	User	E1	User	User	User
Processes	1	Validate order	X													
	2	Send to production planning	x	X												
	6	Schedule production		x	X											
	7	Verify materials availability with logistics			x	X										
	3	Check materials/parts availability request				x	X									
	4	Procure parts					x	X								
	5	Parts procured					x	x	X							
	8	Update parts availability date							x	X						
	9	Rectify master production schedule								x	X					
Human Resources	xD1	User1	x	x								X				
	External	External1					x	x	x				X	x	x	x
	xP	User1			x	x				x	x	x	x	X	x	x
		User2			x	x				x	x	x	x	x	X	x
		User3			x	x				x	x	x	x	x	x	X

Figure 7.41 MDM matrix for “to-be” SS_1’s collaboration with flattened and sequenced SS_1’s processes DSM.

The resulting DSM matrix displays an alternate sequence of procedures that may be performed by SS_1. Based on this sequence, a new re-organisation of the processes could be suggested. Instead of having sales and logistics in the same section, the processes could be arranged by the employees interactions needs. Production planning and procurement should be put together because the logistics activities are required in order to close the master production schedule (MPS). Hence, the MDM is proposed (see Figure 7.42).

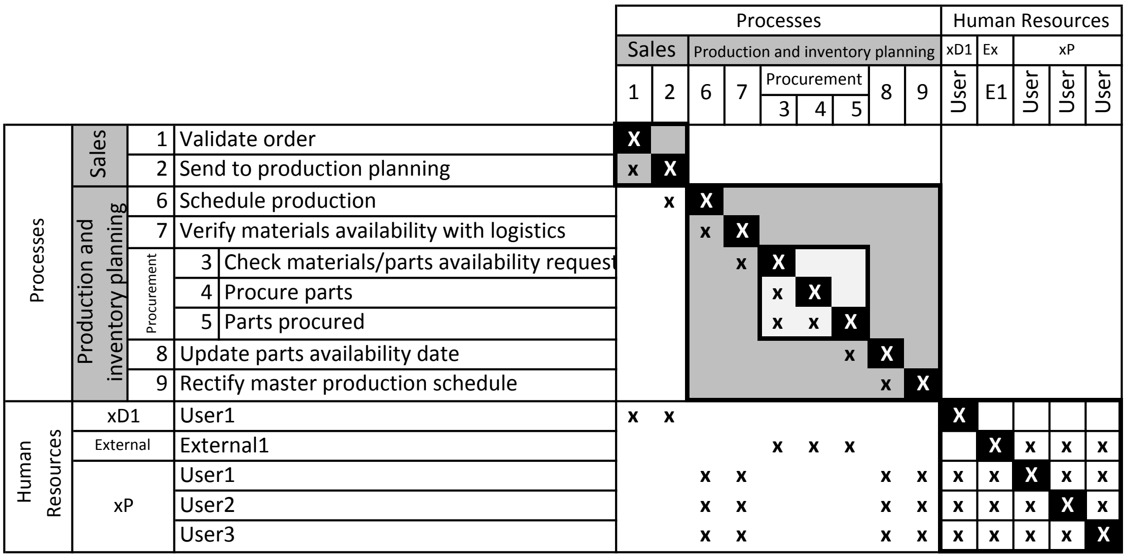


Figure 7.42. MDM matrix for "to-be" SS_1's collaboration with new process arrangement.

Based on this MDM, the new BPM for sales, logistics and production planning is proposed in Figure 7.43.

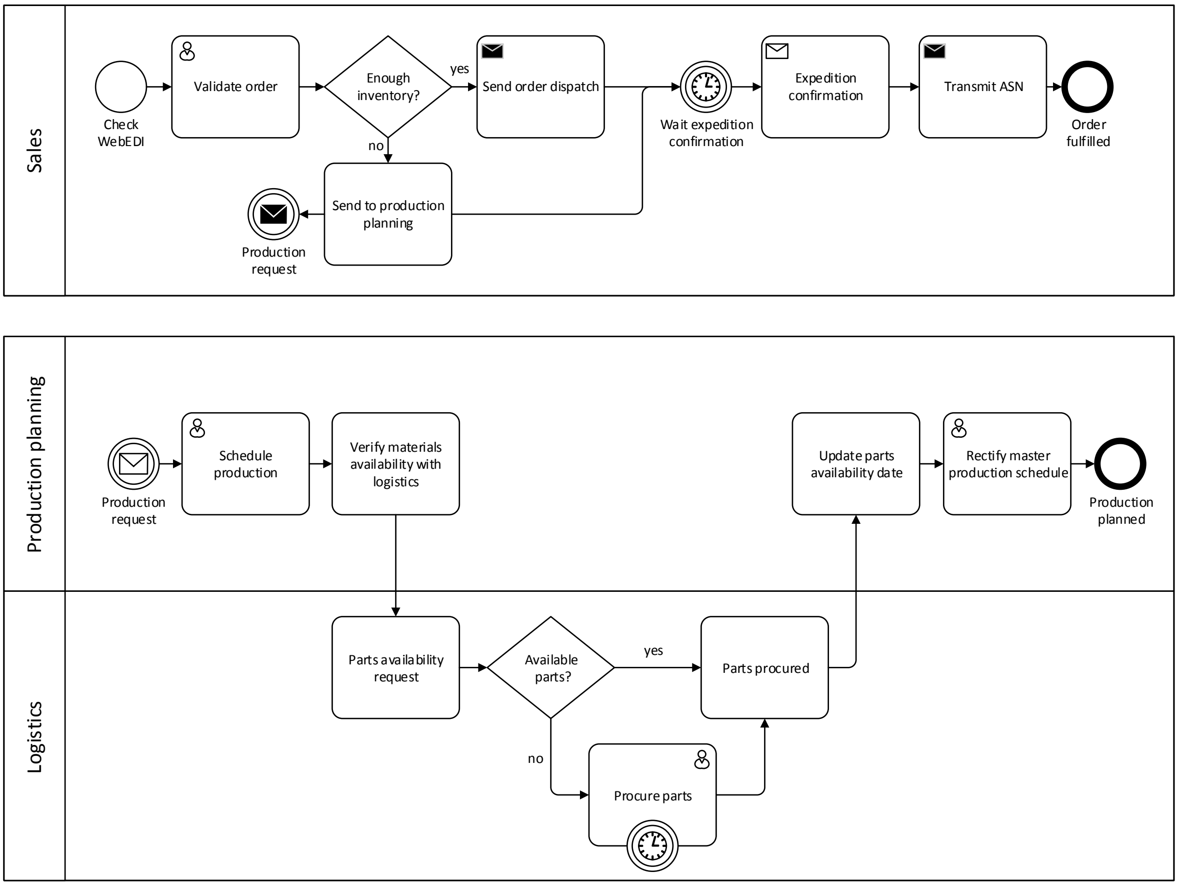


Figure 7.43. New process sequence and arrangement for sales, logistics and production planning activities.

Using this process sequence, the dependency of $FR_{3.1.2.3}$ from $DP_{3.1.2.1}$ is solved. Instead of allocating several processes to the same organisational section, the selling process has a proper section. The final BPM for the SS_1's processes is presented in Figure 7.44.

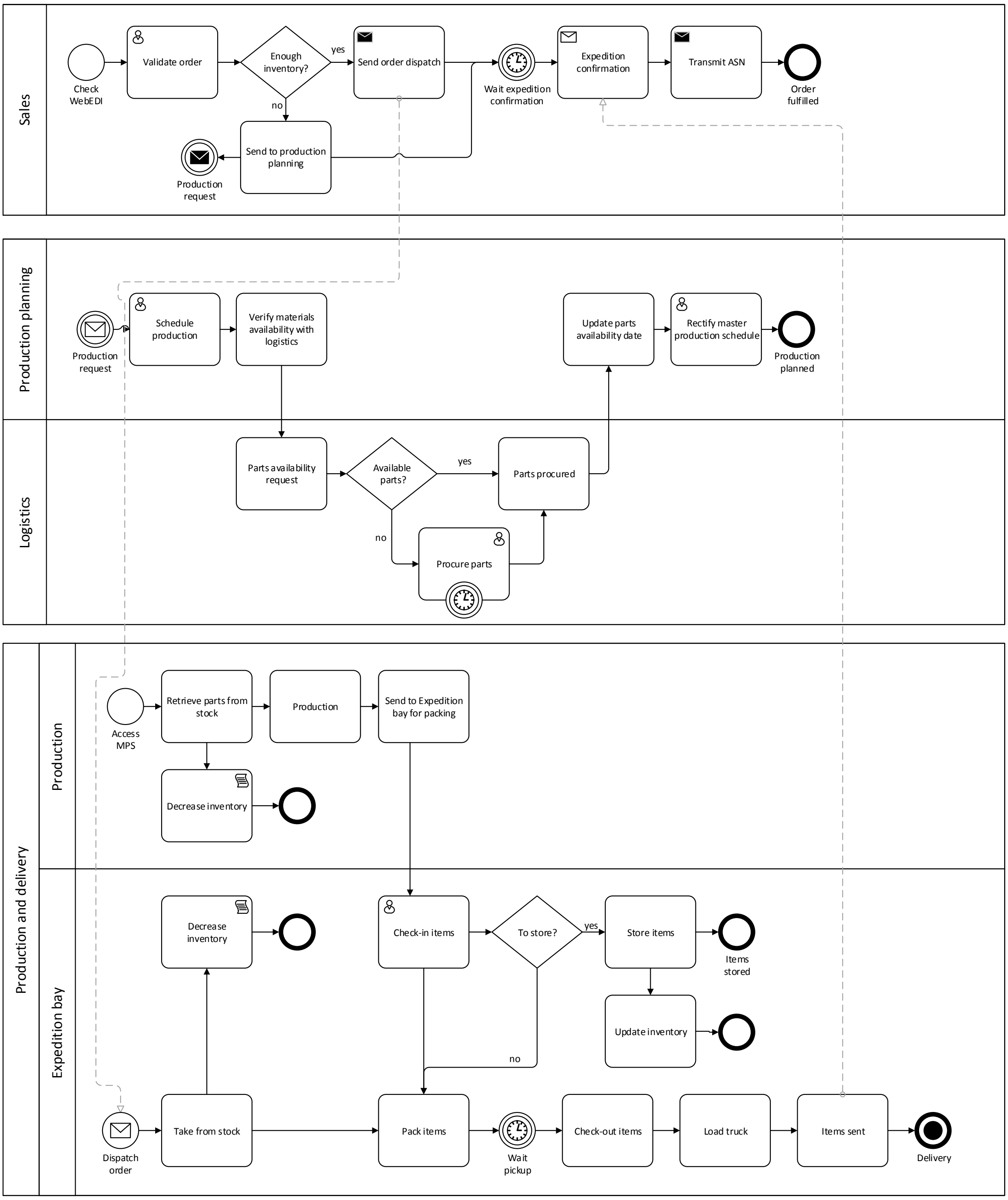


Figure 7.44. SS_1's internal processes after new process sequence and organisational alignment.

The interface BPM ($DP_{3.1.3}$) is presented in Figure 7.45.

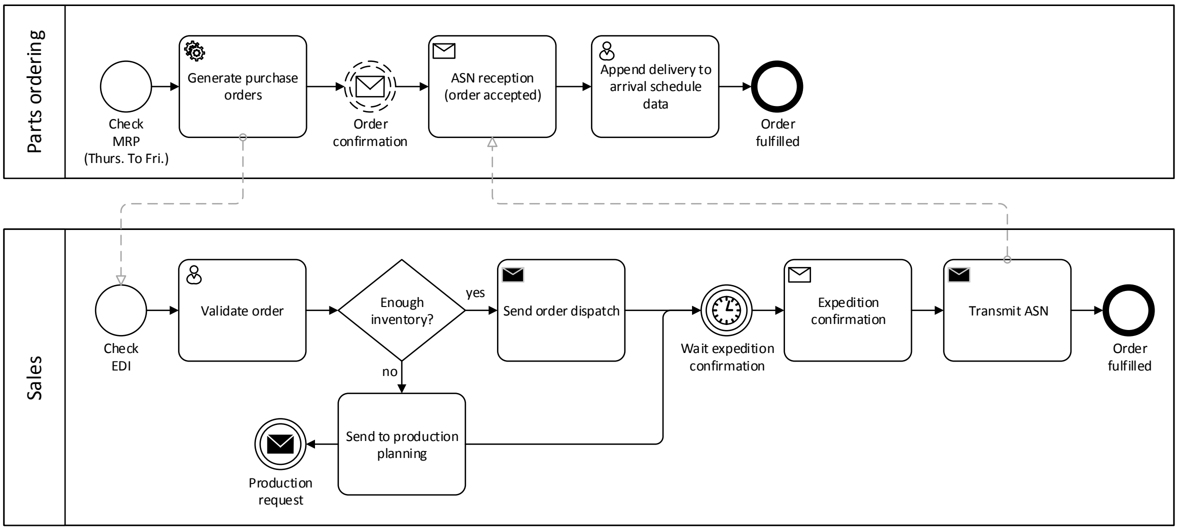


Figure 7.45. "To-be" interface between parts ordering and sales section.

7.5. Case study 2

The objective of this case study is to improve interoperability in the expedition-reception interaction (i2) of the FS-SS_1 dyad. The CN for this case is to “achieve optimal interoperability in the expedition-reception interaction of the FS-SS_1 dyad”.

7.5.1. Interoperability characterization and modelling of processes and resources

The procedure takes place after the purchased components are produced and send to pack and deliver section (xD3) of SS_1. In this section, the components are labelled, packed and stored until freight forwarder picks them to deliver to FS’s reception (dS2). This interaction is represented by i2 in Figure 7.46.

				FS		SS_1			
				dS1	dS2	xD1	xP	xM	xD3
Dyad operations	FS	Purchasing	dS1	X					
		Reception	dS2	x	X				i2
	SS_1	Sales	xD1			X	x		x
		Plan	xP			x	X		
		Production	xM				x	X	
		Pack and Deliver	xD3			x		x	X

Figure 7.46. Supply chain operations involved in the delivery-reception interaction.

The design of the delivery-reception interaction in dyad is given by the FRs, DPs and PVs presented in Table 7.25.

Table 7.25. The “as-is” design of the delivery-reception interaction.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.2}$: Model and manage the expedition-reception relationship.	$DP_{3.2}$: Features of delivery preparation and order reception.	
$FR_{3.2.1}$: Model and manage SS_1 processes.	$DP_{3.2.1}$: SS_1 actual BPM for delivery preparation (see Figure 7.49).	
$FR_{3.2.1.1}$: Model the process sequence of SS_1 delivery processes.	$DP_{3.2.1.1}$: Sequential activities.	$PV_{3.2.1.1}$: Expedition procedure doesn't require interaction with other activities. There are no resource limitations.
$FR_{3.2.1.2}$: Manage the AIDC system to identify components.	$DP_{3.2.1.2}$: Manual entry of component data.	$PV_{3.2.1.2}$: Users at the expedition bay entry manually the component information on the labelling system.
$FR_{3.2.1.3}$: Manage the method to identify components.	$DP_{3.2.1.3}$: Manual labelling.	$PV_{3.2.1.3}$: Users tag items manually.
$FR_{3.2.1.4}$: Manage product ID on storage check-in.	$DP_{3.2.1.4}$: Handheld scanners to test and check-in components on SAP.	$PV_{3.2.1.4}$: Users test the print barcodes and check-in on SAP.
$FR_{3.2.1.5}$: Align SS_1’s processes with organisational structure.	$DP_{3.2.1.5}$: One section for each task (see Figure 7.50).	$PV_{3.2.1.5}$: Warehouse activities have dedicated section.
$FR_{3.2.2}$: Model and manage FS processes.	$DP_{3.2.2}$: FS actual BPM for reception (see Figure 7.51 and Figure 7.52).	
$FR_{3.2.2.1}$: Model the process sequence of FS's reception processes.	$DP_{3.2.2.1}$: Sequential procedures without external dependencies.	$PV_{3.2.2.1}$: Reception procedure occurs independently from other FS's

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
		processes. Resource quantity is variable. Every employee from warehouse and production facility that are available may perform the warehouse activities.
$FR_{3.2.2.2}$: Monitor orders.	$DP_{3.2.2.2}$: ASN received before shipment.	$PV_{3.2.2.2}$: Users at parts ordering receive ASN and append the data to a reception schedule.
$FR_{3.2.2.3}$: Manage product identification on materials/components reception.	$DP_{3.2.2.3}$: Components tagged with SS_1's barcode system.	$PV_{3.2.2.3}$: Users at reception unload the truck and scan the SS_1's labels using handheld barcode scanners.
$FR_{3.2.2.4}$: Manage the AIDC systems for product identification and control.	$DP_{3.2.2.4}$: Citrix labelling system to use ASN data and order data (SAP) to create labels.	$PV_{3.2.2.4}$: Users at reception check SAP for component information and generate labels on Citrix system.
$FR_{3.2.2.5}$: Manage the method to identify items.	$DP_{3.2.2.5}$: Manual labelling of components.	$PV_{3.2.2.5}$: Users tag pallets, packages and units manually.
$FR_{3.2.2.6}$: Align reception with FS organisational structure.	$DP_{3.2.2.6}$: Functional process distribution, matching reception procedure with a section (see Figure 7.53).	$PV_{3.2.1.6}$: Reception section handles the material income, makes verification, labels and stores.
$FR_{3.2.3}$: Align companies' internal processes.	$DP_{3.2.3}$: The collaboration BPM and features of delivery.	
$FR_{3.2.3.1}$: Manage the communication path to monitor orders.	$DP_{3.2.3.1}$: Standard procedure defined to communicate orders.	$PV_{3.2.3.1}$: The user from sales and logistics section confirms orders by EDI sending an ASN.
$FR_{3.2.3.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.2.3.2}$: ASN is integrated directly on SAP system.	$PV_{3.2.3.2}$: User from parts ordering review daily the order confirmations in order to prepare for component reception.
$FR_{3.2.3.3}$: Manage the interface between AIDC systems from both companies.	$DP_{3.2.3.3}$: Companies use similar AIDC systems, but different barcodes (data not interoperable).	$PV_{3.2.3.3}$: Users from FS's reception need to label the items upon their arrival.
$FR_{3.2.4}$: Select metrics to monitor interface processes.	$DP_{3.2.4}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.2.4}$: See Excel PID DSM Metrics

The corresponding design matrices are presented in Figure 7.47 and Figure 7.48. This matrix relates, also, to the preceding BS and RM aspects of the dyad.

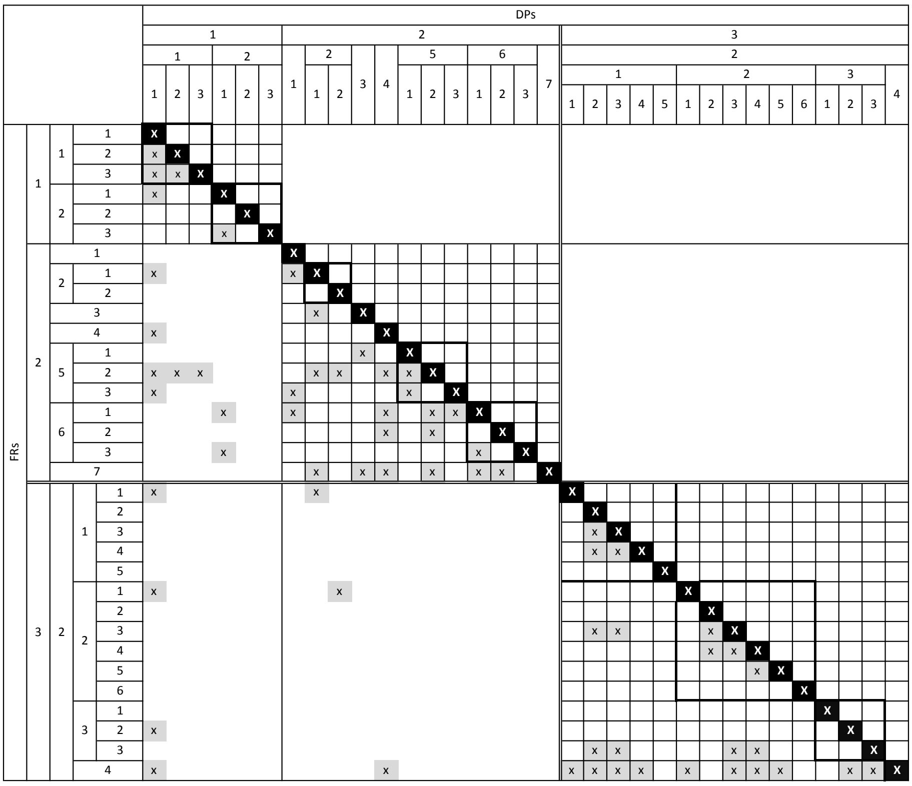


Figure 7.47. Design matrix for the "as-is" design of delivery-reception interaction (mapping between FRs and DPs).

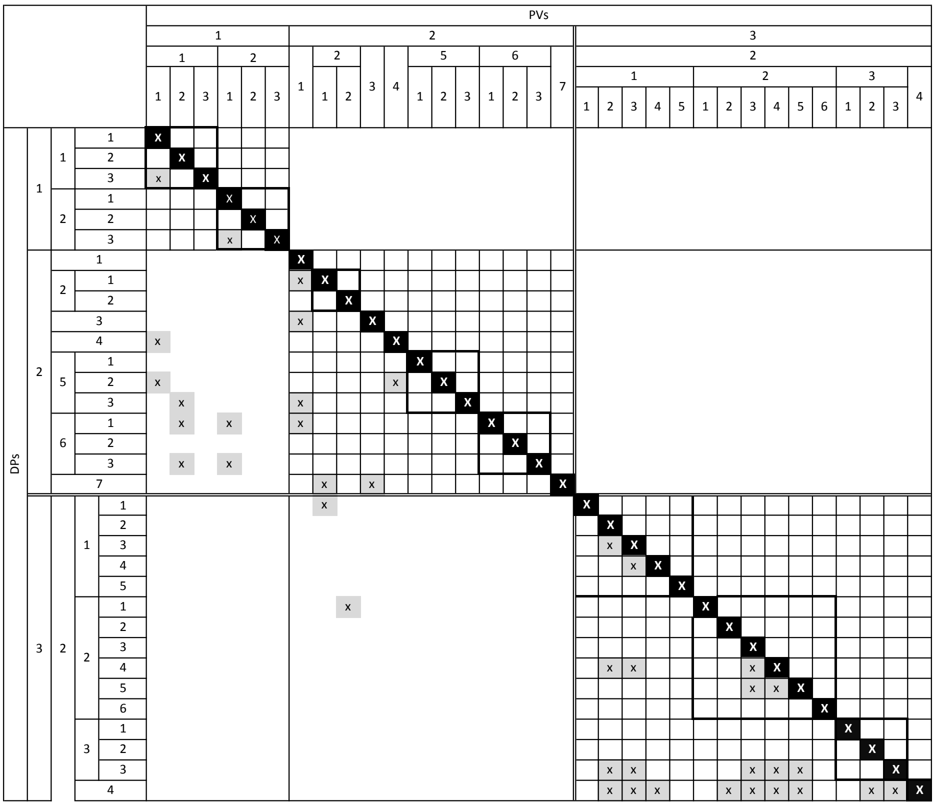


Figure 7.48. Design matrix for the "as-is" design of delivery-reception interaction (mapping between DPs and PVs).

SS_1's internal processes

The delivery-reception interaction starts in SS_1 with the arrival of the requested components to the "expedition bay". The processes of production and delivery are represented by Figure 7.49.

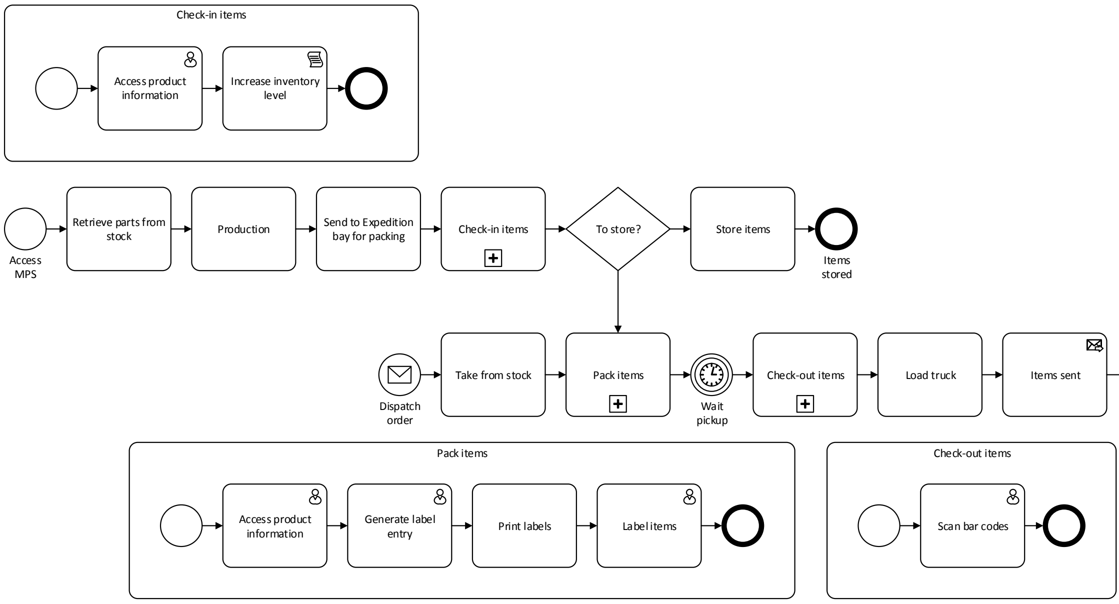


Figure 7.49. SS_1's production and delivery processes.

In terms of process sequence ($FR_{3.2.2.1}$), in this one the activities are sequential ($DP_{3.2.2.1}$) not requiring interaction with another company's sections.

On $FR_{3.2.2.2\text{-}4}$, the procedure to identify and control components in warehouse is managed. This one is mostly manual, resulting on the design matrix presented in equation (7.7).

$$\begin{bmatrix} FR_{3.2.2.1} \\ FR_{3.2.2.2} \\ FR_{3.2.2.3} \\ FR_{3.2.2.4} \\ FR_{3.2.2.5} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 \\ 0 & x & x & x & 0 \\ 0 & 0 & 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.2.2.1} \\ DP_{3.2.2.2} \\ DP_{3.2.2.3} \\ DP_{3.2.2.4} \\ DP_{3.2.2.5} \end{bmatrix} \tag{7.7}$$

$FR_{3.2.2.2\text{-}4}$ and $DP_{3.2.2.2\text{-}4}$ are decoupled because the design solution is not the one that fits best the FRs. The component identification in the IS is performed after the products being produced by entering manually the product information ($DP_{3.2.2.2}$), manually labelling them ($DP_{3.2.2.3}$) and using handheld scanners to test and check-in components ($DP_{3.2.2.4}$). Instead of this design approach, an automated labelling system could be implemented to tag the components automatically, during production or after production. The automated labelling system generates and tags components automatically. Though, due to the dimension of the SS_1's products (20 to 80 kg copper wire drums), in each shipment few products are sent (maximum 13 copper wire drums of 80 kg). Hence, the selected method for labelling is manual, and no optimization was suggested for this aspect.

Regarding the alignment of processes ($FR_{3.2.2.5}$), the production and component preparation for expedition are distributed in two sections (see Figure 7.50), i.e., one section for each task ($DP_{3.2.2.5}$).

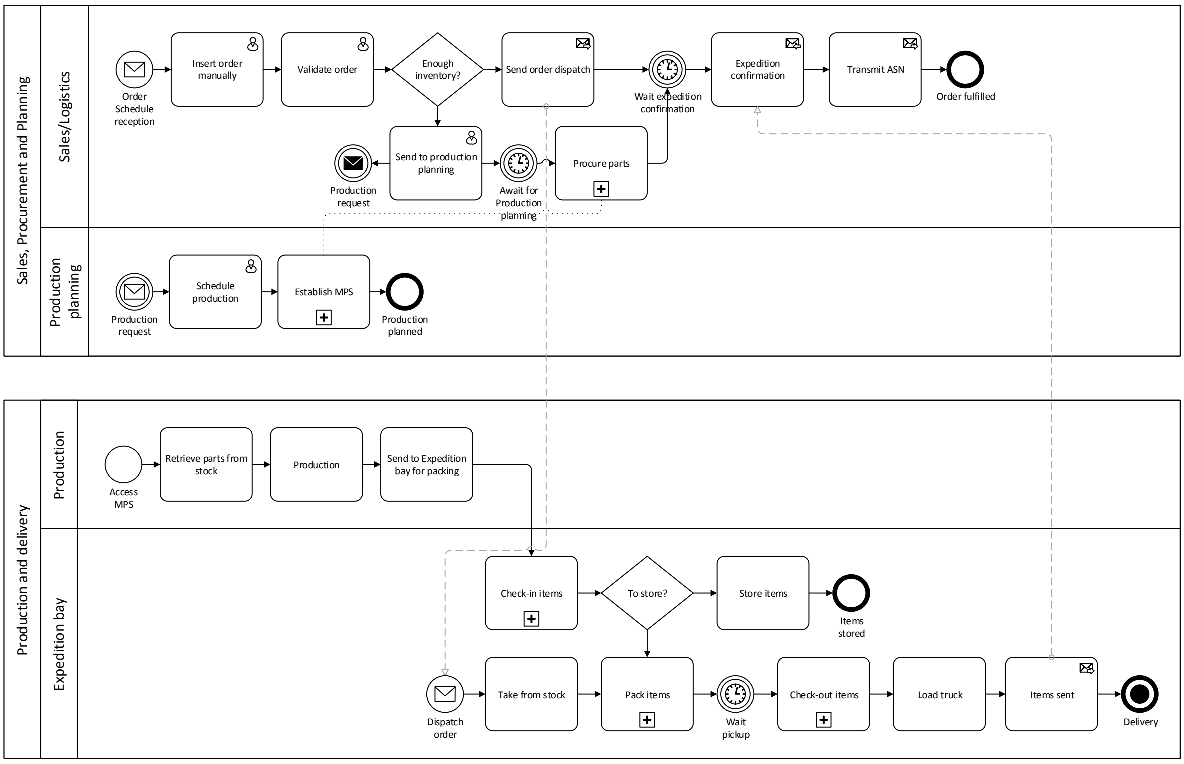


Figure 7.50. Alignment of production and warehouse processes with SS$_1$'s organisational sections.

FS's internal processes

In turn, FS processes start with the reception of SS$_1$'s ASN and, afterwards, the components reception. These processes are represented by Figure 7.51 and Figure 7.52.

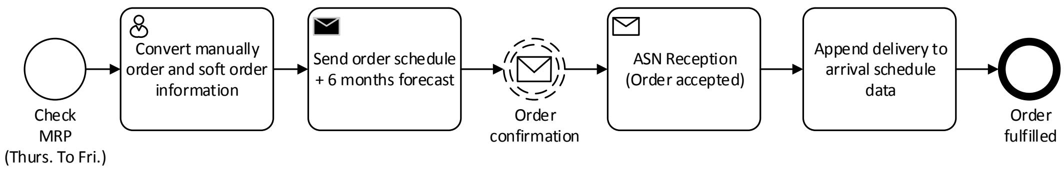


Figure 7.51. FS's parts ordering processes.

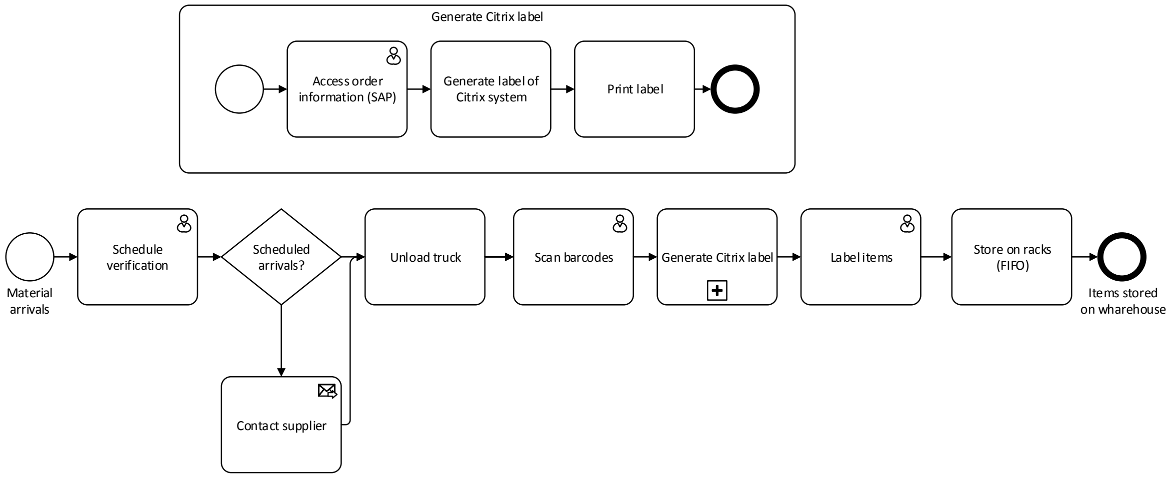


Figure 7.52. FS's reception processes.

In terms of process sequence, both BPM are sequential ($DP_{3.2.1.1}$). Exists only one interaction between parts ordering and reception to communicate the arrival schedule, but this factor it isn't determinant for reception process execution. It is only a mechanism to ensure that the arrival was programmed and the corresponding ASN was already received before the arrival.

The first activity to approach is the monitoring of orders ($FR_{3.2.1.2}$). This FR refers to the form FS accompanies the progress of the delivery. The design approach for this FS is the reception of an ASN before shipment ($DP_{3.2.1.2}$). Real-time or periodic monitoring it isn't implemented. Only for problem solving situations, contacting directly the freight forwarder.

Product identification on components reception ($FR_{3.2.1.3}$) is already performed previously by SS_1 before shipment ($DP_{3.2.1.3}$). Though, this labelling method it isn't appropriate for FS needs, representing an interoperability problem in terms of the exchanged data. FS requires more information encoded in barcode labels in a specific format. As consequence, $FR_{3.2.1.4}$ and $FR_{3.2.1.5}$ are a requirement due to lack of interoperability in the data format between barcodes, adding the need for a labelling system. These two FRs are, then, solved in the "as-is" situation by: a "Citrix labelling system to use ASN data and order data (SAP) to create labels ($DP_{3.2.1.4}$); and "manual labelling of components" ($DP_{3.2.1.5}$).

Last, FS's process alignment is achieved in a functional manner, with the ASN reception procedure integrated in the parts ordering section and reception and warehouse activities in reception section (see Figure 7.53).

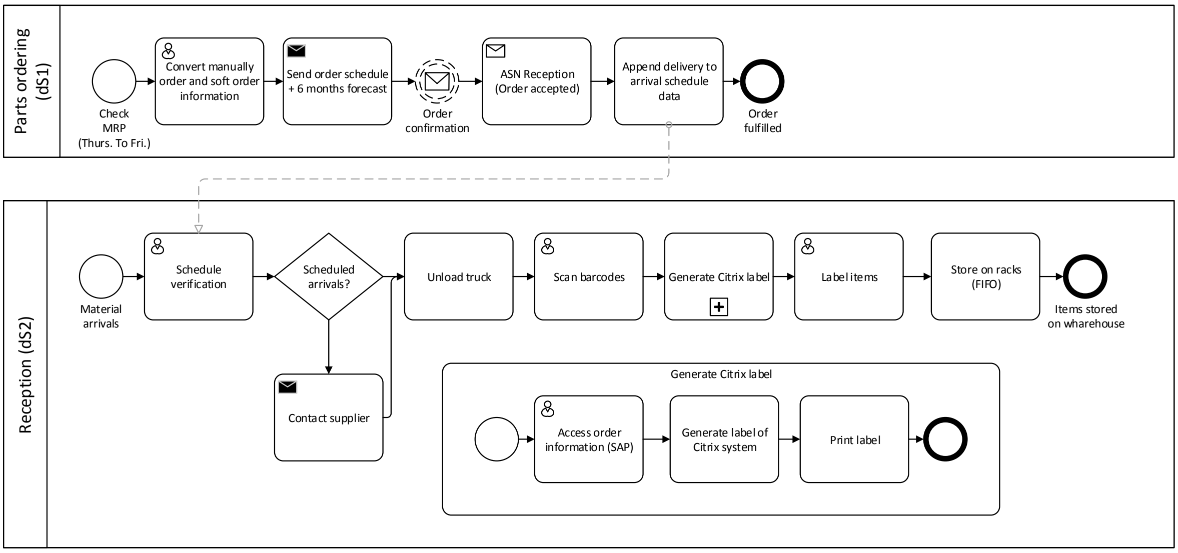


Figure 7.53. Functional alignment of purchasing and reception processes with parts ordering and reception sections, respectively.

The resulting design matrix for FS's internal processes ($FR_{3.2.1}$) is given by equation (7.8).

$$\begin{bmatrix} FR_{3.2.1.1} \\ FR_{3.2.1.2} \\ FR_{3.2.1.3} \\ FR_{3.2.1.4} \\ FR_{3.2.1.5} \\ FR_{3.2.1.6} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 & 0 & 0 \\ 0 & x & 0 & 0 & 0 & 0 \\ 0 & x & x & 0 & 0 & 0 \\ 0 & x & x & x & 0 & 0 \\ 0 & 0 & 0 & x & x & 0 \\ 0 & 0 & 0 & 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.2.1.1} \\ DP_{3.2.1.2} \\ DP_{3.2.1.3} \\ DP_{3.2.1.4} \\ DP_{3.2.1.5} \\ DP_{3.2.1.6} \end{bmatrix} \tag{7.8}$$

There are two couplings between FRs and DPs in the presented matrix. The first one refers to the dependence of the product identification and the AIDC systems from the data from ASN. The second refers to additional work performed to place labels manually, instead of an automated process.

Internal processes alignment between firms ($FR_{3.2.3}$) is the third FR of this interface. This FR is fulfilled by the collaboration BPM (see Figure 7.54) and the features of delivery. The interface is characterized by a material flow and two message flows. One of the message flows coincides with the material flow. It is the information content of the barcodes attached to components. The other message flow is the ASN transmission, which is illustrated in Figure 7.13.

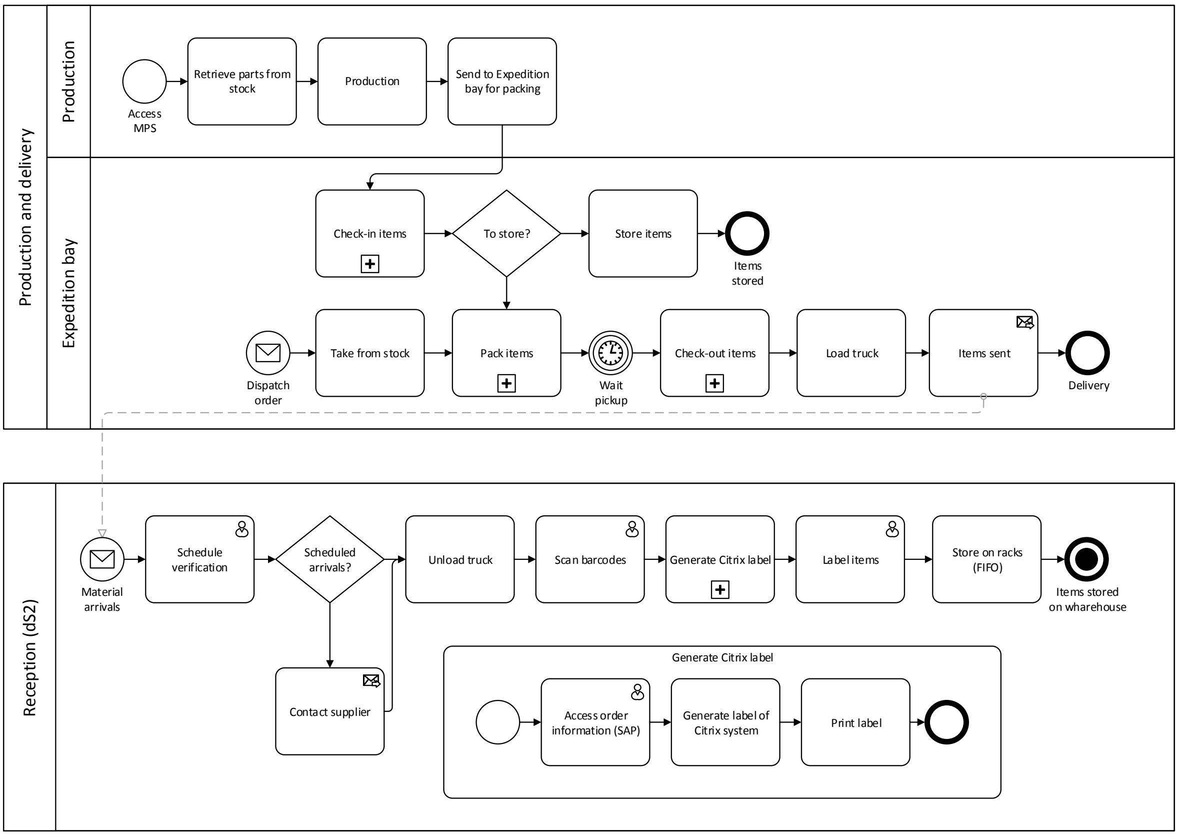


Figure 7.54. Interface between expedition bay and reception section.

Interface processes

Interface design is achieved by equation (7.9).

$$\begin{bmatrix} FR_{3.2.3.1} \\ FR_{3.2.3.2} \\ FR_{3.2.3.3} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 \\ 0 & x & 0 \\ 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.2.3.1} \\ DP_{3.2.3.2} \\ DP_{3.2.3.3} \end{bmatrix} \tag{7.9}$$

This one is uncoupled, not reflecting interoperability issues on the interface. Though, $FR_{3.2.1.3}$ is fulfilled by the use of compatible AIDC systems, but different data ($DP_{3.2.1.3}$). Interoperability problems are inherent to different barcodes on products performed individually and, as consequence, reflected on the receiver and on the interface.

7.5.2. Optimization procedure

Having in consideration the "as-is" interoperability conditions, the dyad performance in the expedition-reception interaction can be improved by implementing a different solution for component identification and tracking in the dyad (i.e. the proposal of a new interoperability solution – B).

To support the optimisation procedure, performance metrics were selected to assess the impact of interoperability improvements in the interaction:

- Order lead-time on material reception (OLT) and after reception processing (OLTreal).
- Conversion time (Cv) in SS_1 and FS.
- Time of interoperation (TI) in SS_1 and FS.

Adoption of the FS's barcode system in SS_1's reception processes

On the actual configuration of the dyad, both actors use bar code system in order to identify and track item location on-site ($DP_{3.3.3}$). Upon components reception, FS's reception employees unload the truck and label manually the packaged and individual items ($PV_{3.1.3}$). This procedure is applied in both companies in order to track internally goods and keep the inventory updated electronically. Though, the "as-is" processes have little room for improvement. There are no limitations in terms of resources in the SS_1 and FS processes, and there is no coupling of process sequence and organisational alignment aspects.

In the management and control of the components onsite some problems are portrayed in the design matrix (see Figure 7.47). In SS_1, some couplings were identified but none of them are passible to be solved because of the limitations of the product. In turn, in FS the problem occurrence is due to the data encoded by SS_1. Two additional processes ("generate label in Citrix system" and "label items" in Figure 7.54) are required to label the components appropriately.

Nevertheless, having a duplicated procedure on both companies leads to delays of additional NVA activities and is subject to the increase of human errors and may be resource-consuming. On the one hand, SS_1 labels the finished products in order to keep track of them on storage and, when an order dispatch is received, has to pack the components and create documentation that must accompany the shipped products. On the other hand, FS needs to check-in items upon reception and label them to keep track of inventories, location and ensure FIFO[20] policies for production.

The suggested alternative is to establish requirements for SS_1 to encode additional data in the barcode labels. This implies that, in terms of BS, a future contract should negotiate the labelling specifications. The FR for this aspect could be stated as: "establish labelling specifications for suppliers".

In terms of RM, responsibilities should be shifted from FS ($FR_{2.2.2}$) to be added to supplier ($FR_{2.2.1}$). Namely, the labelling of components is performed by SS_1, like it is performed nowadays, but with the FS's specifications.

In terms of responsibility assignment ($FR_{2.2}$), responsibilities should be shifted from FS ($FR_{2.2.2}$) to be added to supplier ($FR_{2.2.1}$). The DPs could be maintained, but the PV will have a change in the existing responsibilities to pass the activity of labelling to the supplier. Changes on the DPs and PVs of $FR_{2.2.1}$

[20] FIFO – First in first out

according to the design matrix affect $FR_{3.2.1.1}$ and $FR_{3.2.2.1}$, on the expedition business process and on the reception business process, respectively.

Regarding PI, in FS, the activities of “generate label in Citrix system” and “label items” are eliminated. Shifting the responsibility of labelling to SS_1 would imply that FS only has to unload the truck and read the bar codes to entry them on the inventory management system. The process for this implementation is presented in Figure 7.55.

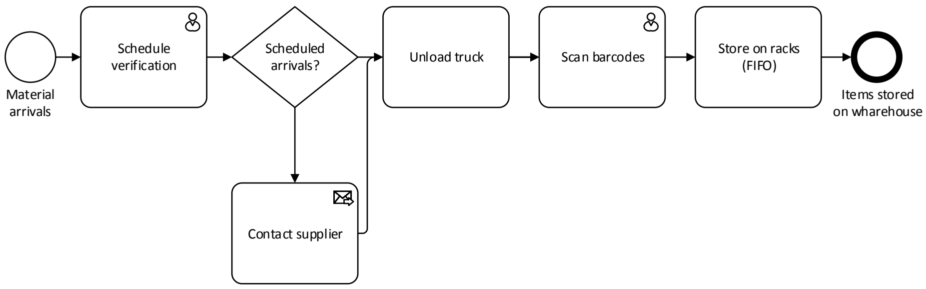


Figure 7.55. Proposed FS’s reception process.

Regarding the packing procedure of SS_1, this alteration implies additional work beyond packing. Users on expedition bay need to label the copper wire rods with appropriate labels readable by FS (see DI, SSI, OHI specifications). In terms of processes, the new procedure is presented in Figure 7.56.

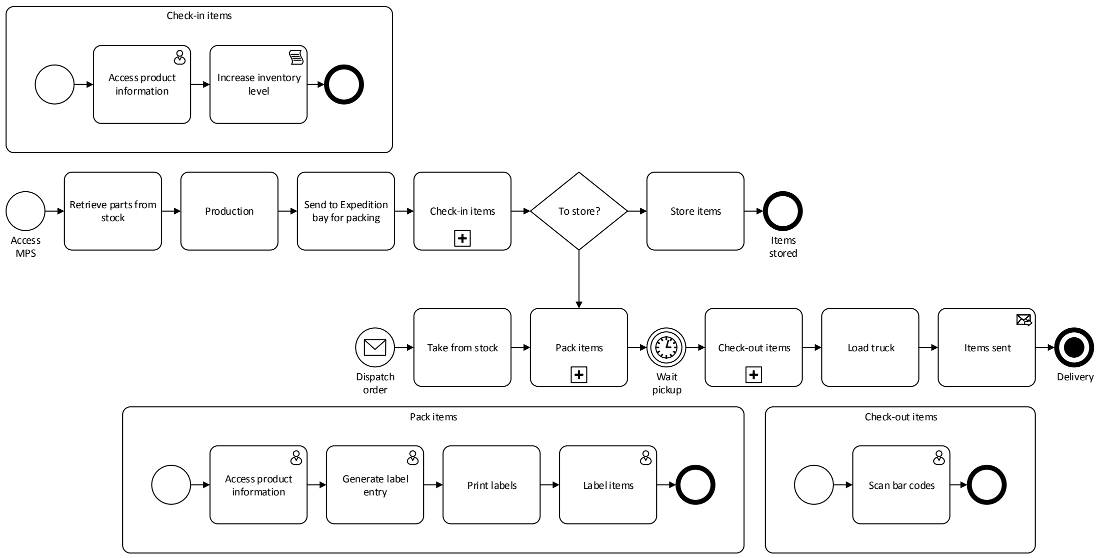


Figure 7.56. Proposed SS_1’s expedition process.

This BPM is similar to the “as-is”, but differs in terms of the labels and the data encoded.

In sum, the scenarios to test are the following:

- “as-is” conditions for the delivery-reception interface;

- Adoption of the FS's barcode system by SS_1.

The results for both scenarios are presented in Table 7.26.

Table 7.26. Simulation results regarding the "as-is" and the proposed barcode system.

Scenarios	Order lead-time		Conversion time (Cv)			Time of interoperation (TI)		
	On material reception (OLT)	After reception processing (OLTreal)	Total	SS_1	FS	Total	SS_1	FS
	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
"as-is"	118,732	128,96	12,899	3,967	8,932	10,674	3,967	6,707
FS's barcode system	121,005	124,72	8,559	6,239	2,32	6,322	6,239	0,083

Graphically, these results are represented in Figure 7.57, Figure 7.58 and Figure 7.59.

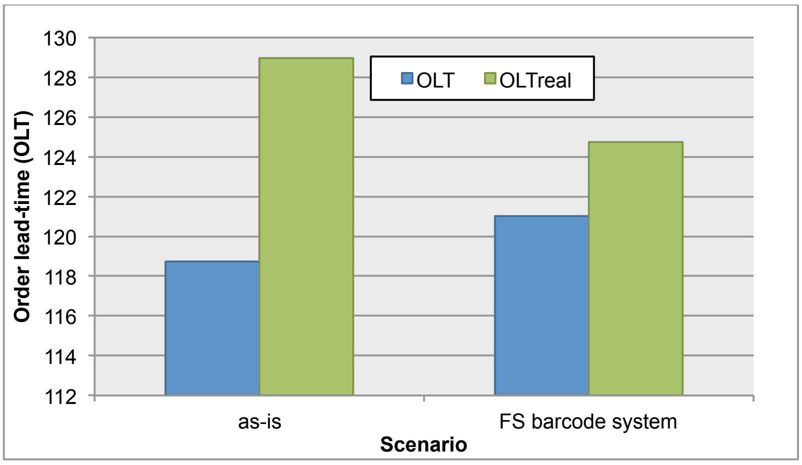


Figure 7.57. Comparison of order lead-time values for "as-is" and the proposed barcode system.

From the analysis of the influence of each scenario on order lead-time (see Figure 7.57), the implementation of the FS's barcode system leads to worse results in terms of OLT, but some improvement on OLTreal. This means that by implementing the FS's barcode system on SS_1, components will be received, identified and stored more quickly (a difference in about 4 hours).

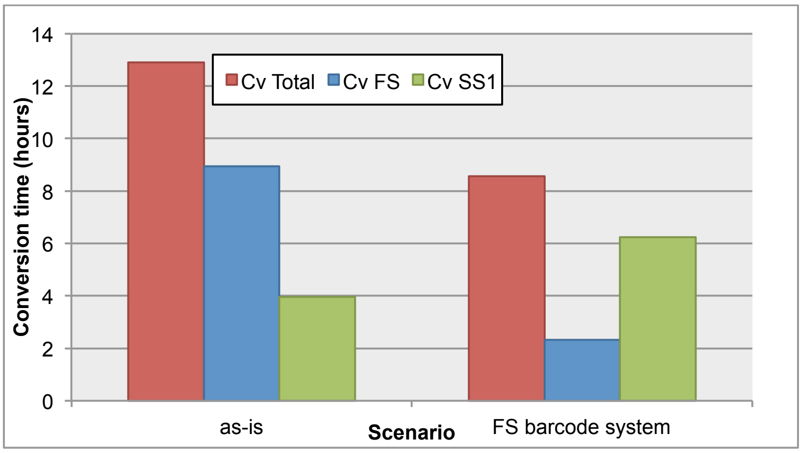


Figure 7.58. Comparison of wasted time in conversion values for "as-is" and the proposed barcode system.

In terms of conversion time (see Figure 7.58), this change leads to less wasted time in conversion in total and on FS. Nevertheless, the conversion time increased on SS_1. In addition to the SS_1 barcode system, employees on SS_1's expedition bay have to access the required data to input on the labelling system that will produce the barcode labels according to FS's specifications. This originated that more time was spent doing this activities. That is also reinforced on the analysis of time of interoperation (see Figure 7.59).

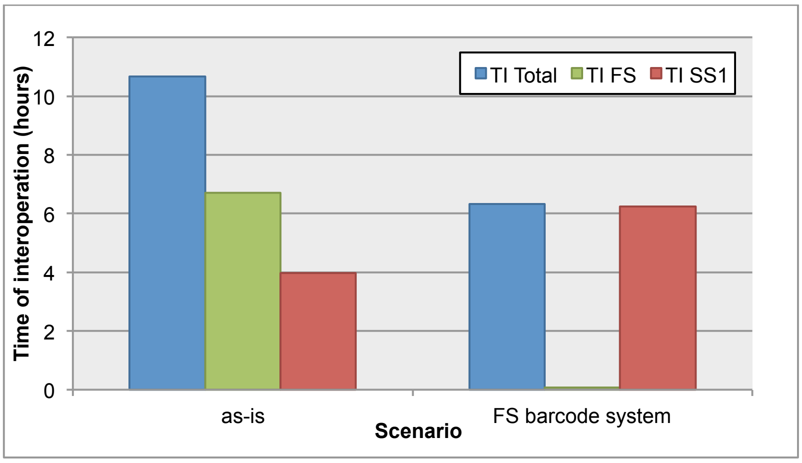


Figure 7.59. Comparison of time of interoperation values for "as-is" and the proposed barcode system.

In conclusion, the proposed scenario only brings benefits to FS by reducing the OLT_{real}, conversion time and time of interoperation on the reception procedures. With this solution, FS would have access to the components more quickly, that has impact directly on planning activities, by updating rapidly the inventory, and also will diminish the required time to receive and store components, reducing the resource occupancy. In counterpart, the adoption of FS's barcode system would make resource occupancy and availability higher on SS_1.

7.5.3. Scenario comparison and discussion

Using equation (7.6) the improvement percentage towards the "as-is" scenario was determined for the overall perspective and for the companies' individual perspectives (see Table 7.27 and Table 7.28).

Table 7.27. Overall improvement of metrics for FS's barcode system scenario.

Scenario	OLT improvement (%)	OLTreal improvement (%)	TI total improvement (%)	Cv total improvement (%)	Total improvement (%)
FS barcode system	-1,91	3,29	40,77	33,65	72,50

Table 7.28. Individual improvement percentage for time of interoperation and wasted time in conversion.

Perspective	TI improvement (%)	Cv improvement (%)
FS	98,76	74,03
SS_1	-57,27	-57,27

On an overall view of the results (see Figure 7.60), though the OLTreal, Cv and TI improve in the proposed scenario, the obtained value for order lead-time is worse than the "as-is" in about 1,91 %. This value exceeds the contracted conditions for the delivery lead-time (5 working days, 120 hours). Nevertheless, this value is too small to consider a delay and this scenario should be considered in the combination of the several interfaces for dyad.

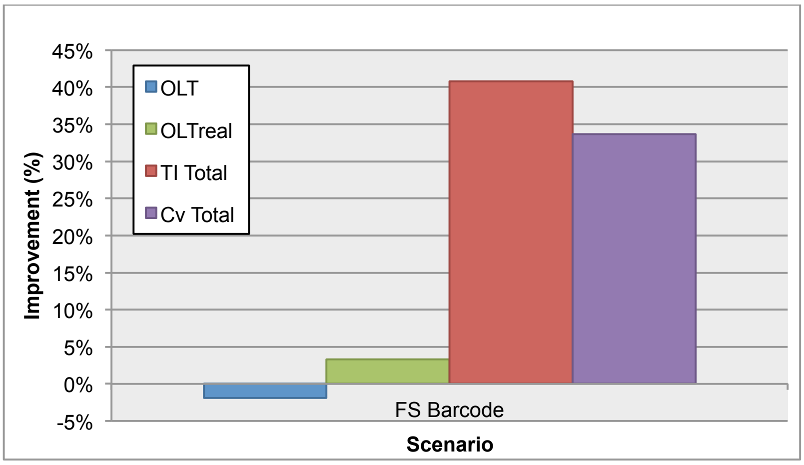


Figure 7.60. Overall improvement percentage.

Regarding companies individual perspectives (see Figure 7.61), the proposed scenario benefits FS and affects SS_1's performance. The shifting of labelling responsibilities from FS to SS_1 may permit a more interoperable and higher performance in terms of the dyad, but will clearly prejudice SS_1.

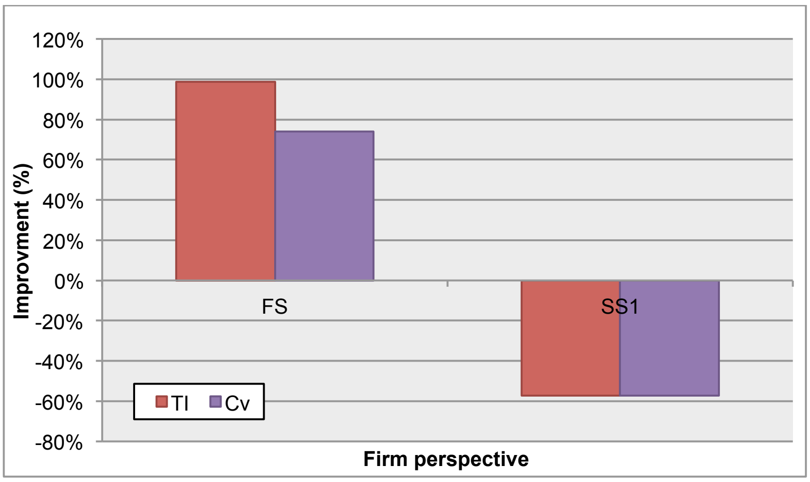


Figure 7.61. Companies's individual improvement.

Though, if the overall gain is considered, and if the increase of OLT is admissible, the FS's barcode system may be adopted to obtain a higher dyad performance.

Implications of the selected alternative in the dyad design – "to-be" scenario

To implement the FS's barcode system, there must be an agreement between the two parts in order to SS_1 change its barcode system. This could be negotiated by a new contract that clearly specifies this requirement. The changes to business strategy (BS) conditions are resumed in Table 7.29.

Table 7.29. Proposed changes in business strategy conditions.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{1,3}$: Establish labelling specifications for suppliers.	$DP_{1,3}$: FS's barcode system and labelling requirements.	
$FR_{1.3.1}$: Establish the labelling specifications.	$DP_{1.3.1}$: All the competencies and resources reviewed to implement the FS's barcode system.	$PV_{1.3.1}$: FS provides the barcode layout and data required on each label.
$FR_{1.3.2}$: Reconcile labelling specifications with the individual strategy.	$DP_{1.3.2}$: Labelling specifications duly discussed and agreed between parts.	$PV_{1.3.2}$: FS's barcode system incorporated in SS_1's warehouse barcode system.
$FR_{1.3.3}$: Ensure clarity in the labelling specifications for both actors.	$DP_{1.3.3}$: Partners adopt the same barcode system and review its efficiency.	$PV_{1.3.3}$: FS's provides a validation tool for the barcodes.

In terms of relationship management (RM), there are some changes regarding the responsibility assignment. This would impact the FRs, DPs and PVs on Table 7.30.

Table 7.30. Changes in RM PVs for the "to-be" scenario.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{2.2.1}$: Assign responsibilities to the supplier.	$DP_{2.2.1}$: Well-defined. The responsibility and roles assignment is not an issue.	**$PV_{2.2.1}$: SS_1 is responsible for receiving orders from the focal firm, produce, pack, <u>label according to FS's requirements</u> and deliver the goods in the specified times and supporting all the costs.**
$FR_{2.2.2}$: Assign responsibilities to the focal firm.	$DP_{2.2.2}$: Well-defined. The responsibility and roles assignment is not an issue.	**$PV_{2.2.2}$: FS places orders, delivers the production schedules and forecasts, manages the relationship by monitoring it onsite, receives the goods, inspects and performs the payments.**

Last, the changes in process interoperability (PI) to implement the FS's barcode system are presented on Table 7.31 and the design matrix on Figure 7.62 and Figure 7.63.

Table 7.31. The "to-be" design of the delivery-reception interaction.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.2}$: Model and manage the expedition-reception relationship.	$DP_{3.2}$: Features of delivery preparation and order reception.	
$FR_{3.2.1}$: Model and manage SS_1 processes.	**$DP_{3.2.1}$: SS_1 new BPM for delivery preparation (see Figure 7.56).**	
$FR_{3.2.1.1}$: Model the process sequence of SS_1 delivery processes.	$DP_{3.2.1.1}$: Sequential activities.	$PV_{3.2.1.1}$: Expedition procedure doesn't require interaction with other activities. There are no resource limitations.
$FR_{3.2.1.2}$: Manage the AIDC system to identify components.	$DP_{3.2.1.2}$: Manual entry of component data.	**$PV_{3.2.1.2}$: Users at the expedition bay entry manually the component information on the FS's labelling system.**
$FR_{3.2.1.3}$: Manage the method to identify components.	$DP_{3.2.1.3}$: Manual labelling.	$PV_{3.2.1.3}$: Users tag items manually.
$FR_{3.2.1.4}$: Manage product ID on storage check-in.	$DP_{3.2.1.4}$: Handheld scanners to test and check-in components on SAP.	$PV_{3.2.1.4}$: Users test the print barcodes and check-in on SAP.
$FR_{3.2.1.5}$: Align SS_1's processes with organisational structure.	$DP_{3.2.1.5}$: One section for each task (see Figure 7.50).	$PV_{3.2.1.5}$: Warehouse activities have dedicated section.
$FR_{3.2.2}$: Model and manage FS processes.	**$DP_{3.2.2}$: FS actual BPM for parts ordering (see Figure 7.51) and new process for reception (see Figure 7.55).**	
$FR_{3.2.2.1}$: Model the process sequence of FS's reception processes.	$DP_{3.2.2.1}$: Sequential procedures without external dependencies.	$PV_{3.2.2.1}$: Reception procedure occurs independently from other FS's processes. Resource quantity is variable. Every employee from warehouse and production facility that are available may perform the warehouse activities.
$FR_{3.2.2.2}$: Monitor orders.	$DP_{3.2.2.2}$: ASN received before shipment.	$PV_{3.2.2.2}$: Users at parts ordering receive ASN and append the data to a reception schedule.
$FR_{3.2.2.3}$: Manage product identification on materials/components reception.	**$DP_{3.2.2.3}$: Components tagged with FS's barcode system.**	**$PV_{3.2.2.3}$: Users at reception unload the truck and scan the SS_1's labels using handheld barcode scanners.**
$FR_{3.2.2.4}$: Manage the AIDC systems for product identification and control.	**$DP_{3.2.2.4}$: Labelling data received by EDI (ASN) and integrated on SAP.**	**$PV_{3.2.2.4}$: Items checked-in on SAP by the handheld scanners.**
$FR_{3.2.2.5}$: Manage the method to identify items.	**$DP_{3.2.2.5}$: Components labelled by SS_1.**	**$PV_{3.2.2.5}$: Components ready to store.**
$FR_{3.2.2.6}$: Align reception with FS organisational structure.	**$DP_{3.2.2.6}$: Functional process distribution, matching reception procedure with a section (see Figure 7.56).**	**$PV_{3.2.1.6}$: Reception section handles the material income, makes verification and stores.**
$FR_{3.2.3}$: Align companies' internal processes.	$DP_{3.2.3}$: The collaboration BPM and features of delivery.	
$FR_{3.2.3.1}$: Manage the communication path to monitor orders.	$DP_{3.2.3.1}$: Standard procedure defined to communicate orders.	$PV_{3.2.3.1}$: The user from sales and logistics section confirms orders by EDI sending an ASN.
$FR_{3.2.3.2}$: Manage the interface between ICT's used to confirm orders.	$DP_{3.2.3.2}$: ASN is integrated directly on SAP system.	$PV_{3.2.3.2}$: User from parts ordering review daily the order confirmations in order to prepare for component reception.
$FR_{3.2.3.3}$: Manage the interface between AIDC systems from both companies.	**$DP_{3.2.3.3}$: Companies share the same barcode system.**	**$PV_{3.2.3.3}$: Received components are ready to scan and store.**
$FR_{3.2.4}$: Select metrics to monitor interface processes.	$DP_{3.2.4}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.2.4}$: See Excel PID DSM Metrics

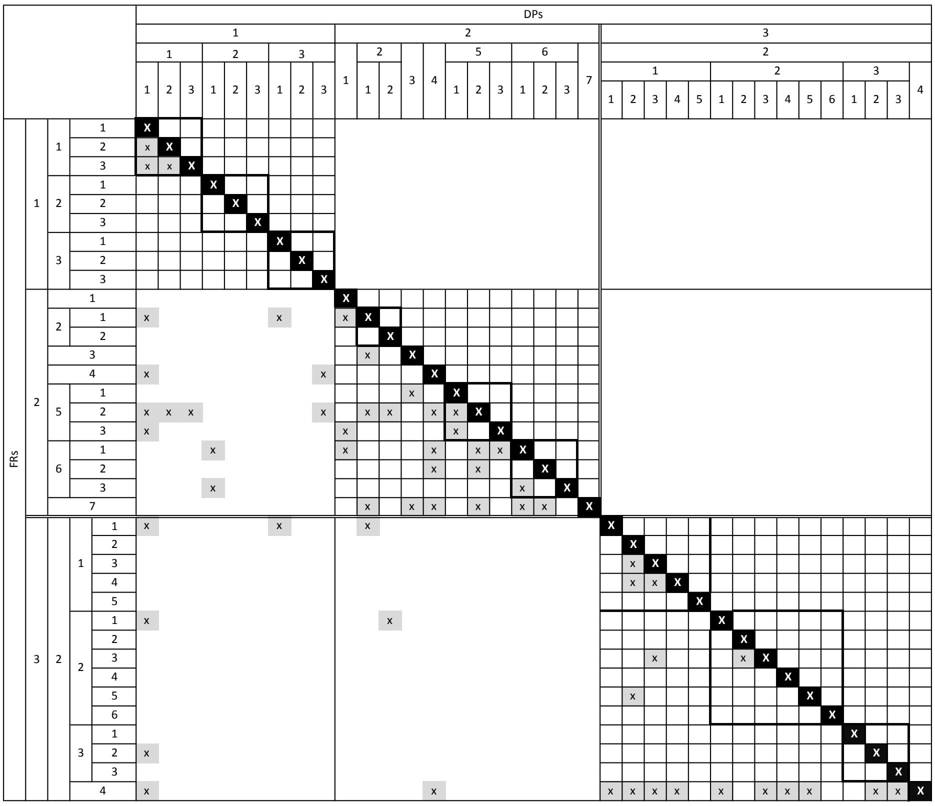


Figure 7.62. Design matrix for the “to-be” design of delivery-reception interaction (mapping between FRs and DPs).

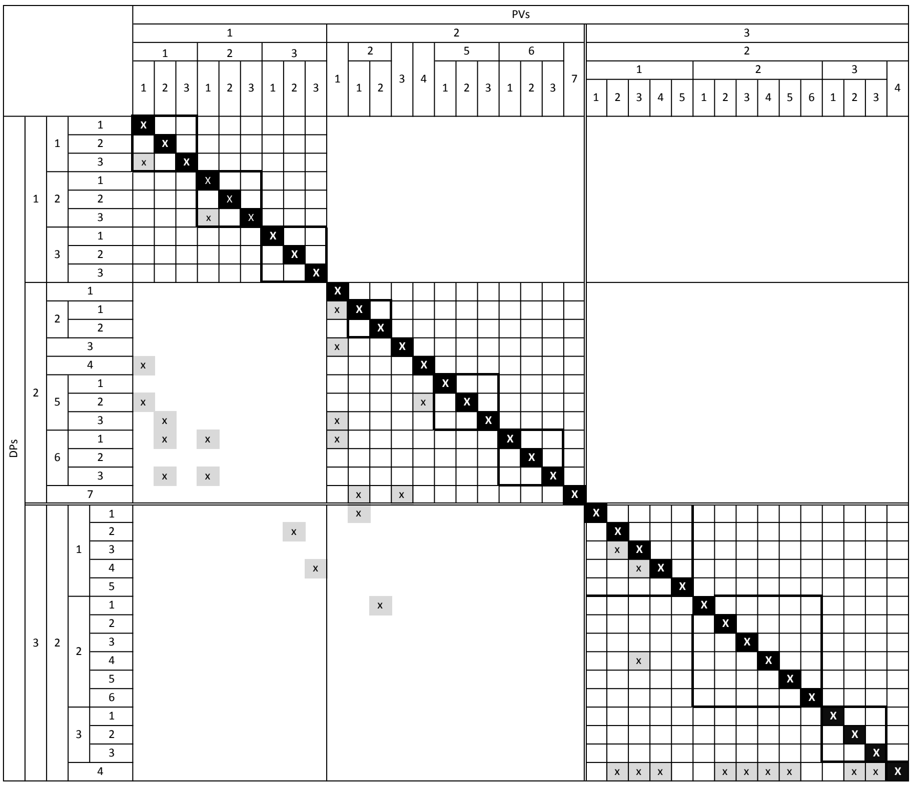


Figure 7.63. Design matrix for the “to-be” design of delivery-reception interaction (mapping between DPs and PVs).

The adoption of FS's barcode system may bring a more efficient dyad by solving some of the coupling on the design matrices, but some issues regarding SS_1 remain unsolved. For instance, $FR_{3.2.1.2}$ (Manage the AIDC system to identify components) and $FR_{3.2.1.3}$ (Manage the method to identify components) are still performed manually (check-in and labelling). Due to the size of the copper wire rods, the component labelling is performed manually, instead of using an automated process. This will impact the FS's method to identify items ($FR_{3.2.2.5}$). FS's is unable to manage this method, and could be subject to human error.

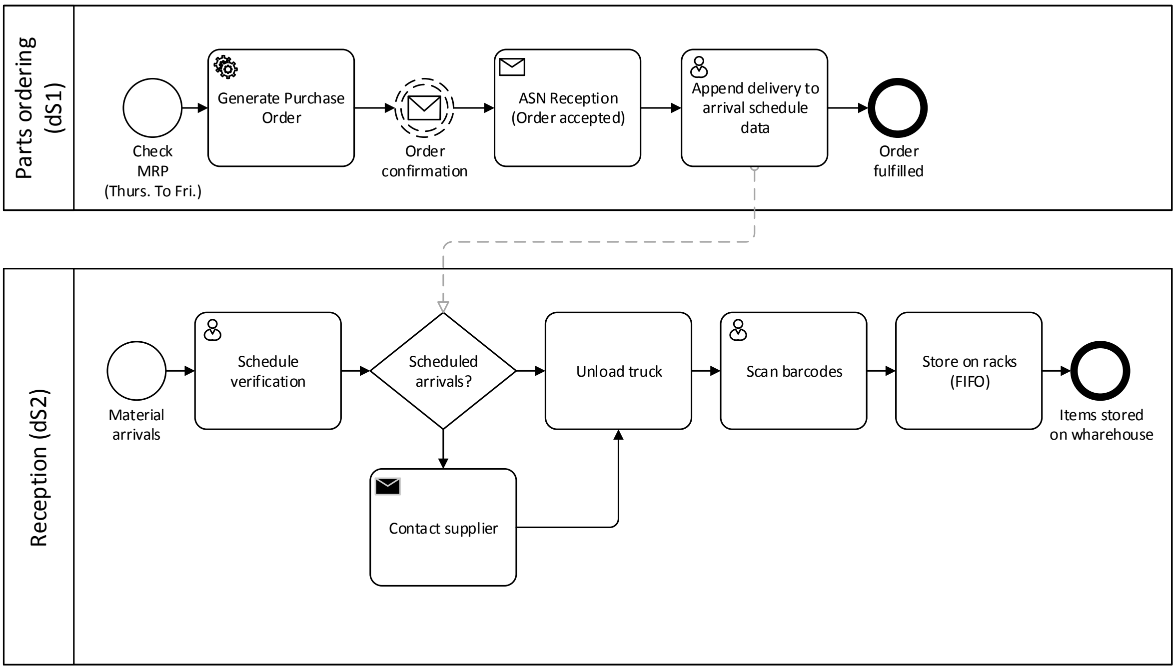


Figure 7.64. "To-be" functional alignment of purchasing and reception processes with parts ordering and reception sections, respectively.

7.6. Case study 3

The objective of this case study is to improve interoperability an exceptional procedure implemented in both companies to deal with incomplete orders. The CN for this case is to "achieve optimal interoperability in the missing orders solving and after-sales services of the FS-SS_1 dyad".

7.6.1. Interoperability characterization and modelling of processes and resources

The third interaction of the FS-SS_1 dyad refers to an exceptional procedure applied between the two firms. Upon the reception of materials, two main situations may occur: the received materials may be defective or the received quantity is inferior from the quantity ordered. In this dyad, the implementation of reverse logistics (RL) is not an issue raised by FS. The reverse flow of materials is based on the purchase of scrap rather than a complex interactive business model, to decide which kind of treatment each component needs to receive. Therefore, this kind of interaction wasn't addressed on this dyad.

On the other hand, the reception of orders with a quantity lesser than the ordered is an issue that requires attention. SS_1 is one of the most important suppliers for FS, and problem occurrence is closely monitored. At the BS level, $FR_{1.2}$ has significant participation on this interaction. The establishment of the liabilities and conditions for failure to commitments ($FR_{1.2.1}$) was handled by a negotiated and signed contract ($DP_{1.2.1}$). These ones where aligned with the companies individual objectives ($FR_{1.2.2}$-$DP_{1.2.2}$). Both companies have dedicated sections to deal with faulty component reception ($PV_{1.2.2}$). Though, conflicts occur to lack of definition of how to handle complications, resulting in an ad-hoc negotiation of penalties ($FR_{1.2.3}$, $DP_{1.2.3}$ and $PV_{1.2.3}$).

In terms of RM, the risk management systems put in action by both companies act on this interaction. Namely, $FR_{2.6.1}$ and $FR_{2.6.3}$. Though, the contingency plan for delays ($FR_{2.6.1}$) is strongly influenced by the governance position of FS. Contract obligations are the design approach for this FR, resulting in a set of consequences (see $PV_{2.6.1}$) that FS may implement, depending on the situation.

In counterpart, $FR_{2.6.3}$ sets in motion exceptional procedures to ease the treatment of missing items on shipments. These aspects have a strong influence on the processes implemented on this interaction.

Figure 7.65 represents the SC operations involved in the third interaction. The process starts in FS's reception (dS2), where the components are received. Upon their arrival, an ABC sampling is performed to determine whether to proceed to storage or to perform a manual inspection. After inspecting the components, if missing parts are identified, a report is created and sent to a sub-section of parts ordering, which deals with missing parts. This one analyses the report, and contact the supplier to make a complaint. In turn, the SS_1's after-sales service verifies the complaint and proceeds to a new order validation. This order is dealt with exceptionally, because SS_1's has to arrange a special transportation to guarantee that parts are shipped quickly. Two more communications are performed to inform FS and to receive a credit memo for the shipment. Then, the regular procedures of planning, production and expedition are performed in order to replenish the missing quantity.

				FS		SS_1			
				dS2	dS1	xD1	xP	xM	xD3
Dyad operations	FS	Reception	dS2	X					i3
		Purchasing	dS1	x	X	i3			
	SS_1	Sales	xD1		i3	X	x		x
		Plan	xP			x	X		
		Production	xM				x	X	
		Pack and Deliver	xD3			x		x	X

Figure 7.65. Supply chain operations involved in the exceptions handling interaction.

The FRs, DPs, and PVs, on Table 7.32, give the design of the missing parts handling.

Table 7.32. The "as-is" design of missing parts handling interaction.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.3}$: Manage faulty orders handling.	$DP_{3.3}$: Features of exceptions handling procedures.	
$FR_{3.3.1}$: Model and manage FS processes for faulty order detection and solving.	$DP_{3.3.1}$: FS actual business process model for missing parts identification and solving (see Figure 7.68 and Figure 7.69).	
$FR_{3.3.1.1}$: Model and manage the process sequence of FS processes.	$DP_{3.3.1.1}$: Conditional procedure for reception and sequential procedure for missing parts solving.	$PV_{3.3.1.1}$: Missing parts solving triggered by the identification of missing parts on reception. Missing parts solving procedure performed by one user, shared with purchase planning and parts ordering.
$FR_{3.3.1.2}$: Manage the material inspection management system.	$DP_{3.3.1.2}$: User-dependant operation requiring manual counting and entry of data in MS Access.	$PV_{3.3.1.2}$: Upon material reception, users on storage perform an ABC sampling using Access, do a manual verification and insert the results on the form.
$FR_{3.3.1.3}$: Manage the procedure to treat faulty orders.	$DP_{3.3.1.3}$: User-dependant procedure using internal software (MS Access) to handle the complaint procedure.	$PV_{3.3.1.3}$: A user from purchasing planning and parts ordering reviews the inspection report and places a complaint to the supplier by phone/e-mail.
$FR_{3.3.1.4}$: Align missing parts identification and handling with FS's OS.	$DP_{3.3.1.4}$: Exceptional procedures added to reception and parts ordering (see Figure 7.70).	$PV_{3.3.1.4}$: Missing parts identification performed in Reception. Missing parts solving is performed on parts ordering section. Resources are shared with these main processes.
$FR_{3.3.2}$: Model and manage SS_1 after-sales processes.	$DP_{3.3.2}$: SS_1 actual BPM for after-sales service (see Figure 7.71).	
$FR_{3.3.2.1}$: Model the process sequence of SS_1 processes.	$DP_{3.3.2.1}$: Parallel process to deal with complaints.	$PV_{3.3.2.1}$: After-sales procedure is triggered by a costumer complaint. The complaint is dealt as a new order, which is validated and planned in an urgency context. One user, from sales and logistics, performs the full procedure.
$FR_{3.3.2.2}$: Manage the interface between the ICT for complaints and the order management system.	$DP_{3.3.2.2}$: Manual insertion of E-mail data into SAP. E-mail and SAP are not interoperable. Complaint must be inserted manually into SAP.	$PV_{3.3.2.2}$: User from sales and logistics receives complaint and verifies if there is enough inventory to ship or places a new order on SAP.

Interoperability requirements (FRs)	Interoperability solutions (DPs)	Process Variables (PVs)
$FR_{3.3.2.3}$: Manage the delivery context.	$DP_{3.3.2.3}$: Normal and express delivery, based on the time available for production and FS's delivery date.	$PV_{3.3.2.3}$: User from sales and logistics checks production availability and confirms with FS's availability.
$FR_{3.3.2.4}$: Align after-sales procedure with SS_1's OS.	$DP_{3.3.2.4}$: Exceptional procedure integrated in sales and logistics section (see Figure 7.72).	$PV_{3.3.2.4}$: Complaints handled by sales and logistics section. Resources are shared with sales and logistics section, and are the same and univocal for all processes.
$FR_{3.3.3}$: Align companies' internal processes to handle missing parts.	$DP_{3.3.3}$: The collaboration BPM for missing parts solving (see Figure 7.73).	
$FR_{3.3.3.1}$: Manage the complaint procedure.	$DP_{3.3.3.1}$: Features of the complaint process.	
$FR_{3.3.3.1.1}$: Assign employees to the interface for complaint reception.	$DP_{3.3.3.1.1}$: Contact points defined.	$PV_{3.3.3.1.1}$: The user from parts ordering is dedicated to deal with the missing parts detected on reception and contact with the user from sales and logistics section, which is responsible for FS's complaints solving.
$FR_{3.3.3.1.2}$: Manage the interface between systems (ICT and software) used to make and manage complaints.	$DP_{3.3.3.1.2}$: Different systems used in each company. Information received from FS by e-mail/phone is unstructured due to a company personalized MS Access database to handle complaints.	$PV_{3.3.3.1.2}$: Users on SS_1's after-sales service need to insert the complaint manually on SAP.
$FR_{3.3.3.1.3}$: Manage the communication path to make complaints.	$DP_{3.3.3.1.3}$: Standard procedure defined to communicate complaints.	$PV_{3.3.3.1.3}$: One user from missing parts solving (same user as parts ordering) send the complaint by e-mail or phone. 1 user from after-sales service (same user as sales/logistics) receives complaint and solves it.
$FR_{3.3.3.2}$: Manage the confirmation procedure.	$DP_{3.3.3.2}$: Features of complaint response.	
$FR_{3.3.3.2.1}$: Manage the communication path to answer complaints.	$DP_{3.3.3.2.1}$: Standard procedure defined to communicate orders.	$PV_{3.3.3.2.1}$: The user from after-sales service informs FS of the delivery date.
$FR_{3.3.3.2.2}$: Manage the interface between ICT's used to answer complaints.	$DP_{3.3.3.2.2}$: Information exchanged by e-mail or phone.	$PV_{3.3.3.2.2}$: User from SS_1's after-sales service contacts FS to provide information about the time the missing parts will be delivered.
$FR_{3.3.3.3}$: Establish a delivery process for material flow.	$DP_{3.3.3.3}$: Features of delivery.	
$FR_{3.3.3.3.1}$: Establish a procedure for regular deliveries.	$DP_{3.3.3.3.1}$: 3rd party freight forwarder to retrieve components from SS_1 and deliver them to FS.	$PV_{3.3.3.3.1}$: Delivery is scheduled by SS_1 and the components are delivered to FS in 2-3 days. SS_1 supports the costs.
$FR_{3.3.3.3.2}$: Establish a procedure for express deliveries.	$DP_{3.3.3.3.2}$: Premium service.	$PV_{3.3.3.3.2}$: Delivery is scheduled by SS_1 and the components are delivered to FS in 1 day. SS_1 supports the costs.
$FR_{3.3.4}$: Select metrics to monitor interface processes.	$DP_{3.3.4}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.3.4}$: See Excel PID DSM Metrics

The design equations for these FRs, DPs and PVs are presented in Figure 7.66 and Figure 7.67.

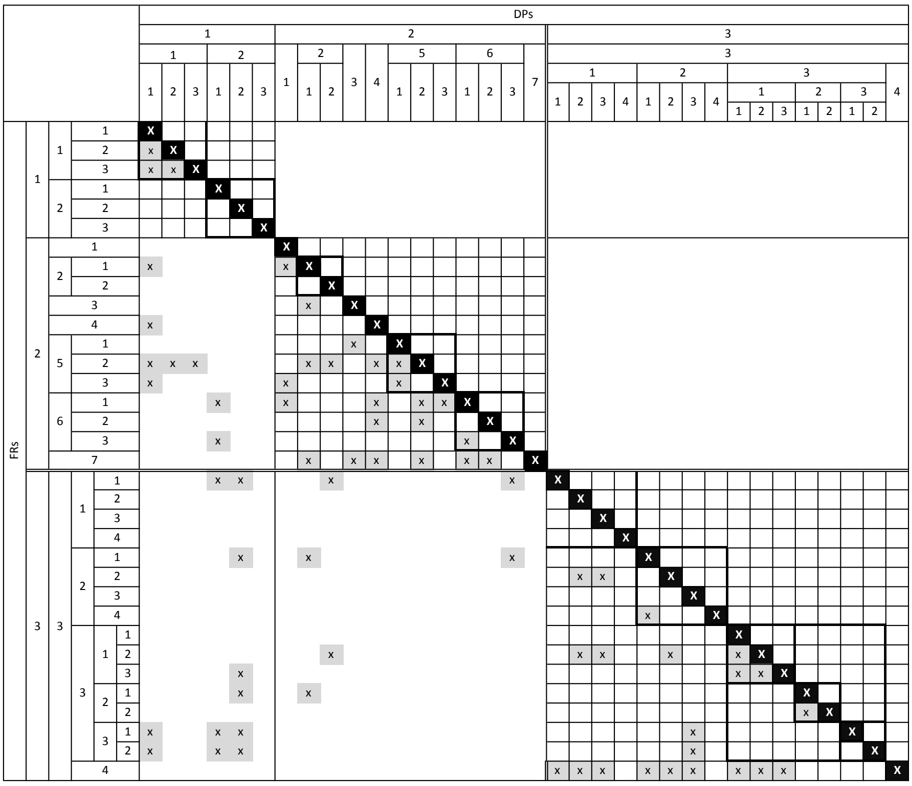


Figure 7.66. Design matrix for the “as-is” design of exceptions handling interaction (mapping between FRs and DPs).

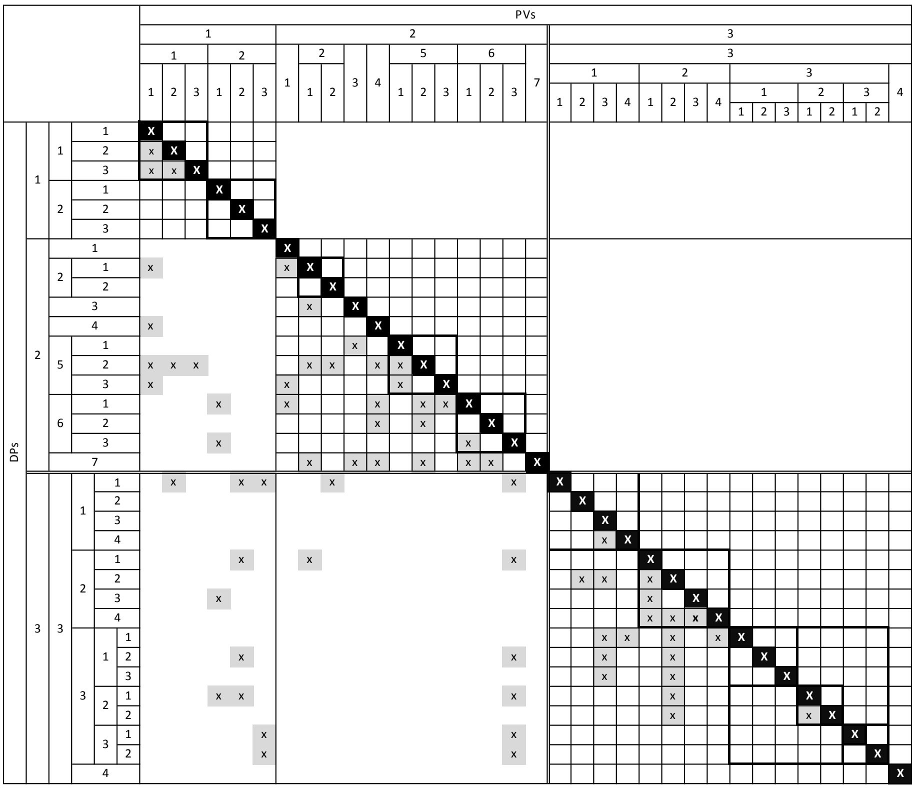


Figure 7.67. Design matrix for the “as-is” design of exceptions handling interaction (mapping between DPs and PVs).

FS's internal processes

The FS's procedures for the third interaction are presented in Figure 7.68 and Figure 7.69.

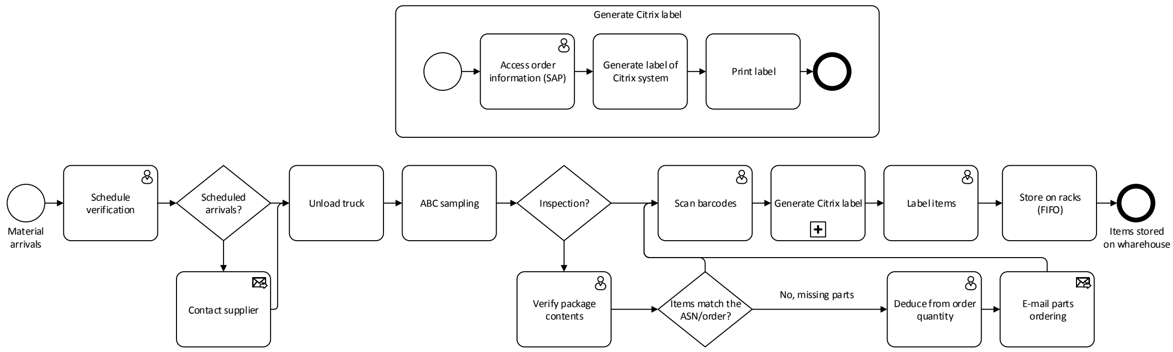


Figure 7.68. FS's reception process with detail on material/component inspection.

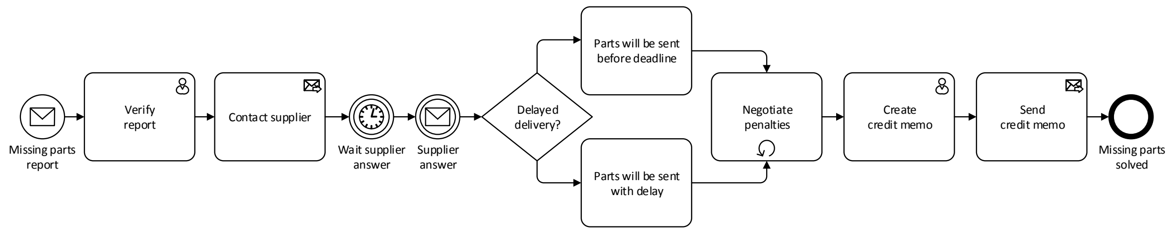


Figure 7.69. FS's process to handle missing items in orders.

Regarding process sequence $FR_{3.3.1.1}$, there is a conditional procedure in reception and a sequential procedure in missing parts solving section ($DP_{3.3.1.1}$). Material and component inspection is a procedure supported by a material inspection management system. This system consists in an ABC sampling, which is a result from the suppliers' historic data of faulty orders, and an MS Access database to insert the count of missing parts and create a report. In turn, the detection of parts missing in a shipment triggers the exceptional procedure in parts ordering ($PV_{3.3.1.1}$).

$FR_{3.3.1.2}$ corresponds to the activities performed by reception that accompany the inspection process. These one is performed by users (ABC sorting and inspection report) and manually (counting components individually) ($DP_{3.3.1.2}$). The reception section doesn't have HR limitations neither there are any process constraints. For this motive, the "as-is" method for inspection wasn't changed.

Regarding the treatment of the faulty orders in the missing parts procedure (see Figure 7.69), four main activities address: report verification, supplier contact, determination of penalties, and credit memo issue. In terms of FS's internal processes ($FR_{3.3.1}$), only report verification and supplier contact are modelled. Penalty determination and credit memo are presented only as a metric and for BPMN representation.

In $FR_{3.3.1.3}$, the procedure to treat administratively faulty orders is managed. This is achieved by one user (user-dependant operation in $DP_{3.3.1.3}$) from parts ordering and purchasing planning, which reviews the inspection reports and places a complaint. Improvements in the existing conditions focuses on HR quantity and whether new employees could be added or perform this activity exclusively, instead of shared resources between FS's activities.

Regarding process alignment ($FR_{3.3.1.4}$), these two exceptional procedures are added to the existing ones performed in reception and parts ordering (see Figure 7.70).

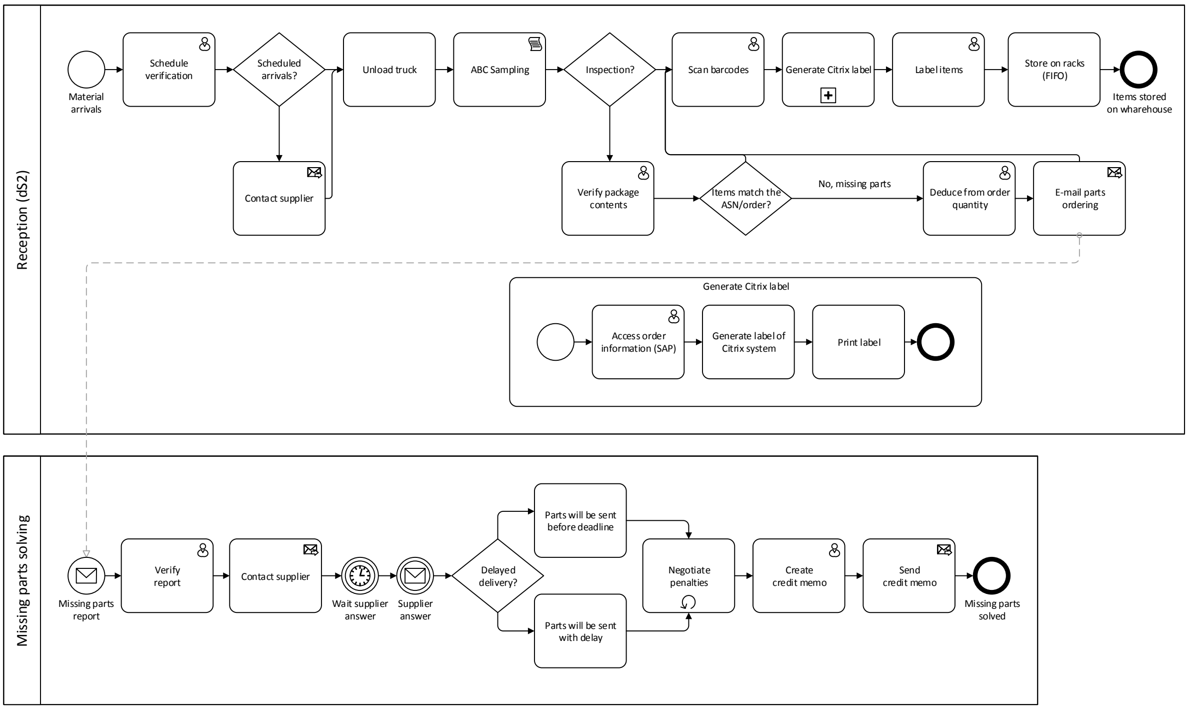


Figure 7.70. Alignment of reception and missing parts solving procedures with FS's organisational structure.

The independence axiom is accomplished for $FR_{3.3.1}$ decomposition, by the equation (7.10).

$$\begin{bmatrix} FR_{3.3.1.1} \\ FR_{3.3.1.2} \\ FR_{3.3.1.3} \\ FR_{3.3.1.4} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 \\ 0 & x & 0 & 0 \\ 0 & 0 & x & 0 \\ 0 & 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.3.1.1} \\ DP_{3.3.1.2} \\ DP_{3.3.1.3} \\ DP_{3.3.1.4} \end{bmatrix} \tag{7.10}$$

This equation is uncoupled, reflecting that there aren't problems regarding process sequence, alignment and the management of information procedures that have impact one another.

Regarding the mapping between the DPs and PVs, the design equation is coupled (see (7.11)) due to overlapping of resources (HR) between sections. To perform missing parts treatment it is required the sharing of the same resources from another business process. The use of resources should be studied by simulation, in order to determine the best PVs for FS.

$$\begin{bmatrix} DP_{3.3.1.1} \\ DP_{3.3.1.2} \\ DP_{3.3.1.3} \\ DP_{3.3.1.4} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 \\ 0 & x & 0 & 0 \\ 0 & 0 & x & 0 \\ 0 & 0 & x & x \end{bmatrix} \begin{bmatrix} PV_{3.3.1.1} \\ PV_{3.3.1.2} \\ PV_{3.3.1.3} \\ PV_{3.3.1.4} \end{bmatrix} \tag{7.11}$$

In the case of inspection procedures on reception, there aren't HR limitations. Hence, there isn't dependence of $DP_{3.3.2.4}$ of $PV_{3.3.2.2}$.

SS_1's internal processes

SS_1's internal procedures for this interaction are composed by the after-sales service that deals with complaints from the customer (see Figure 7.71).

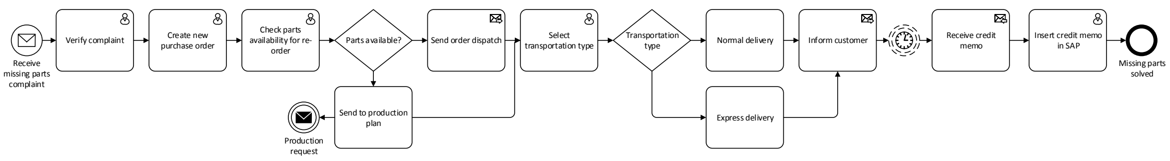


Figure 7.71. SS_1's after-sales services.

The after-sales service BPM is a dedicated procedure than occurs in parallel with the sales/logistics activities ($DP_{3.3.2.1}$). This procedure is triggered by FS's complaints, and they're handled like an urgent order, where an urgent transport may be contracted by SS_1 for quick order fulfilment ($PV_{3.3.2.1}$).

After triggering this procedure, a data conversion is required to make compatible the exchanged information with the SAP (see $FR_{3.3.2.2}$-$DP_{3.3.2.2}$). The complaint is handled as an ordinary order in SAP, but in a special context. This context is managed in $FR_{3.3.2.3}$, where a transport arranged by SS_1 can be either normal or express ($DP_{3.3.2.3}$), in order to deliver the delayed parts rapidly.

The work method, and user distribution and quantity characterize the PVs for order conversion and validation and the management of the delivery context. One user performs all the activities in all processes (see $PV_{3.3.2.2}$ and $PV_{3.3.2.3}$).

Last, $FR_{3.3.2.4}$ refers to the alignment of the SS_1's after-sales processes with the SS_1's organisational structure. The after-sales procedure is performed in the sales and logistics department (see Figure 7.72), in a parallel BPM dedicated to these particular cases ($DP_{3.3.2.4}$). Though, although functionally the integration of after-sales service with sales and logistics may seem appropriate, the motive for integration is the resource constrain. The employee from sales and logistics section accumulates three different functions: order reception and treatment, procurement and complaints handling (see $PV_{3.3.2.4}$).

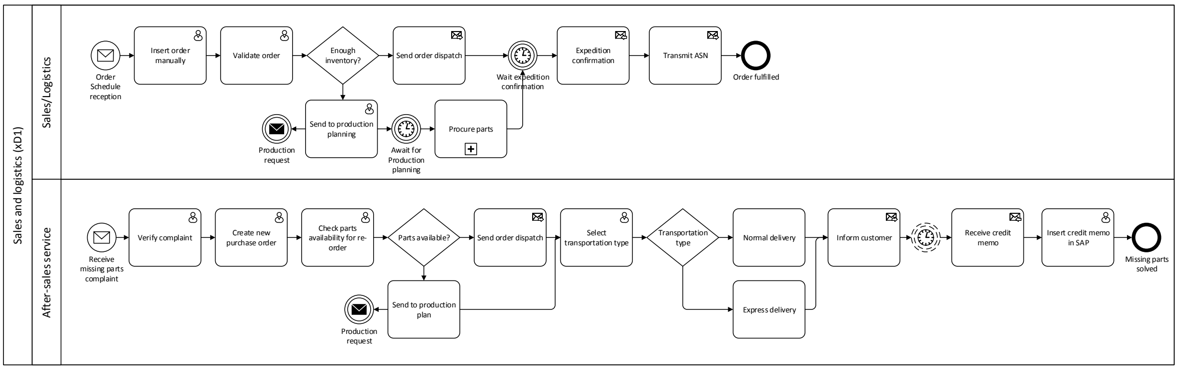


Figure 7.72. SS_1's after-sales service integrated on sales and logistics section.

The design equations for $FR_{3.3.2}$ decomposition are given by equations (7.12) and (7.13). On the mapping between FRs and DPs for SS_1's internal processes, there is dependence between process sequencing and process alignment with organisational structures. This is due to the difficulty of align several processes in the same organisational section. One only company's section is responsible for performing several procedures that could be arranged differently, if there exist more resources.

$$\begin{bmatrix} FR_{3.3.2.1} \\ FR_{3.3.2.2} \\ FR_{3.3.2.3} \\ FR_{3.3.2.4} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 \\ 0 & x & 0 & 0 \\ 0 & 0 & x & 0 \\ x & 0 & 0 & x \end{bmatrix} \begin{bmatrix} DP_{3.3.2.1} \\ DP_{3.3.2.2} \\ DP_{3.3.2.3} \\ DP_{3.3.2.4} \end{bmatrix} \tag{7.12}$$

Consequently, this is reflected operationally on the mapping between DPs and PVs (see equation (7.13)). The performance of the procedures on after-sales service depends on the work method and the resource distribution on $PV_{3.3.2.1}$. This hypothesis should be tested using simulation to determine if there is, in fact, dependence on the work distribution and the HR quantity assigned to each information procedure ($PV_{3.3.2.2}$ and $PV_{3.3.2.3}$).

$$\begin{bmatrix} DP_{3.3.2.1} \\ DP_{3.3.2.2} \\ DP_{3.3.2.3} \\ DP_{3.3.2.4} \end{bmatrix} = \begin{bmatrix} x & 0 & 0 & 0 \\ x & x & 0 & 0 \\ x & 0 & x & 0 \\ x & x & x & x \end{bmatrix} \begin{bmatrix} PV_{3.3.2.1} \\ PV_{3.3.2.2} \\ PV_{3.3.2.3} \\ PV_{3.3.2.4} \end{bmatrix} \tag{7.13}$$

To execute $DP_{3.3.2.4}$ there is dependence from all the previous DPs. This is due to the need to share the resources from the 3 main procedures from sales and logistics section.

Interface processes

On the mapping between the internal conditions of both actors, there is a dependence of $FR_{3.3.2.2}$ from $DP_{3.1.2.2}$ and $DP_{3.1.2.3}$. The manual insertion of data (on MS Access) and firm specific data handling on FS led to the need of data conversion by SS_1. Subsequent processes are the result of the work method implemented by SS_1. A missing parts complaint is handled as a regular order. Therefore, this one is managed on SAP system but with a different delivery context.

The same is reflected at the DPs-PVs mapping. There is the dependence of $DP_{3.3.2.2}$ from $PV_{3.1.2.2}$ and $PV_{3.1.2.3}$. The execution of the SS_1's conversion and missing parts complaint handling depends on the FS's efficiency, that is associated with HR quantity and distribution at the process level.

Another solutions for the combination of both internal processes should aim at solving data incompatibility, at the FRs-DPs level, or to determine the most efficient resource and process arrangement that deliver higher interoperability performance, at the DPs-PVs level.

The interface is characterized by $FR_{3.3.3}$, which is achieved by the collaboration BPM for missing parts solving ($DP_{3.3.3}$), portrayed in Figure 7.73.

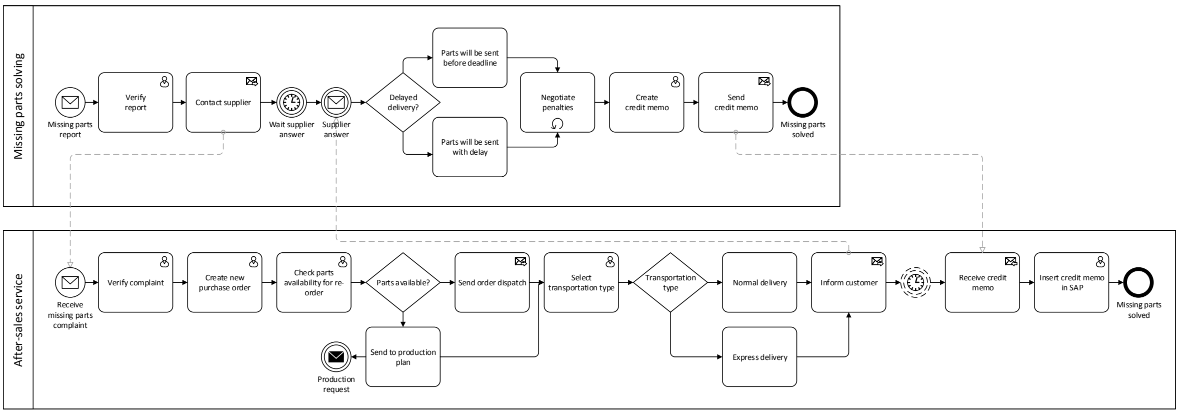


Figure 7.73. Collaboration BPM for missing parts solving.

In the complaint procedure ($FR_{3.3.3.1.1}$), three main interactions are performed: the sending of the complaint, the supplier response and the delivery.

The established contact points are the same for the purchasing and delivery interface (see $PV_{3.3.3.1.3}$). The advantage of this configuration is that the same user accompanies regular and faulty orders and handles the contact with the costumer/supplier. Though, the use of the same resource in several processes may constrain the dyad performance.

In $FR_{3.3.3.1.2}$, the systems interoperability is low, due to the use of different systems to manage faulty orders (see $DP_{3.3.3.1.2}$). In turn, that results in the need for a conversion mechanism for SS_1 to deal with the complaint information reflected on the work method to operationalize the systems incompatibility (see $PV_{3.3.3.1.2}$).

Communication paths for complaint formalization and response are performed according to a standard procedure implemented in both companies (see $FR_{3.3.3.1.3}$-$DP_{3.3.3.1.3}$-$PV_{3.3.3.1.3}$ and $FR_{3.3.3.2.1}$-$DP_{3.3.3.2.1}$-$PV_{3.3.3.2.1}$).

The physical flow of material is established according to the delivery context. Regular orders are performed by a 3rd party freight forwarder in 2-3 days (see $DP_{3.3.3.3.1}$-$PV_{3.3.3.3.1}$). Express deliveries are performed by a premium service in 1 day.

The design matrix for the interface design reveals problems in the mapping between the FRs and DPs (see Figure 7.66). Dependencies on the lower part of the design matrix refer to the lack of interoperability due to the use of different systems to manage missing parts solving. The FS's internal procedure is applied using an MS Access solution to deal with faulty orders. When interaction with SS_1, this one is confronted with unstructured data that is handled differently than FS. Solutions to this incompatibly may be a different approach to the faulty orders handling. FS may use SAP as a complaint management system, and an EDI could be implemented to ease the data exchange.

7.6.2. Optimization procedure

In order to perform the interaction optimization, the following metrics were selected to measure the improvements:

- Order lead-time (OLT) and order lead-time of re-ordering (OLTmissing).
- Time of interoperation (TI) of the missing parts solving (FS) and after-sales service (SS_1).
- Conversion time (Cv) on after-sales service.

The study of alternative scenarios

From the identified interoperability problems, new scenarios can be proposed to solve the problems. Table 7.33 displays the main addressed problems and the solutions to test.

Table 7.33. Proposed solutions to identified interoperability problems according to A and B optimisation possibilities.

Optimisation approach	Identified problems	Proposed solutions	Impact on
A	- The use of the same resources of missing parts and parts ordering processes.	- Study new resource quantity and distribution.	FS's internal processes
	- The use of the same resources between sales/logistics and after-sales business processes.	- Study new resource distribution and quantity in those sections.	SS's internal processes
B	- Incompatibility of complaint data with SS1's system	- Study the implementation of EDI combined with SAP to handle complaints	FS's internal processes SS's internal processes

A. *Improvement of existing interoperability conditions*

Modifications in FS's internal processes

On FS's internal processes, the faulty order treatment in parts ordering section was remarked as having interoperability problems in terms of process execution. The proposed improvement is to study the resource quantity and distribution that enable procedure to treat faulty orders.

Through simulation, two kinds of improvements were studied:

- FS-A - Add employees to the existing user on "missing parts solving" business process;
- FS-B - New employees on "missing parts solving" business process, exclusively.

The obtained results are presented in Table 7.34.

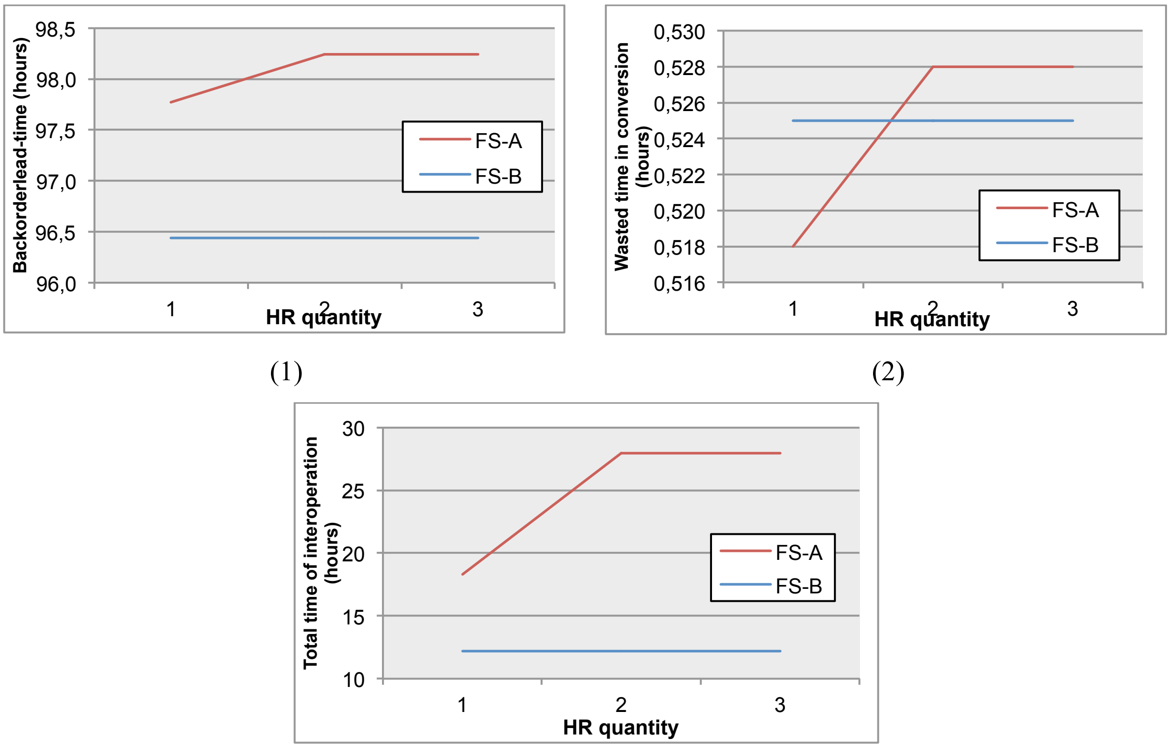
Table 7.34. Simulation results for FS-A and FS-B scenarios.

Scenario	Nr of employees	Order lead-time		Time of interoperation (TI)			Conversion time (Cv)	Nr of occurrences
		Order lead-time (OLT)	Missing parts lead-time (OLTmissing)	Total	FS	SS_1		
		(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	
FS-A	1	118,671	97,770	18,306	13,791	4,515	0,518	94
	2	118,710	98,245	27,949	22,025	5,924	0,528	87
	3	118,710	98,245	27,949	22,025	5,924	0,528	87
FS-B	1	118,781	96,439	12,196	6,206	5,990	0,525	83
	2	118,781	96,439	12,196	6,206	5,990	0,525	83
	3	118,781	96,439	12,196	6,206	5,990	0,525	83

The indirect impact of these changes on order-lead-time was determined (see Figure 7.74) and it is possible to conclude that using the existing employee (FS-A scenario) is the option that has less impact on OLT.

Figure 7.74. Influence of HR quantity on "missing parts solving" business process in regular order lead-time (OLT).

Though, the influence of HR quantity on missing parts lead-time (OLTmissing) has better results using new employees working exclusively (FS-B scenario) on the "verify report" process (see (1) in Figure 7.75Figure 7.75). This is supported by the wasted time in conversion and time of interoperation values (see (2) and (3) in Figure 7.75). Lower values of Cv and TI are obtained in the FS-B scenario by using one or more new employees exclusively on "missing parts solving".



(1) (2)

(3)

Figure 7.75. Influence of HR quantity on "missing parts solving" business process in: (1) – missing parts lead-time (OLTmissing); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

Since the minor difference on OLT (about 6 minutes per order), a solution that yields better results for a rapid resolution of backorder is the FS-B scenario with one user.

Modifications in SS_1's internal processes

Regarding SS_1's internal processes, the identified problems concern the inefficient organisational alignment, resource distribution and quantity. The organisational alignment it is not addressed in this section.

The suggested improvements for SS_1's internal processes are presented in Table 7.35.

Table 7.35. Proposed scenarios for SS_1.

Scenarios	Changes	Employee quantity by process			
		Create new purchase order		Check parts availability for re-order	
		Existing	New	Existing	New
SS_1-A	Maintain process distribution and add new employees.	1	[0,1,2]	1	[0,1,2]
SS_1-B	New employees perform all the tasks exclusively.	0	[1,2,3]	0	[1,2,3]
SS_1-C	Add employees to "create new purchase order".	1	[0,1,2]	1	0
SS_1-D	New employees perform, exclusively, "create new purchase order".	0	[1,2,3]	1	0
SS_1-E	Add employees to "check parts availability for re-order".	1	0	1	[0,1,2]
SS_1-F	New employees perform, exclusively, "check parts availability for re-order".	1	0	0	[1,2,3]

In Table 7.36 are presented the simulation results for the suggested scenarios.

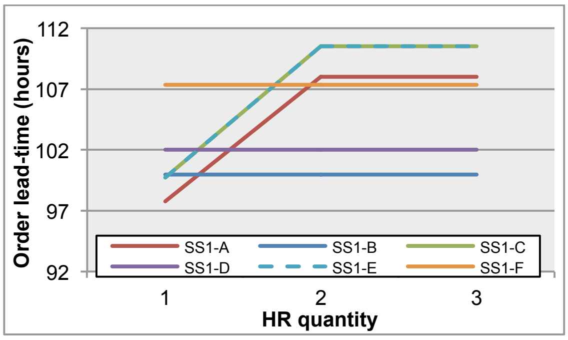
Table 7.36. Simulation results for SS_1's scenarios.

Scenario	Number of employees	Order lead-time: Order lead-time (OLT) (hours)	Order lead-time: Missing parts lead-time (OLTmissing) (hours)	Time of interoperation: Total (hours)	Time of interoperation: FS (hours)	Time of interoperation: SS_1 (hours)	Conversion time (Cv) (hours)	Nr of occurrences
SS_1-A	1	118,671	97,770	18,306	13,791	4,515	0,518	94
	2	118,693	108,031	34,118	21,961	12,157	0,522	82
	3	118,667	108,023	34,579	22,211	12,368	0,517	81
SS_1-B	1	118,768	99,972	15,615	12,077	3,538	0,529	89
	2	118,768	99,972	15,615	12,077	3,538	0,529	89
	3	118,768	99,972	15,615	12,077	3,538	0,529	89
SS_1-C	1	118,532	99,728	20,475	14,420	6,055	0,521	99
	2	118,556	110,509	41,652	25,386	16,266	0,537	90
	3	118,556	110,509	41,652	25,386	16,266	0,537	90
SS_1-D	1	118,53	102,014	25,313	16,604	8,709	0,522	87
	2	118,53	102,014	25,313	16,604	8,709	0,522	87
	3	118,53	102,014	25,313	16,604	8,709	0,522	87
SS_1-E	1	118,532	99,728	20,475	14,420	6,055	0,521	99
	2	118,612	110,540	40,707	24,896	15,811	0,523	99
	3	118,612	110,540	40,707	24,896	15,811	0,523	99
SS_1-F	1	118,692	107,347	29,164	18,338	10,826	0,523	106
	2	118,692	107,347	29,164	18,338	10,826	0,523	106
	3	118,692	107,347	29,164	18,338	10,826	0,523	106

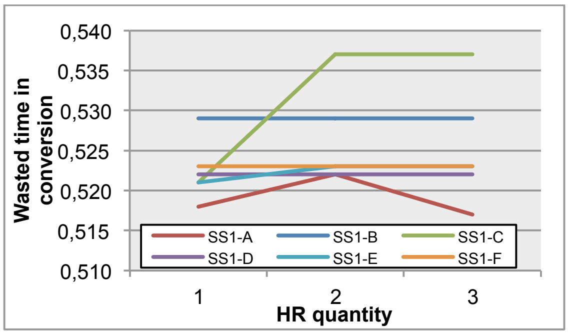
In terms of influence on OLT, the SS_1-F scenario is the one that has the best values (see Figure 7.76).

Figure 7.76. Influence of HR quantity and distribution on SS_1's "after-sales service" business process in order lead-time (OLT).

In terms of backorder lead-time, the SS_1-A scenario with one employee (i.e., "as-is") is the one that provides the less time to resolve each missing quantity resolve (see (1) in Figure 7.77). The same is reflected in Cv, where SS_1-A provides the lowest Cv value by using 3 employees total (see (2) in Figure 7.77). Though in terms of TI, SS1-B permits SS_1 to achieve the lowest value (see (3) in Figure 7.77).



(1)



(2)

(3)

Figure 7.77. Influence of HR quantity and distribution on SS_1's "after-sales service" business process in: (1) – missing parts lead-time (OLTmissing); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

The best resource distribution and quantity is not conclusive by the representations on Figure 7.77. Using equation (7.6) the improvement percentage towards the "as-is" scenario was determined using the best scenario value, and corresponding resource quantity, and the results are presented in Table 7.37 and Figure 7.78.

Table 7.37. Improvement percentage of each SS_1 scenario in terms of OLT, OLTmissing, TI, Cv and total.

Scenario	OLT improvement (%)	OLTmissing Improvement (%)	TI improvement (%)	Cv improvement (%)	Total improvement (%)
SS_1-A	0,00%	0,00%	0,00%	0,00%	0,00%
SS_1-B	-0,08%	-2,25%	14,70%	-2,12%	10,24%
SS_1-C	0,12%	-2,00%	-11,85%	-0,58%	-14,31%
SS_1-D	0,12%	-4,34%	-38,28%	-0,77%	-43,27%
SS_1-E	0,12%	-2,00%	-11,85%	-0,58%	-14,31%
SS_1-F	-0,02%	-9,80%	-59,31%	-0,97%	-70,09%

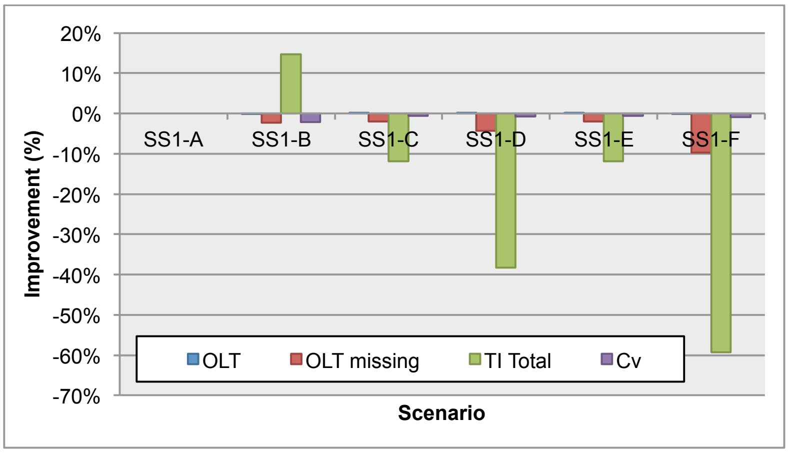


Figure 7.78. Improvement percentage by SS_1's scenario.

Comparing the different scenarios improvement, the one that has bigger influence on the performance is SS_1-B in 10,24 per cent. TI has the higher influence in this value (14,7%), but OLT, OLTmissing and Cv, present worse values, but with little impact on these metrics (about 0,8 to 2,25%).

To study the dependence of SS_1's process from FS's, it was studied a combined scenario. The results are presented in Table 7.38.

Table 7.38. Simulation results for the study of the influence of FS's scenarios in SS_1's.

Scenario (HR quantity)		Order lead-time		Time of interoperation			Conversion time (Cv)	Nr of occurrences
		Order lead-time (OLT)	Missing parts lead-time (OLTmissing)	Total	FS	SS_1		
FS	SS_1	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	
FS-B (1) "as-is"	SS_1-B (1)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (2)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (3)	118,646	93,654	2,089	1,238	0,851	0,540	94
FS-B (2)	SS_1-B (1)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (2)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (3)	118,646	93,654	2,089	1,238	0,851	0,540	94
FS-B (3)	SS_1-B (1)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (2)	118,646	93,654	2,089	1,238	0,851	0,540	94
	SS_1-B (3)	118,625	93,683	2,040	1,193	0,847	0,541	94

Regarding the influence on OLT, FS-B scenario with 3 employees is the one that provides slight improvement, in about 1,2 minutes, which is less significant (see Figure 7.79).

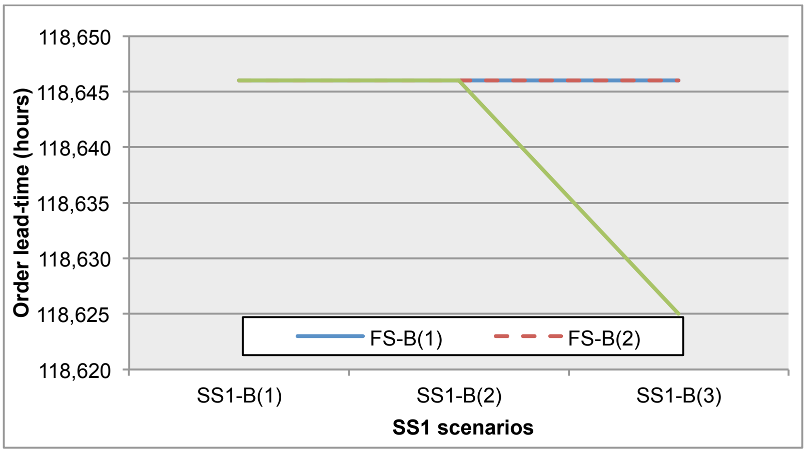
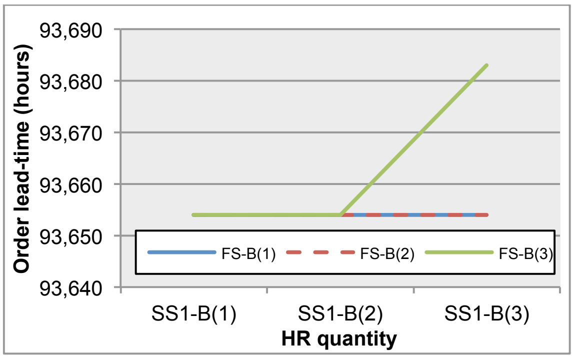


Figure 7.79. Influence the combined scenarios in order lead-time (OLT).

The combined scenario of FS-B with SS_1-B, both with 1 new employee working in exclusive, is best solution in terms of OLTmissing, Cv and TI (see Figure 7.80). The FS-B(3) scenario presents the lowest value of TI, with less 3 minutes than the other scenarios. Though, this improvement is less significant and the best solution should be the minimal use of HR.



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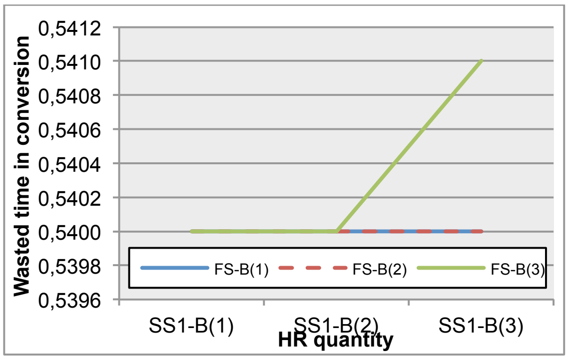

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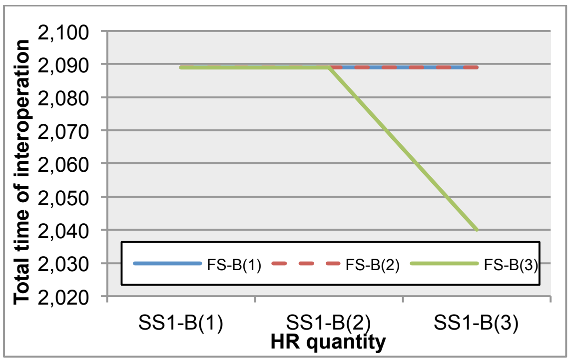


(3)

Figure 7.80. Influence the combined scenarios in order lead-time (OLT) : (1) – missing parts lead-time (OLTmissing); (2) – wasted time in conversion (Cv); and (3) – time of interoperation (TI).

B. Proposal of new interoperability solutions

To overcome the incompatibility between complaint management systems and the ICT, it is proposed that FS adopts the SAP as a complaint management system and the EDI as a standard communication. This solution would imply a few changes in internal and interface processes and the study of a new resource distribution.

On FS's internal processes, this change would imply a new BPM (see Figure 7.81).

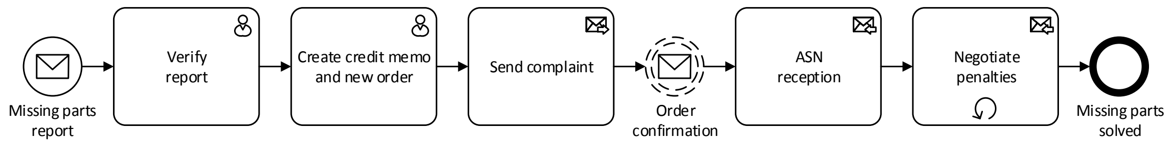


Figure 7.81. Proposed BPM for FS to solve missing parts.

Through simulation, two kinds of improvements were studied:

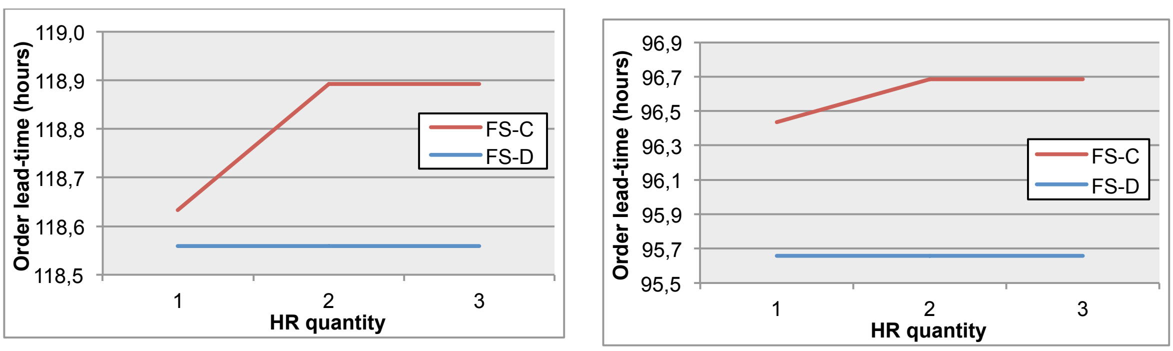
- FS-C - Add employees to the existing user on "to-be" "missing parts solving" business process;
- FS-D - New employees work on "to-be" "missing parts solving" business process, exclusively.

The results are presented in Table 7.39.

Table 7.39. Simulation results for FS-C and FS-D scenarios, regarding EDI and SAP implementation.

Scenario	Nr of employees	Order lead-time: Order lead-time (OLT) (hours)	Order lead-time: Missing parts lead-time (OLTmissing) (hours)	Time of interoperation (TI): Total (hours)	Time of interoperation (TI): FS (hours)	Time of interoperation (TI): SS_1 (hours)	Conversion time (Cv) (hours)	Nr of occurrences
FS-C	1	118,633	96,434	18,734	13,915	4,819	0	105
	2	118,892	96,687	26,333	20,758	5,575	0	90
	3	118,892	96,687	26,333	20,758	5,575	0	90
FS-D	1	118,559	95,658	12,187	6,321	5,866	0	81
	2	118,559	95,658	12,187	6,321	5,866	0	81
	3	118,559	95,658	12,187	6,321	5,866	0	81

Graphically, these results are represented in Figure 7.82.



(1) (2)

(3)

Figure 7.82. Influence of HR quantity on "missing parts solving" business process in: (1) – order lead-time (OLT); (2) – missing parts lead-time (OLTmissing); and (3) – time of interoperation (TI).

With this results, was possible to conclude that the implementation of EDI and the use of SAP as a complaint management system has better results if FS contracts an employee that performs the missing parts solving processes, exclusively – FS-D.

On the perspective of SS_1, the implementation of EDI and adoption of SAP by FS leads to better integration of data between companies, eliminating the manual insertion of data. As consequence, the new BPM is similar to the "as-is" without the manual insertion of data (see Figure 7.83).

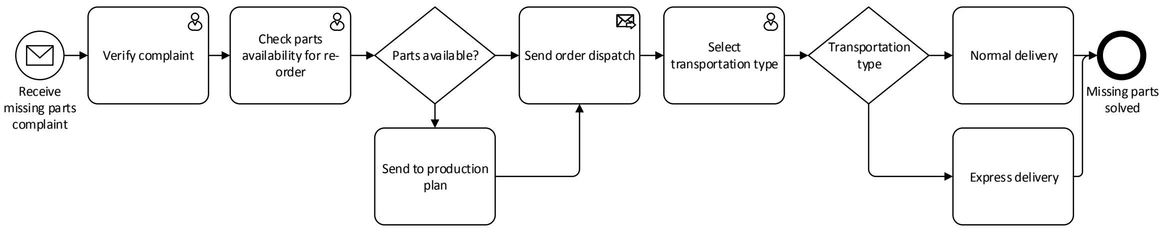


Figure 7.83. Proposed BPM for SS_1's after-sales service.

The scenarios to test are presented in Table 7.40.

Table 7.40. Proposed SS_1's scenarios for EDI and SAP implementation.

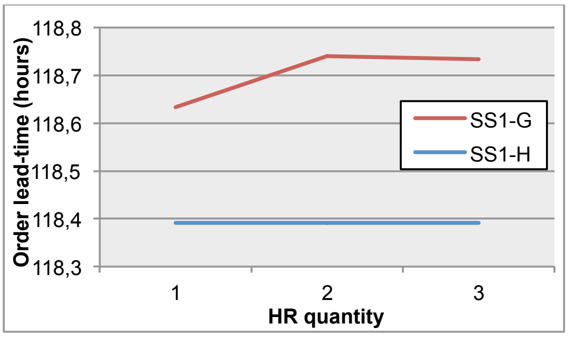
Scenarios	Changes	Employee quantity in check parts availability for re-order	
		Existing	New
SS_1-G	Add employees to "check parts availability for re-order".	1	[0,1,2]
SS_1-H	New employees perform, exclusively, "check parts availability for re-order".	0	[1,2,3]

The obtained results for each scenario are presented in

Table 7.41 and represented, graphically, in Figure 7.84.

Table 7.41. Simulation results for SS_1's scenarios.

Scenario	Number of employees	Order lead-time		Time of interoperation			Conversion time (Cv)	Nr of occurrences
		Order lead-time (OLT) (hours)	Missing parts lead-time (OLTmissing) (hours)	Total (hours)	FS (hours)	SS_1 (hours)	(hours)	
SS_1-G	1	118,633	96,434	18,734	13,915	4,819	0	105
	2	118,740	107,726	36,788	22,554	14,234	0	86
	3	118,733	107,897	37,039	22,916	14,123	0	87
SS_1-H	1	118,391	100,721	15,184	11,727	3,457	0	91
	2	118,391	100,721	15,184	11,727	3,457	0	91
	3	118,391	100,853	15,31	11,803	3,507	0	92



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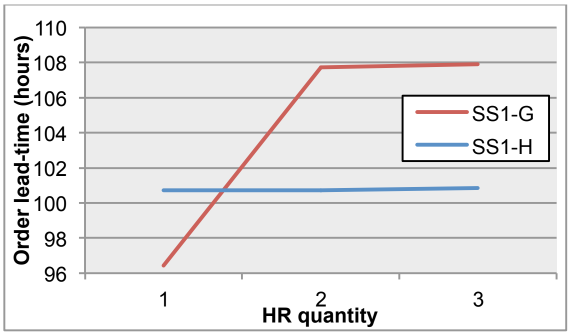

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Figure 7.84. Influence of HR quantity and distribution on SS_1's "after-sales service" business process in: (1) – order lead-time (OLT); (2) – missing parts lead-time (OLTmissing); and (3) – time of interoperation (TI).

The best scenario that delivers better results in terms of the selected metrics is not conclusive by the representations on Figure 7.84. In terms of OLTmissing, SS_1-G delivers the best results. Though, SS_1-H has better values in terms of OLT and TI. Hence, using equation (7.6) the improvement percentage towards the "as-is" scenario was determined using the best scenario value, and corresponding resource quantity, and the results are presented in Table 7.42 and Figure 7.85.

Table 7.42. Improvement percentage of each SS_1 scenario in terms of OLT, OLTmissing, TI, Cv and total.

Scenario	OLT improvement (%)	OLTmissing Improvement (%)	TI improvement (%)	Total improvement (%)
SS_1-G	0,03%	1,37%	-2,34%	-0,94%
SS_1-H	0,24%	-3,02%	17,05%	14,27%

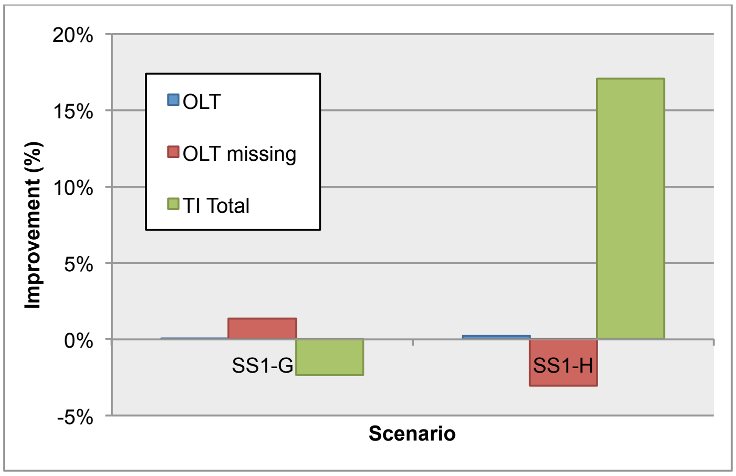


Figure 7.85. Improvement percentage by SS_1's scenario.

By comparing the scenarios with the "as-is", was possible to conclude that SS_1-H is the one that permits more improvement, in about 14,27%.

To study the dependence of SS_1's process from FS's, it was studied a combined scenario. The results are presented in Table 7.43.

Table 7.43. Simulation results for the study of the influence of FS's scenarios in SS_1's.

Scenario (HR quantity)		Order lead-time		Time of interoperation			Conversion time (Cv)	Nr of occurrences
		Order lead-time (OLT)	Missing parts lead-time (OLTmissing)	Total	FS	SS_1		
FS	SS_1	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	
FS-D (1)	SS_1-H (1)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (2)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (3)	118,709	93,925	0,891	0,555	0,336	0	87
FS-D (2)	SS_1-H (1)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (2)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (3)	118,709	93,925	0,891	0,555	0,336	0	87
FS-D (3)	SS_1-H (1)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (2)	118,726	93,713	0,905	0,562	0,343	0	86
	SS_1-H (3)	118,709	93,925	0,891	0,555	0,336	0	87

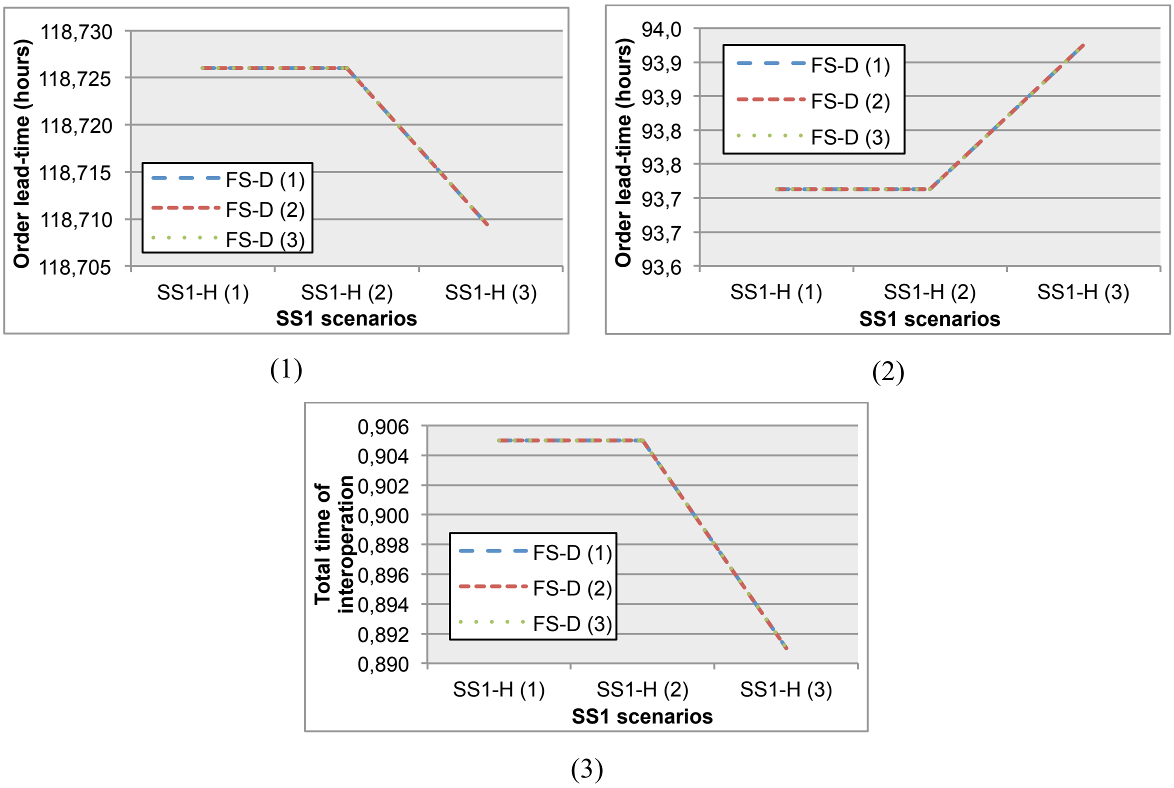


Figure 7.86. Influence the combined scenarios in: (1) – order lead-time (OLT); (2) – missing parts lead-time (OLTmissing); and (3) – time of interoperation (TI).

The best solution is the contracting of one employee, in each company, to perform the missing parts solving in exclusive. This is the best solution because is the one that involves least employees, in spite of delivering the worse dyad performance in the obtained results. Though, the improvement, in terms of OLT and TI, by using 3 employees in SS_1 is less significant. It only permits a gain of 1,2 and 0,84 minutes in terms of OLT and TI, respectively.

7.6.3. Scenario comparison and discussion

The two studied alternatives provide different approaches to the form dyad's companies perform the exceptions handling interaction (D1CS3).

The first alternative was to improve the existing conditions, by providing new resource distribution and studying the influence of HR quantity on the processes that require interoperability. The best solution for FS was to contract a new employee that performs the missing parts solving tasks – scenario FS-B(1). In turn, the best solution to improve the SS_1's existing conditions was to contract a new employee that performs the after-sales service tasks in exclusive – scenario SS_1-B(1).

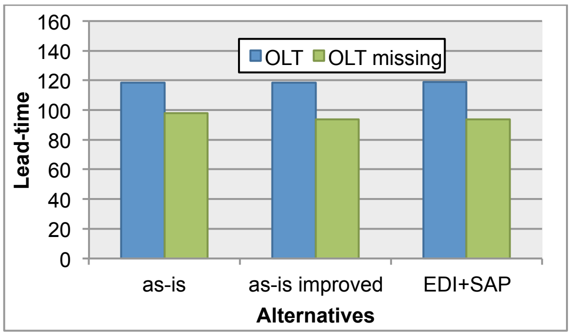
The second studied alternative consisted of adopting the SAP as complaint management system in both companies, and the use of EDI as the standard ICT for complaints. This scenario led to a new BPM in order to incorporate the new work method, and to the study of resource quantity and distribution among the BPM processes. Hence, the best result for the dyad was similar to the improvement of the existing conditions: a new employee performing the activities exclusively both in FS and in SS_1 – scenarios FS-H(1) and SS_1-H(1).

To determine the best solution for the interaction, the results from the studied were compared, having obtained the results in Table 7.44.

Table 7.44. Comparison of the studied scenarios with the "as-is".

Alternatives	Order lead-time (OLT) (hours)	Missing parts lead-time (OLTmissing) (hours)	Conversion time (Cv) (hours)	Time of interoperation (TI) (hours)
"as-is"	118,671	97,770	0,518	18,306
"as-is" improved	118,646	93,654	0,540	2,089
EDI+SAP	118,726	93,713	0	0,905

The most significant improvement is visible on the time of interoperation and the conversion time. Both alternatives provide better values in terms of TI (see (2) in Figure 7.87), but the implementation of EDI and adoption of SAP as complaint management system provides best results in terms of Cv (see (3) in Figure 7.87).



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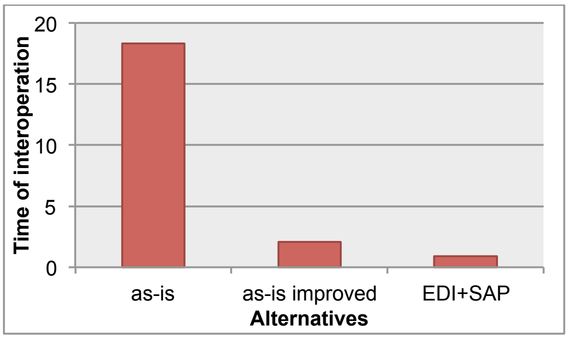

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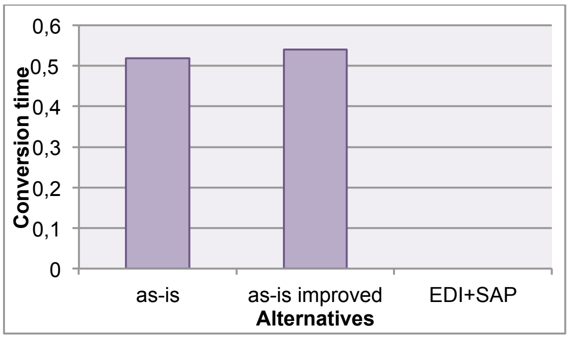


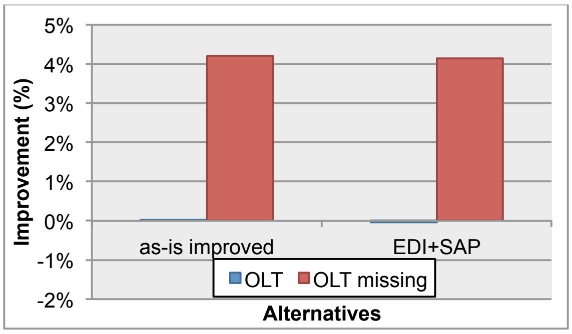
(3)

Figure 7.87. Graphic representation of results for each scenario in terms of: (1) – order lead-time and missing parts lead-time; (2) – time of interoperation (TI); and (3) – wasted time in conversion (Cv).

Using equation (7.6) was determined the improvement of each alternative towards the "as-is" (see Table 7.45 and Figure 7.88).

Table 7.45. Improvement percentage of each scenario.

Alternative	OLT improvement (%)	OLTmissing Improvement (%)	TI improvement (%)	Cv improvement (%)	Total improvement (%)
"as-is" improved	0,02%	4,21%	88,59%	-4,25%	88,57%
EDI+SAP	-0,05%	4,15%	95,06%	100%	199,16%



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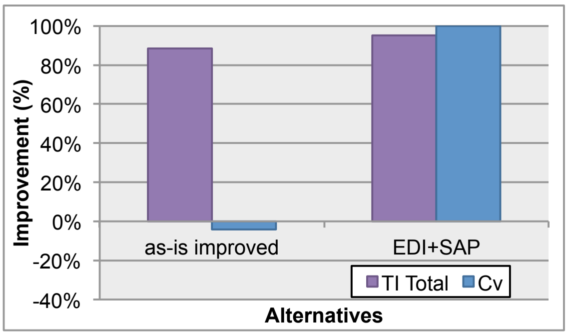

(2)

Figure 7.88. Improvement percentage of each scenario in terms of: (1) – order lead-time and missing parts lead-time; and (2) – time of interoperation (TI) and wasted time in conversion (Cv).

The best solution for exceptions handling interaction is to implement an EDI, and adopt SAP as complaint management system, with two new employees (one in each company) performing the activities in exclusive.

Hence, the BPM presented in Figure 7.89 is proposed.

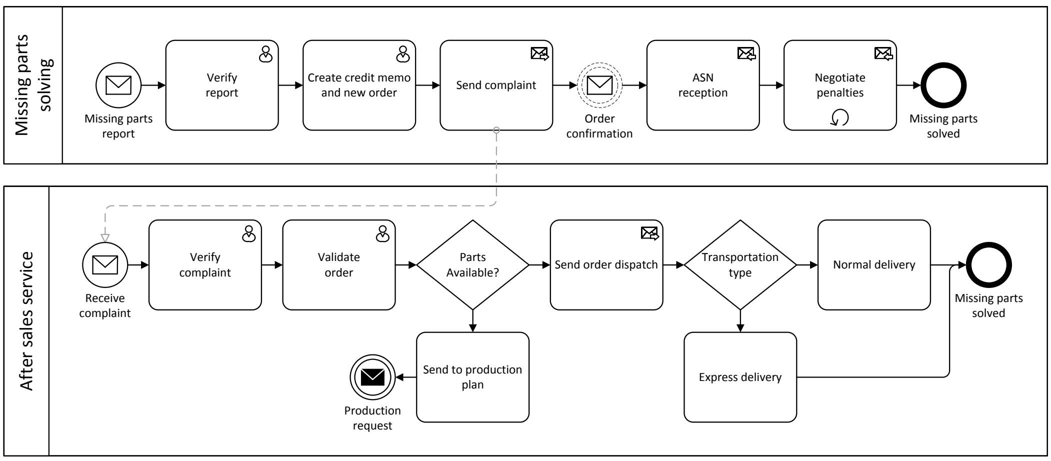

Figure 7.89. Proposed BPM for EDI and SAP implementation as a complaint management system.

By using SAP and EDI to process orders, the users in missing parts solving section can create a credit memo with the quantity missing on the order to deduce from the invoice and, additionally places an order with the missing quantity.

Implications of the selected alternative in the dyad design – "to-be" scenario

The implications of the modelling and simulation results are presented in the following FRs, DPs and PVs (see Table 7.46) and design matrices (see Figure 7.90 and Figure 7.91).

Table 7.46. FRs, DPs and PVs for the "to-be" scenario for exceptions handling interface (D1CS3).

Functional Requirements (FRs)	Design Parameters (DPs)	Process Variables (PVs)
$FR_{3.3}$: Manage faulty orders handling.	$DP_{3.3}$: Features of exceptions handling procedures.	
$FR_{3.3.1}$: Model and manage FS processes for faulty order detection and solving.	**$DP_{3.3.1}$: FS new business process model for missing parts identification and solving (see Figure 7.82 and Figure 7.70).**	
$FR_{3.3.1.1}$: Model and manage the process sequence of FS processes.	$DP_{3.3.1.1}$: Conditional procedure for reception and sequential procedure for missing parts solving.	**$PV_{3.3.1.1}$: Missing parts solving triggered by the identification of missing parts on reception. Missing parts solving procedure performed exclusively by one new user.**
$FR_{3.3.1.2}$: Manage the material inspection management system.	$DP_{3.3.1.2}$: User-dependant operation requiring manual counting and entry of data in MS Access.	$PV_{3.3.1.2}$: Upon material reception, users on storage perform an ABC sampling using Access, do a manual verification and insert the results on the form.
$FR_{3.3.1.3}$: Manage the procedure to treat faulty orders.	**$DP_{3.3.1.3}$: User-dependant procedure, using MS Access and SAP to handle the complaint procedure.**	**$PV_{3.3.1.3}$: A user reviews the inspection report, creates a new order and a credit memo on SAP, and places the complaint to the supplier by EDI.**
$FR_{3.3.1.4}$: Align missing parts identification and handling with FS's OS.	**$DP_{3.3.1.4}$: Exceptional procedures added to reception and parts ordering (see Figure 7.94).**	**$PV_{3.3.1.4}$: Missing parts identification performed in Reception. Missing parts solving is performed on parts ordering section. Resources are shared with these main processes.**
$FR_{3.3.2}$: Model and manage SS_1 after-sales processes.	**$DP_{3.3.2}$: SS_1 actual BPM for after-sales service (see Figure 7.94).** **).**	
$FR_{3.3.2.1}$: Model the process sequence of SS_1 processes.	$DP_{3.3.2.1}$: Parallel process to deal with complaints.	**$PV_{3.3.2.1}$: After-sales procedure is triggered by a costumer complaint. The complaint is dealt as a new order, which is validated and planned in an urgency context. One new user performs the full procedure.**
$FR_{3.3.2.2}$: Manage the interface between the ICT for complaints and the order management system.	**$DP_{3.3.2.2}$: Automated integration of EDI data on SAP.**	**$PV_{3.3.2.2}$: User receives complaint and verifies if there is enough inventory to ship.**
$FR_{3.3.2.3}$: Manage the delivery context.	$DP_{3.3.2.3}$: Normal and express delivery, based on the time available for production and FS's delivery date.	**$PV_{3.3.2.3}$: User checks production availability and confirms with FS's availability.**
$FR_{3.3.2.4}$: Align after-sales procedure with SS_1's OS.	**$DP_{3.3.2.4}$: Exceptional procedure integrated in sales and logistics section (see Figure 7.93).**	**$PV_{3.3.2.4}$: Complaints handled by sales and logistics section. Resources on after-sales service are not shared with logistics and sales processes.**
$FR_{3.3.3}$: Align companies' internal processes to handle missing parts.	$DP_{3.3.3}$: The collaboration BPM for missing parts solving (see Figure 7.94).	

Functional Requirements (FRs)	Design Parameters (DPs)	Process Variables (PVs)
$FR_{3.3.3.1}$: Manage the complaint procedure.	$DP_{3.3.3.1}$: Features of the complaint process.	
$FR_{3.3.3.1.1}$: Assign employees to the interface for complaint reception.	**$DP_{3.3.3.1.1}$: New contact points duly communicated.**	**$PV_{3.3.3.1.1}$: New users assigned to missing parts ordering and after-sales service are the contact points between FS and SS_1.**
$FR_{3.3.3.1.2}$: Manage the interface between systems (ICT and software) used to make and manage complaints.	**$DP_{3.3.3.1.2}$: Direct integration of data.**	**$PV_{3.3.3.1.2}$: Exchanged complaint data is seamlessly integrated between SAPs, through EDI. Complaints are handled as an order in an exceptional context.**
$FR_{3.3.3.1.3}$: Manage the communication path to make complaints.	**$DP_{3.3.3.1.3}$: New procedure defined to communicate complaints.**	**$PV_{3.3.3.1.3}$: One user from missing parts solving send the complaint by EDI. Another user from after-sales service receives complaint and solves it. The complaint is handled as a exceptional order.**
$FR_{3.3.3.2}$: Manage the confirmation procedure.	$DP_{3.3.3.2}$: Features of complaint response.	
$FR_{3.3.3.2.1}$: Manage the communication path to answer complaints.	**$DP_{3.3.3.2.1}$: Standard procedure to communicate order shipments, instead of a direct response for the complaint.**	**$PV_{3.3.3.2.1}$: No formal answer is performed. An ASN is sent upon shipment, and it is considered as the answer for complaint.**
$FR_{3.3.3.2.2}$: Manage the interface between ICT's used to answer complaints.	**$DP_{3.3.3.2.2}$: Information exchanged by EDI.**	**$PV_{3.3.3.2.2}$: An ASN is sent upon shipment.**
$FR_{3.3.3.3}$: Establish a delivery process for material flow.	$DP_{3.3.3.3}$: Features of delivery.	
$FR_{3.3.3.3.1}$: Establish a procedure for regular deliveries.	$DP_{3.3.3.3.1}$: 3rd party freight forwarder to retrieve components from SS_1 and deliver them to FS.	$PV_{3.3.3.3.1}$: Delivery is scheduled by SS_1 and the components are delivered to FS in 2-3 days. SS_1 supports the costs.
$FR_{3.3.3.3.2}$: Establish a procedure for express deliveries.	$DP_{3.3.3.3.2}$: Premium service.	$PV_{3.3.3.3.2}$: Delivery is scheduled by SS_1 and the components are delivered to FS in 1 day. SS_1 supports the costs.
$FR_{3.3.4}$: Select metrics to monitor interface processes.	$DP_{3.3.4}$: Time dimension supply chain and interoperability metrics to assess sourcing and delivery operations.	$PV_{3.3.4}$: See Excel PID DSM Metrics

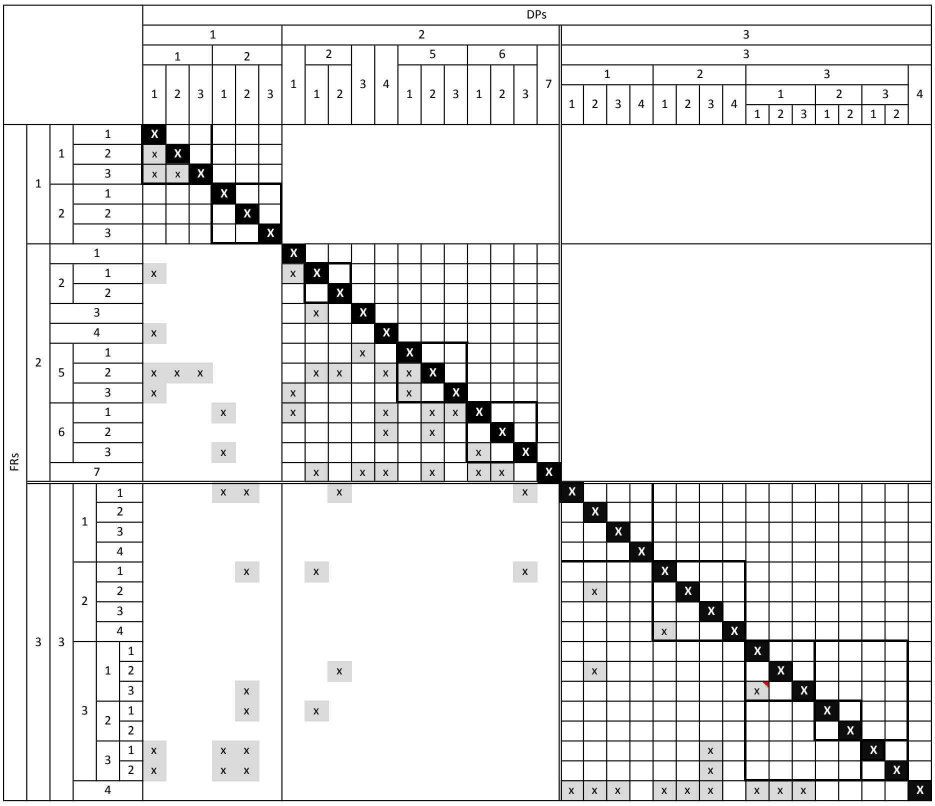

Figure 7.90. “To-be” scenario design matrix for the mapping between FRs and DPs.

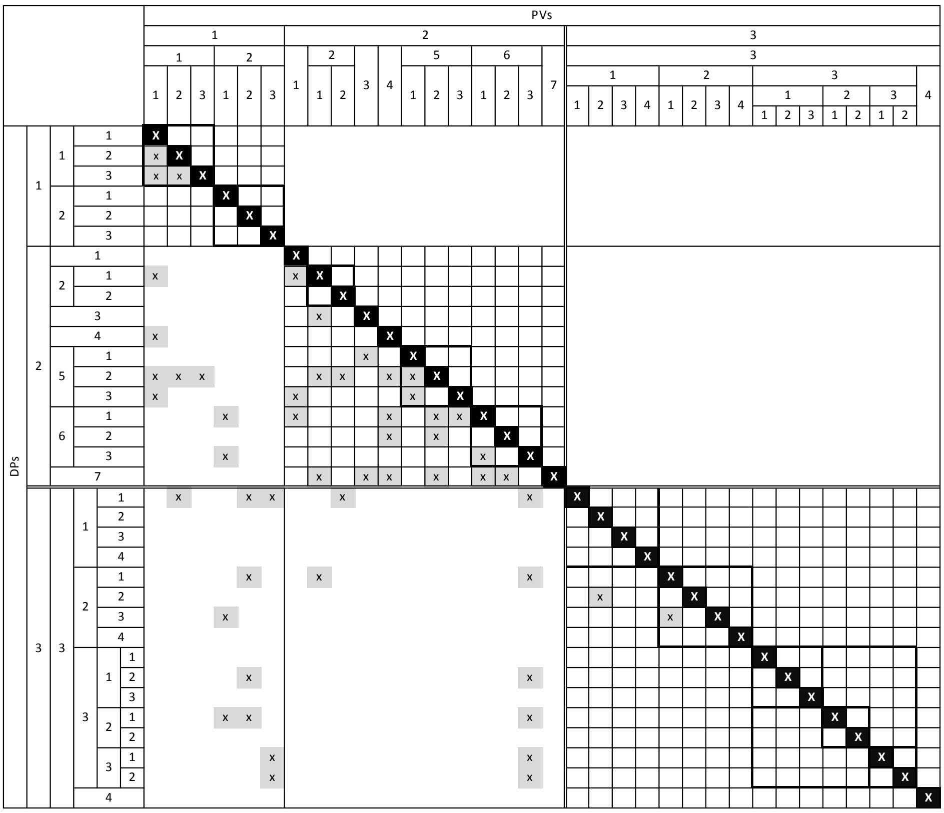

Figure 7.91. “To-be” scenario design matrix for the mapping between DPs and PVs.

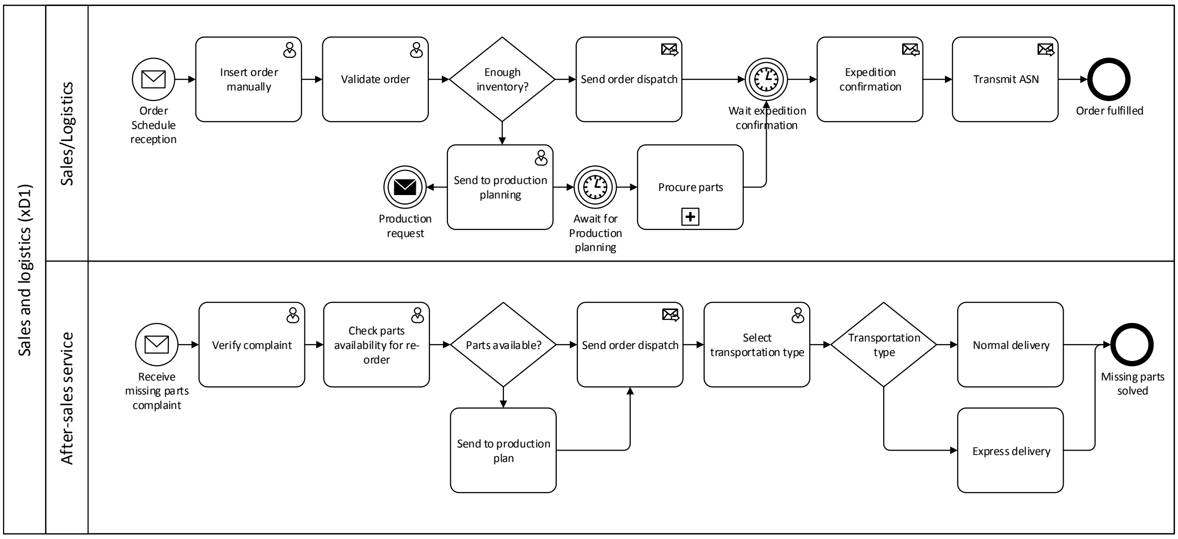

Figure 7.92. Proposed BPM for after-sales procedures integration on sales and logistics section.

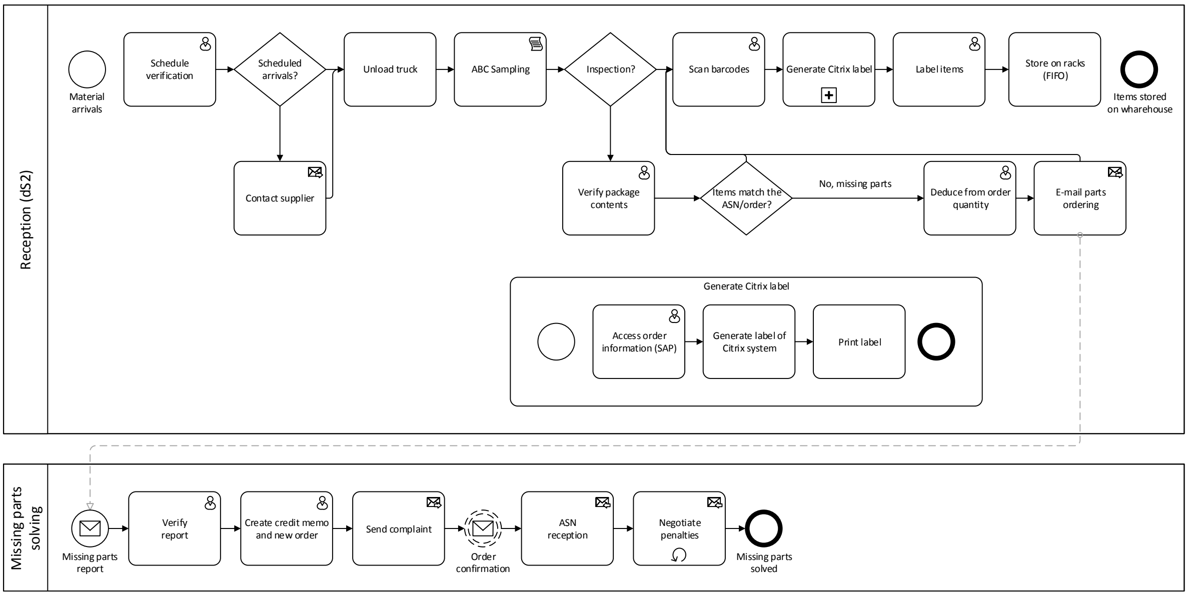

Figure 7.93. Proposed collaboration BPM for missing parts solving.

Though this new design and configuration may provide a more interoperable solution, some aspects are still unsolved. Namely, the material inspection management system in FS ($FR_{3.3.1.2}$) is still done manually. That has consequences in subsequent FRs (see Figure 7.90).

7.7. Case study 4

The design of the dyad was obtained after decomposing analysing the three approached interactions. Figure 7.94 and Figure 7.95 correspond to the design matrices for the "as-is" design of the dyad. Is to be noted that the full matrices are uncoupled. This means that we are faced with an optimization problem rather than a poor design.

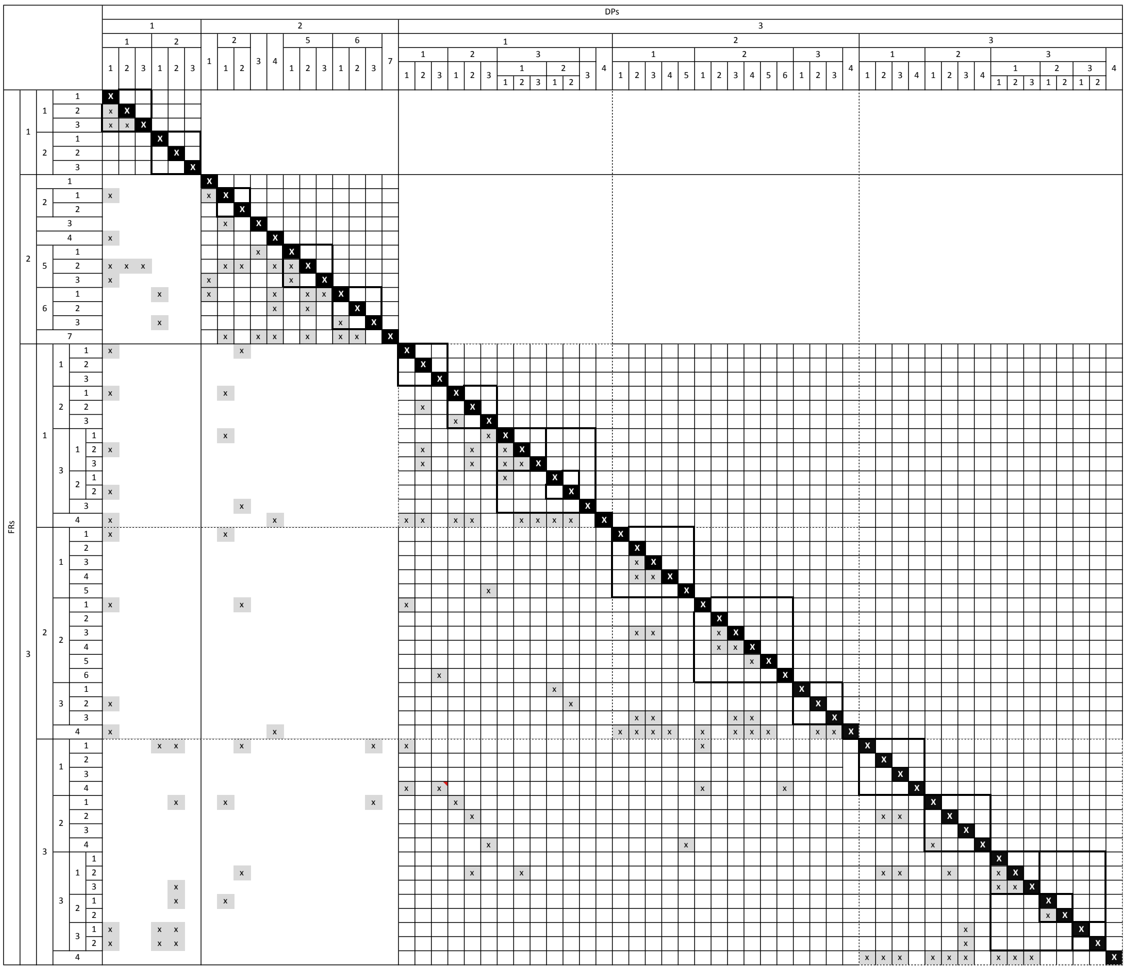

Figure 7.94. Design matrix for the "as-is" design of dyad 1 (mapping between FRs and DPs).

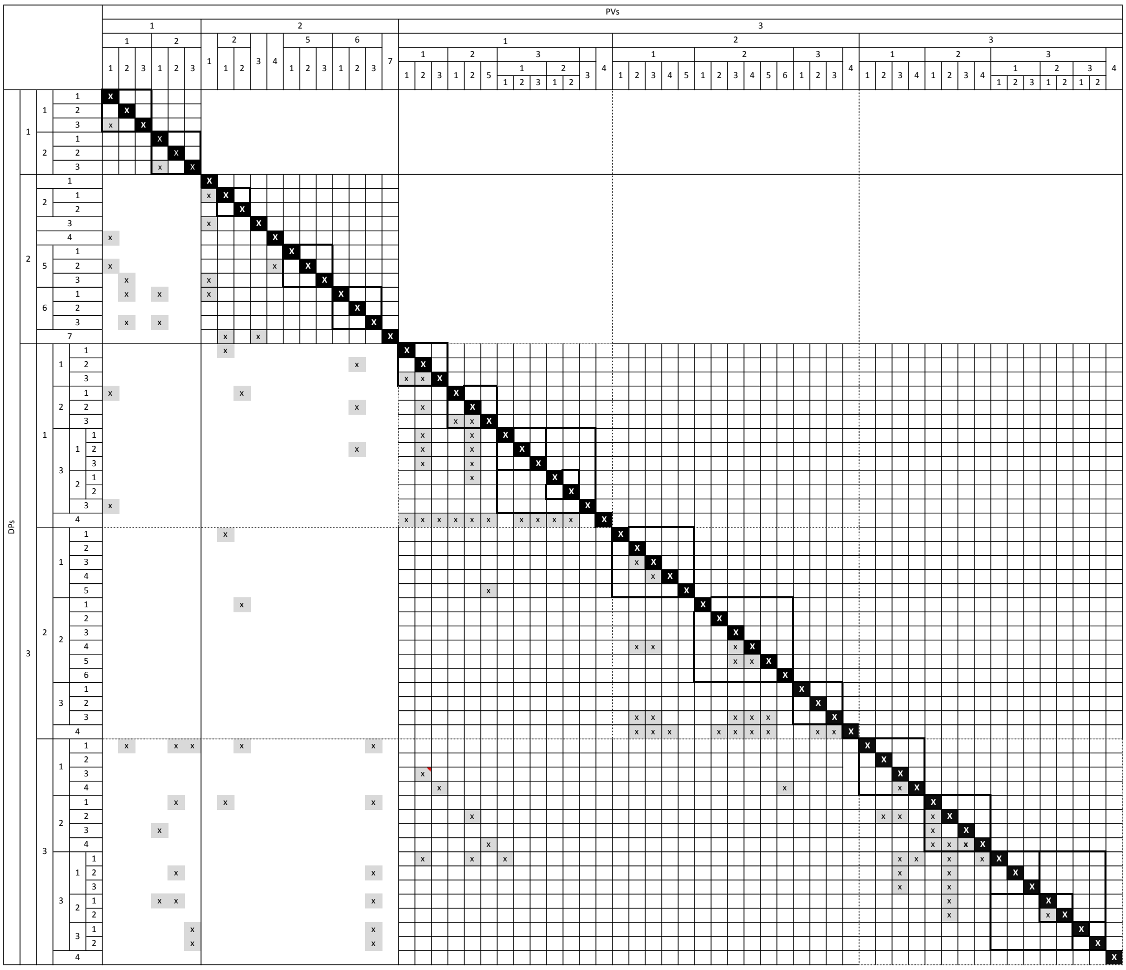

Figure 7.95. Design matrix for the "as-is" design of dyad 1 (mapping between DPs and PVs).

On the previous sections, three main interactions were studied independently. With that, was possible to approach interoperability problems separately, obtaining a solution that increases each interaction's performance. Though, the dyad interactions may impact one another. To minimize the possible dependencies on the upper triangular of the design matrices, the interactions were studied in ascending order. I.e., the buyer-seller interface (i1) is the first relationship of the three. Subsequent processes depend on this one. Hence, in this section are addressed the dependencies between the different interactions in order to determine if the improvement of each individual interaction affects another.

First, the design matrices were rewritten with the optimised interactions, to determine if some of the dependencies portrayed in Figure 7.94 and Figure 7.95 are solved by the "to-be" design. Next, the influence on one another was studied using simulation to determine the one that enhances the dyad's performance.

7.7.1. Influence of D1CS1 in D1CS2

Figure 7.96 details the "as-is" mapping between the i1 and i2 interfaces. On the mapping between functional and physical domains, some dependencies were identified. Namely, there are dependencies between the process sequence and organisational alignment aspects of each actor. These dependencies are due to the approach of the same business processes in different interactions. The final BPMs should present the "to-be" business processes obtained in the previous sections.

FRs/DPs	3.1.1.1	3.1.1.2	3.1.1.3	3.1.2.1	3.1.2.2	3.1.2.3	3.1.3.1.1	3.1.3.1.2	3.1.3.1.3	3.1.3.2.1	3.1.3.2.2	3.1.3.3	3.1.4
3.2.1.1													
3.2.1.2													
3.2.1.3													
3.2.1.4													
3.2.1.5				x		x							
3.2.2.1	x												
3.2.2.2													
3.2.2.3													
3.2.2.4													
3.2.2.5													
3.2.2.6			x										
3.2.3.1										x			
3.2.3.2											x		
3.2.3.3													
3.2.4													

FRs/PVs	3.1.1.1	3.1.1.2	3.1.1.3	3.1.2.1	3.1.2.2	3.1.2.3	3.1.3.1.1	3.1.3.1.2	3.1.3.1.3	3.1.3.2.1	3.1.3.2.2	3.1.3.3	3.1.4
3.2.1.1				x									
3.2.1.2													
3.2.1.3													
3.2.1.4													
3.2.1.5						x							
3.2.2.1	x												
3.2.2.2													
3.2.2.3													
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3.2.2.5													
3.2.2.6			x										
3.2.3.1													
3.2.3.2													
3.2.3.3													
3.2.4													

Figure 7.96. Detail on the "as-is" mappings between i1 and i2.

On the "as-is" design, the alignment of the SS_1's expedition processes with its organisational structure depends on $DP_{3.1.2.1}$ and $DP_{3.1.2.3}$. In the case of $DP_{3.1.2.1}$, the business process to perform sales and the procurement of orders is constrained by the resources, leading to a complex procedure with some loops that affect, as consequence, the subsequent procedures like the production and expedition. Though, by improving i1, a new design was obtained (see Figure 7.42 and Figure 7.43) turning the processes sequential and lowering the dependencies between processes. As consequence, the dependency of $FR_{3.2.1.5}$ from $DP_{3.1.2.1}$ was solved. Though, the dependency of $FR_{3.2.1.5}$ from $DP_{3.1.2.3}$ is maintained. To achieve the alignment of expedition processes with the SS_1's organisational structure, one must attend to the prior interface. Hence, the new BPM for the SS_1's processes is given in Figure 7.97.

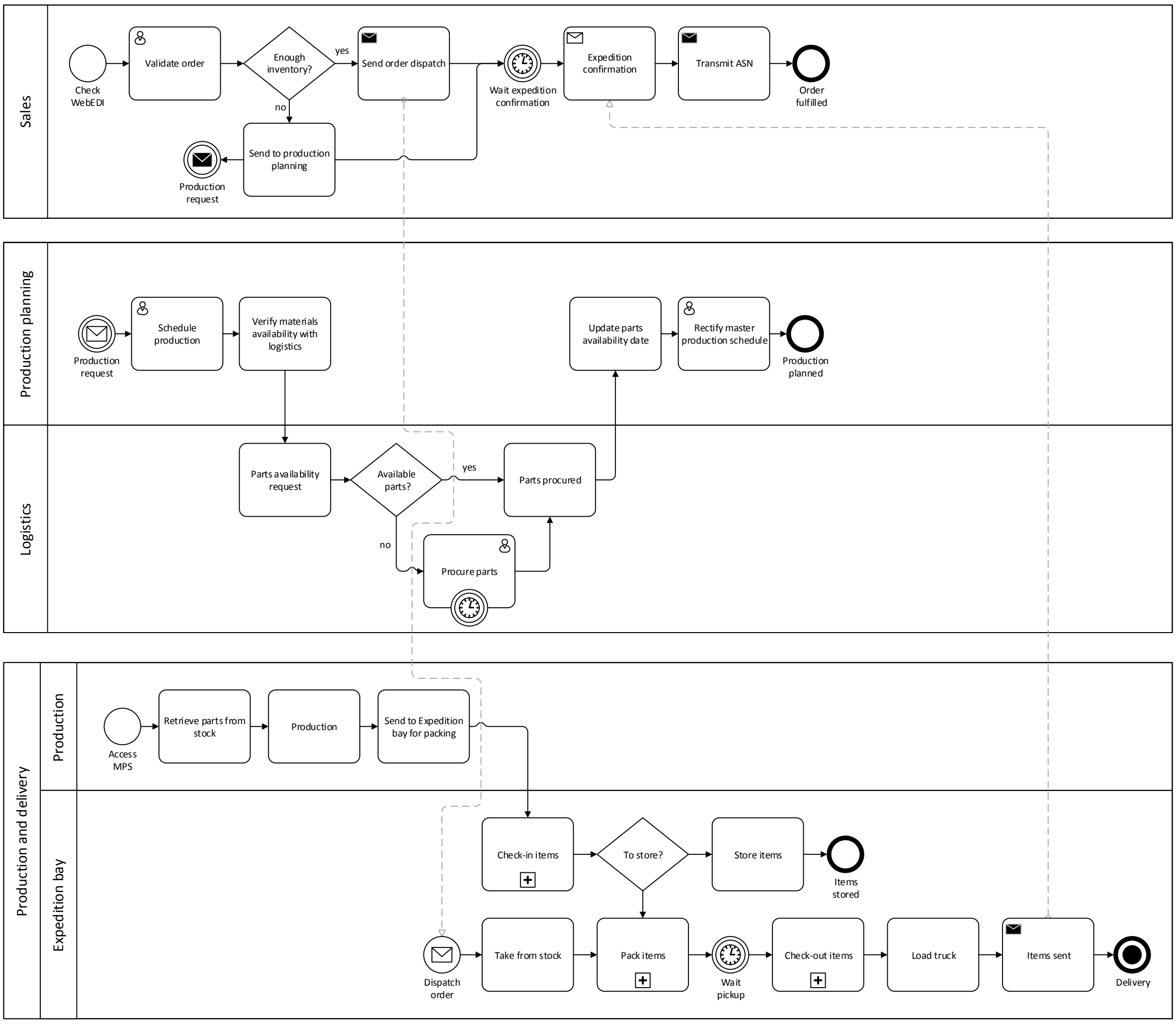


Figure 7.97. SS_1's internal processes, considering changes in i1 and i2.

On the FS's perspective, to model the process sequence of the i2 processes ($FR_{3.2.2.1}$), one must attend to the changes of implementing an EDI in the parts ordering section ($DP_{3.1.1.1}$). The result is two new BPM's for parts ordering (see Figure 7.24) and for reception (see Figure 7.55), where was adopted the FS's barcode system in the dyad. The FS's internal processes are, then, presented in Figure 7.98.

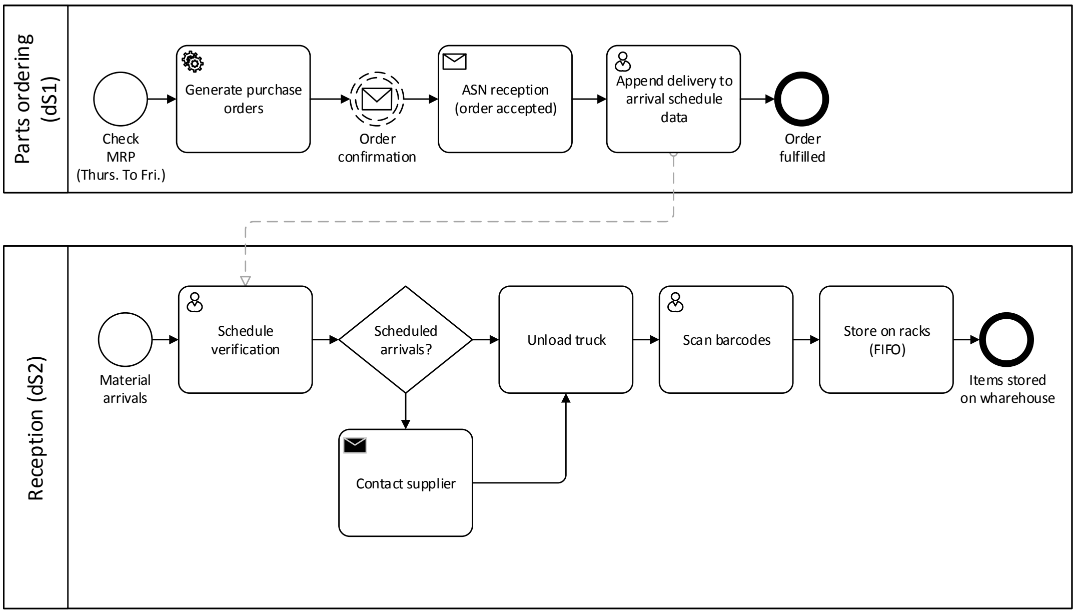


Figure 7.98. FS's internal processes, considering changes in i1 and i2.

On the mapping between physical and process domains, some resource constrains were identified. The resources used in FS's parts ordering and SS_1's sales and logistics are used again in the context of the delivery-reception interface. Hence, any changes in i1 will affect the subsequent processes that, in this case, are the expedition and reception.

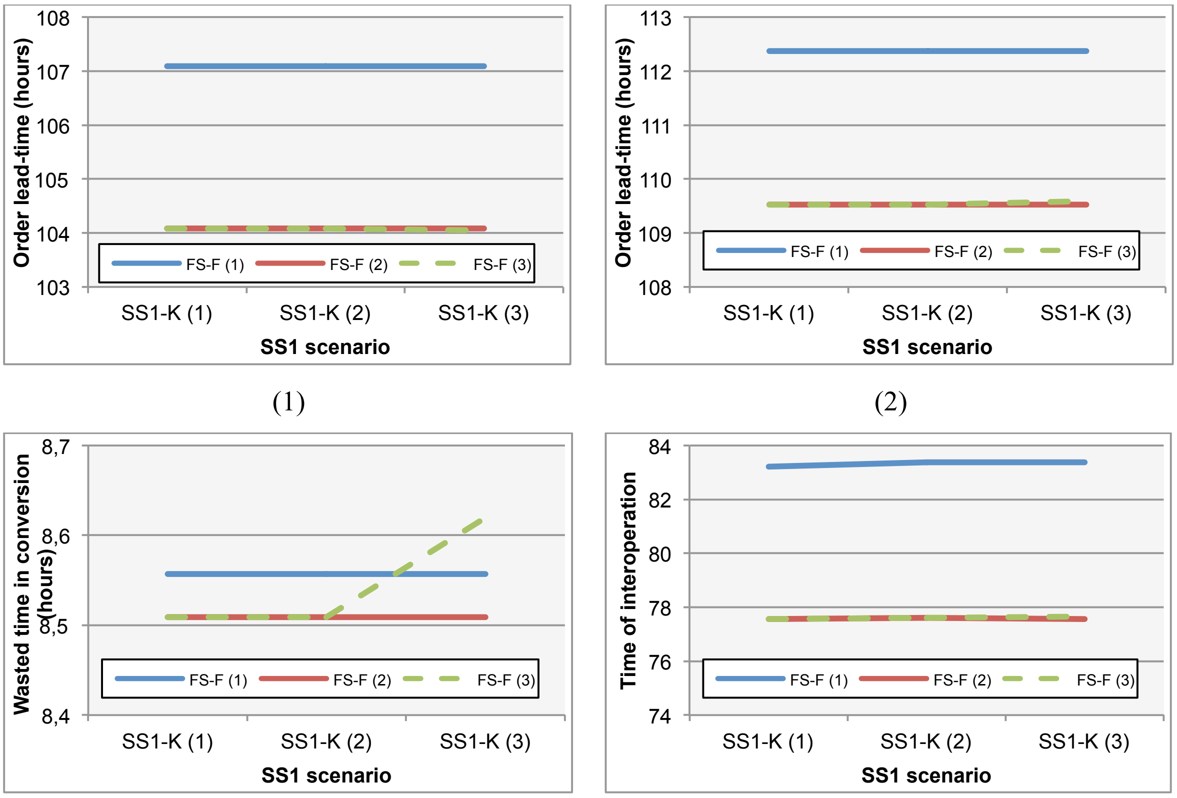
The influence of the new design of i1 in i2 was studied through a simulation model. The results are presented in Table 7.47 and Table 7.48.

Table 7.47. Order lead-time and conversion time values for the combined results of D1CS1 and D1CS2.

Scenarios		OLT	OLTreal	Conversion time				
				Total	SS_1 (sales)	SS_1 (expedition bay)	FS (Parts ordering)	FS (Reception)
FS	SS_1	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)	(hours)
FS-F (1)	SS1-K (1)	107,085	112,370	6,317	0,000	3,967	0,050	2,300
	SS1-K (2)	107,085	112,370	8,557	0,000	6,207	0,050	2,300
	SS1-K (3)	107,085	112,370	8,557	0,000	6,207	0,050	2,300
FS-F (2)	SS1-K (1)	104,084	109,525	8,542	0,000	6,207	0,050	2,285
	SS1-K (2)	104,084	109,525	8,509	0,000	6,174	0,050	2,285
	SS1-K (3)	104,084	109,525	8,509	0,000	6,174	0,050	2,285
FS-F (3)	SS1-K (1)	104,084	109,525	8,509	0,000	6,174	0,050	2,285
	SS1-K (2)	104,084	109,525	8,509	0,000	6,174	0,050	2,285
	SS1-K (3)	104,049	109,585	8,541	0,000	6,174	0,050	2,317

Table 7.48. Time of interoperation values for the combined results of D1CS1 and D1CS2.

Scenarios		Time of interoperation				
FS	SS_1	Total (hours)	TIP (hours)	TUP (hours)	TIR (hours)	TIW (hours)
FS-F (1)	SS1-K (1)	83,206	59,157	17,760	0,082	6,207
	SS1-K (2)	83,381	59,157	17,935	0,082	6,207
	SS1-K (3)	83,381	59,157	17,935	0,082	6,207
FS-F (2)	SS1-K (1)	77,563	56,132	15,175	0,081	6,175
	SS1-K (2)	77,604	56,132	15,216	0,081	6,175
	SS1-K (3)	77,555	56,132	15,167	0,081	6,175
FS-F (3)	SS1-K (1)	77,563	56,132	15,175	0,081	6,175
	SS1-K (2)	77,604	56,132	15,216	0,081	6,175
	SS1-K (3)	77,645	56,094	15,216	0,082	6,253



(1) (2) (3) (4)

Figure 7.99. Influence of the "to-be" design of i1 in i2 in terms of: (1) – order lead-time (OLT); (2) – order lead-time after updating inventory (OLTreal); (3) – wasted time in conversion (Cv); and (4) – time of interoperation (TI).

The solution that delivers the best performance is, still, the contracting of a new employee for all the FS's parts ordering processes – scenario FS-F (2); and the contracting of one new employee for SS_1's procurement processes, performing them exclusively – scenario SS_1-K (1).

Comparing the results for the individual interface optimization and the combined (portrayed on this section) with the "as-is", the obtained results are presented in Table 7.49, Table 7.50, Figure 7.100 and Figure 7.101.

Table 7.49. Alternative comparison for combination of i1 with i2.

Alternatives	Order lead-time (OLT)	Order lead-time after updating inventory (OLTreal)	Conversion time (Cv)	Time of interoperation in purchasing (TI)
	(hours)	(hours)	(hours)	(hours)
"as-is"	118,120	128,964	13,704	124,251
D1CS1	100,704	114,839	8,925	80,407
D1CS2	121,005	124,964	9,366	122,107
D1CS1 and D1CS2	104,084	109,525	8,509	77,563

Table 7.50. Improvement percentage of each alternative compared with the "as-is".

Alternatives	OLT improvement	OLTreal improvement	Cv improvement	TI improvement	Total
	(%)	(%)	(%)	(%)	(%)
D1CS1	14,74	10,95	34,87	35,29	95,86
D1CS2	-2,44	3,10	31,65	1,73	34,04
D1CS1 and D1CS2	11,88	15,07	37,91	37,58	102,44

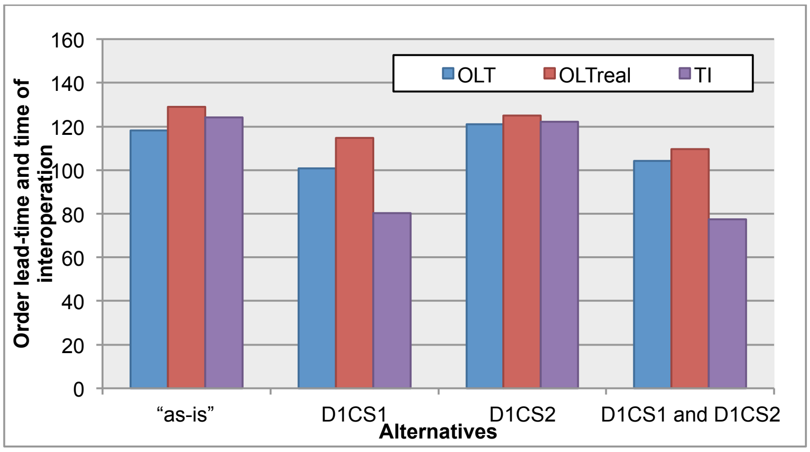


Figure 7.100. Influence of each alternative in order lead-time and in time of interoperation.

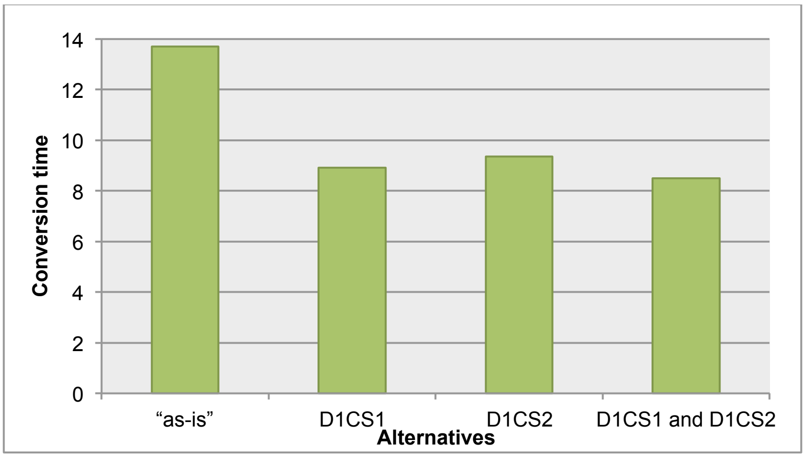


Figure 7.101. Influence of each alternative in conversion time.

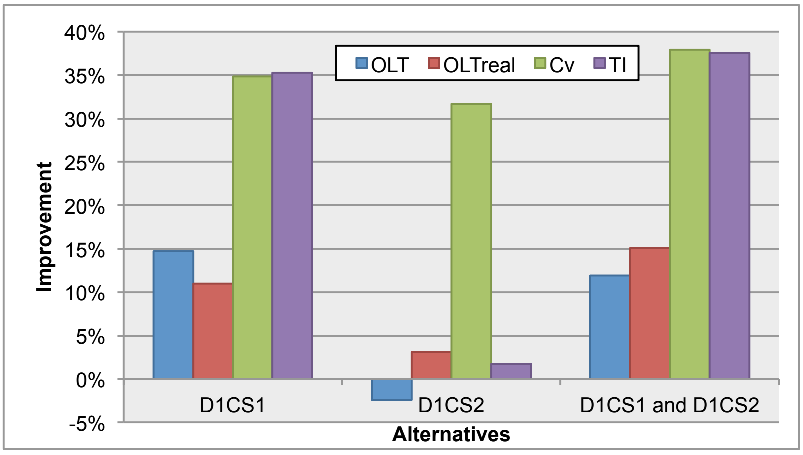


Figure 7.102. Improvement percentage of each alternative towards the "as-is".

The combined interfaces with their optimal values permit an improvement of 11,88%, 15,07%, 37,91% and 37,58% in OLT, OLTreal, Cv and TI, respectively. In Figure 7.102 is possible to observe that enhancing the dyad performance on preceding interfaces has a positive effect on subsequent ones. By combining the design of the buyer-seller with delivery-reception interface, was possible to achieve a higher performance.

In the dependencies portrayed in Figure 7.96 for the mappings between the physical and process domains, there are some resource constrains between the studied interfaces in the "as-is" conditions. The simulation results confirm that the improvement on i1 (through D1CS1) contributes to better results. In turn, the absence of this improvement limits the i2. I.e., if we take into account the OLTreal metric, the maximum improvement was obtained by adopting the FS's barcode system in dyad is 3,1%. By improving the resource quantity and distribution in upstream processes studied on D1CS1, was possible to achieve an improvement of 15,07% of OLTreal.

In conclusion, the implications on the design matrix are detailed in Figure 7.103.

FRs/DPs	DPs 3.1.1.1	3.1.1.2	3.1.1.3	3.1.2.1	3.1.2.2	3.1.2.3	3.1.3.1.1	3.1.3.1.2	3.1.3.1.3	3.1.3.2.1	3.1.3.2.2	3.1.3.3	3.1.4
3.2.1.1													
3.2.1.2													
3.2.1.3													
3.2.1.4													
3.2.1.5						x							
3.2.2.1	x												
3.2.2.2													
3.2.2.3													
3.2.2.4													
3.2.2.5													
3.2.2.6			x										
3.2.3.1										x			
3.2.3.2											x		
3.2.3.3													
3.2.4													

FRs/DPs	PVs 3.1.1.1	3.1.1.2	3.1.1.3	3.1.2.1	3.1.2.2	3.1.2.3	3.1.3.1.1	3.1.3.1.2	3.1.3.1.3	3.1.3.2.1	3.1.3.2.2	3.1.3.3	3.1.4
3.2.1.1													
3.2.1.2													
3.2.1.3													
3.2.1.4													
3.2.1.5													
3.2.2.1													
3.2.2.2													
3.2.2.3													
3.2.2.4													
3.2.2.5													
3.2.2.6													
3.2.3.1													
3.2.3.2													
3.2.3.3													
3.2.4													

Figure 7.103. Detail on the "to-be" mappings between i1 and i2.

Therefore, is possible to conclude that the both optimizations performed in D1CS1 and D1CS2 are appropriate to increase the dyads performance.

7.7.2. Influence of D1CS1 in D1CS3

In the mapping of the “as-is” interoperability conditions between i1 (purchasing-selling interface) and i3 (exceptions handling interface), some issues were identified between functional, physical and process domain (see Figure 7.104).

						DPs												
						3												
						1												
						1			2			3						4
						1	2	3	1	2	3	1			2		3	
												1	2	3	1	2		
FRs/DPs	3	3	1	1														
				2														
				3														
				4				x										
			2	1														
				2						x								
				3														
				4					x		x							
			3	1	1													
					2		x			x			x					
					3													
				2	1													
					2													
				3	1													
					2													
			4															

						PVs												
						3												
						1												
						1			2			3						4
						1	2	3	1	2	3	1			2		3	
												1	2	3	1	2		
FRs/DPs	3	3	1	1		x												
				2														
				3		x	x											
				4				x										
			2	1					x									
				2					x	x								
				3					x	x								
				4					x	x	x							
			3	1	1		x			x		x						
					2								x					
					3													
				2	1													
					2													
				3	1												x	
					2													
			4															

Figure 7.104. Detail on the “as-is” mappings between i1 and i3.

On the FS’s perspective, there are issues regarding the organisational alignment aspect. In order to align the processes for i3, one must attend to the considerations established for parts ordering and reception in i1. Hence, the BPM’s to incorporate the issues raised in D1CS1 are presented in and Figure 7.105.

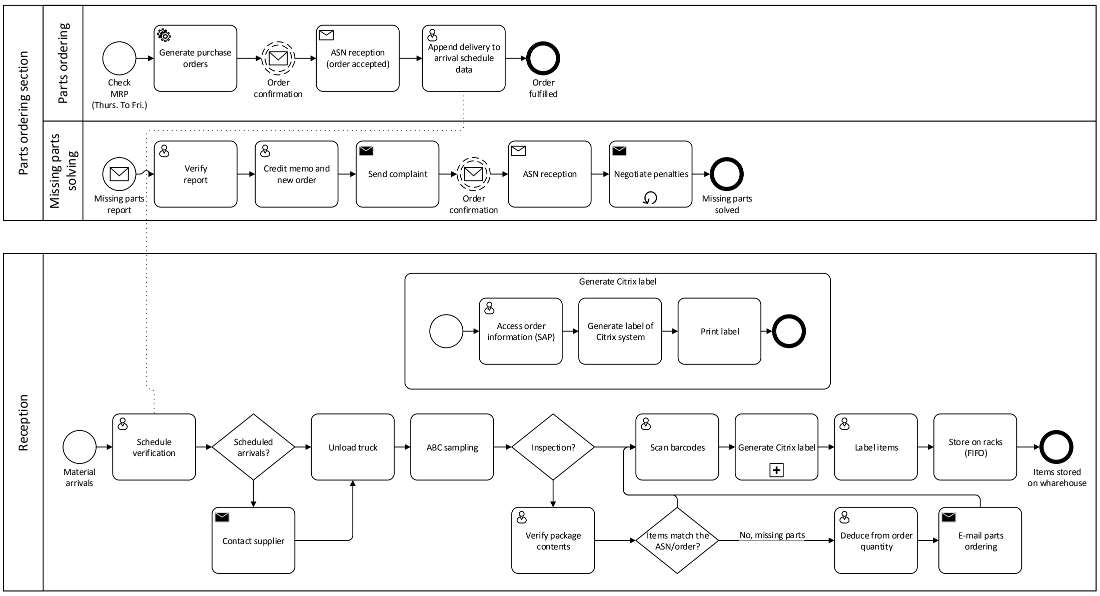


Figure 7.105. FS's internal processes, considering changes in i1 and i3.

Regarding SS_1's processes, there are problems regarding the complaint data processing and the organisational alignment. In terms of data processing, the incompatibility of the exchanged data for complaints handling is due to a similar problem that occurs in i1, where the order data cannot be imported directly to SAP. The use of an inappropriate ICT to exchange order and order complaint data led to the need of a manual conversion procedure. Hence, $FR_{3.3.2.2}$ depends of $DP_{3.1.2.2}$ and $DP_{3.3.2.2}$.
Though, in the optimized interfaces i1 and i3, the conversion process is solved. Hence, this dependency is eliminated, solving the incompatibility by eliminating the conversion process.
In terms of the organisational alignment of SS_1's processes, in the "as-is" interoperability conditions to align the i3 processes depend on $DP_{3.1.2.1}$ and $DP_{3.1.2.3}$. But, by improving the process sequence on D1CS1, this aspect is only dependent of $DP_{3.1.2.3}$. The result is portrayed in Figure 7.106.

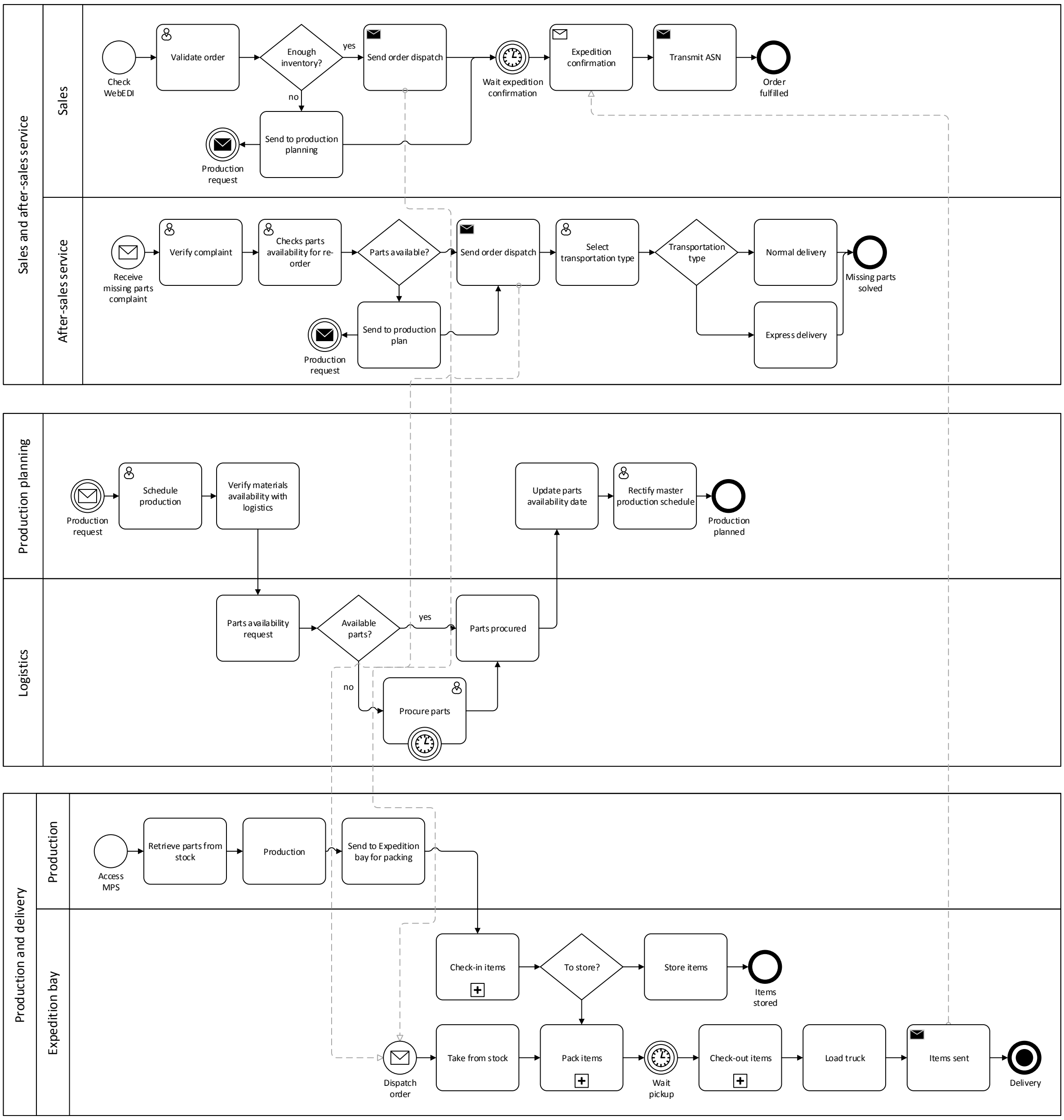


Figure 7.106. SS_1's internal processes, considering changes in i1 and i3.

On the interface processes, some issues are raised regarding the applications interoperability. The use of different applications to manage orders and complaints associated with a non-interoperable ICT led to the incompatibility of data between firms. On the "to-be" designs obtained in D1CS1 and D1CS3, this problem is solved and, therefore, the dependencies referring to order and complaint order data exchange and processing are eliminated.

At the physical and process domains, work methods and resource quantity and distribution present some problems between the interactions. The use of the same resources in different contexts of both interactions is the reason for this problem. Presently, the same employees that perform the main activities – parts ordering in the case of FS and sales and logistics in the case of SS_1 – are the ones that also establish the contact for handling the missing parts on i3.

To determine the optimal conditions to perform both interactions, computer simulations were run considering the effect of each one of the scenarios:

- FS-F – Add new employees to parts ordering.
- SS_1-K – New employees work in procurement, exclusively.
- FS-D – New employees perform missing parts solving processes.
- SS_1-H – New employees perform the after-sales processes.

In each scenario, the employee quantity varies from 1 to 3 total of employees in each addressed section. This implies that 81 simulations should be required to determine the optimal configuration for each scenario. Applying a Taguchi experimental design with a four control factors at three levels each, one can reduce the number of simulations to 9 by using a L_9 (3^4) orthogonal array design (see Table 7.51).

Table 7.51. Simulation configurations using an L_9 orthogonal array.

Simulation no.	Factors (scenarios) and levels (employee quantity)			
	FS-F	SS_1-K	FS-D	SS_1-H
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The computer simulations were run with the specifications on Table 7.51. Each row contains the configuration in terms of employee quantity for each scenario. The resulting "to-be" scenarios studied in D1CS1 and D1CS3 have independent resources and, therefore, possible interactions between each scenario were not considered.

In practice, were determined the metrics values for each simulation run and for each replication (20 replications total) and, then, was determined the values for order lead-time (OLT), backorder lead-time (OLTmissing) and time of interoperation (total and individual TI). The mean values for the metrics are presented in Table 7.52.

Table 7.52. Metrics values for each simulation.

Simulation no.	Factors (scenarios) and levels (employee quantity)				$\overline{OLT}$	$\overline{OLT_{missing}}$	Total TI	TI (i1)	TI (i3)
	FS-F	SS_1-K	FS-D	SS_1-H					
1	1	1	1	1	104,552	93,385	0,776	75,920	76,696
2	1	2	2	2	104,552	93,385	0,776	75,920	76,696
3	1	3	3	3	104,552	93,385	0,776	75,920	76,696
4	2	1	2	3	101,820	90,757	0,913	70,663	71,577
5	2	2	3	1	101,820	90,757	0,913	70,663	71,577
6	2	3	1	2	101,820	90,757	0,913	70,663	71,577
7	3	1	3	2	101,820	90,757	0,913	70,663	71,577
8	3	2	1	3	101,820	90,757	0,913	70,663	71,577
9	3	3	2	1	101,820	90,757	0,913	70,663	71,577

The analysis of means (ANOM) was applied to determine the effects of each scenario. Table 7.53, Table 7.54, Table 7.55, Table 7.56, and Table 7.57 resume the effects of each scenario for each level. The effect of FS-F_1 in OLT is calculated according to equation (7.14):

$$FS - F_1 = \frac{104{,}552 + 104{,}552 + 104{,}552}{3} = 104{,}552 \text{ hours} \tag{7.14}$$

And the range of the factor (Δ) was determined by equation (7.15):

$$\Delta = Max - Min = 104{,}552 - 101{,}820 = 2{,}732 \text{ hours} \tag{7.15}$$

Table 7.53. Response table for order lead-time (OLT).

Level	Factors			
	FS-F	SS_1-K	FS-D	SS_1-H
1	104,552	102,731	102,731	102,731
2	101,820	102,731	102,731	102,731
3	101,820	102,731	102,731	102,731
Δ	2,732	0,000	0,000	0,000
Rank	1	3	3	3

Table 7.54. Response table for backorder lead-time (OLTmissing).

Level	Factors			
	FS-F	SS_1-K	FS-D	SS_1-H
1	93,385	91,633	91,633	91,633
2	90,757	91,633	91,633	91,633
3	90,757	91,633	91,633	91,633
Δ	2,628	0,000	0,000	0,000
Rank	1	3	3	3

Table 7.55. Response table for time of interoperation for i1.

Level	Factors			
	FS-F	SS_1-K	FS-D	SS_1-H
1	75,920	72,416	72,416	72,416
2	70,663	72,416	72,416	72,416
3	70,663	72,416	72,416	72,416
Δ	5,257	0,000	0,000	0,000
Rank	1	3	3	3

Table 7.56. Response table for time of interoperation for i3.

Level	Factors			
	FS-F	SS_1-K	FS-D	SS_1-H
1	0,776	0,867	0,867	0,867
2	0,913	0,867	0,867	0,867
3	0,913	0,867	0,867	0,867
Δ	0,138	0,000	0,000	0,000
Rank	1	3	3	3

Table 7.57. Response table for total time of interoperation.

Level	Factors (scenarios)			
	FS-F	SS_1-K	FS-D	SS_1-H
1	76,696	73,283	73,283	73,283
2	71,577	73,283	73,283	73,283
3	71,577	73,283	73,283	73,283
Δ	5,119	0,000	0,000	0,000
Rank	1	3	3	3

Graphically, the effects plots for each mean are presented in Figure 7.107.

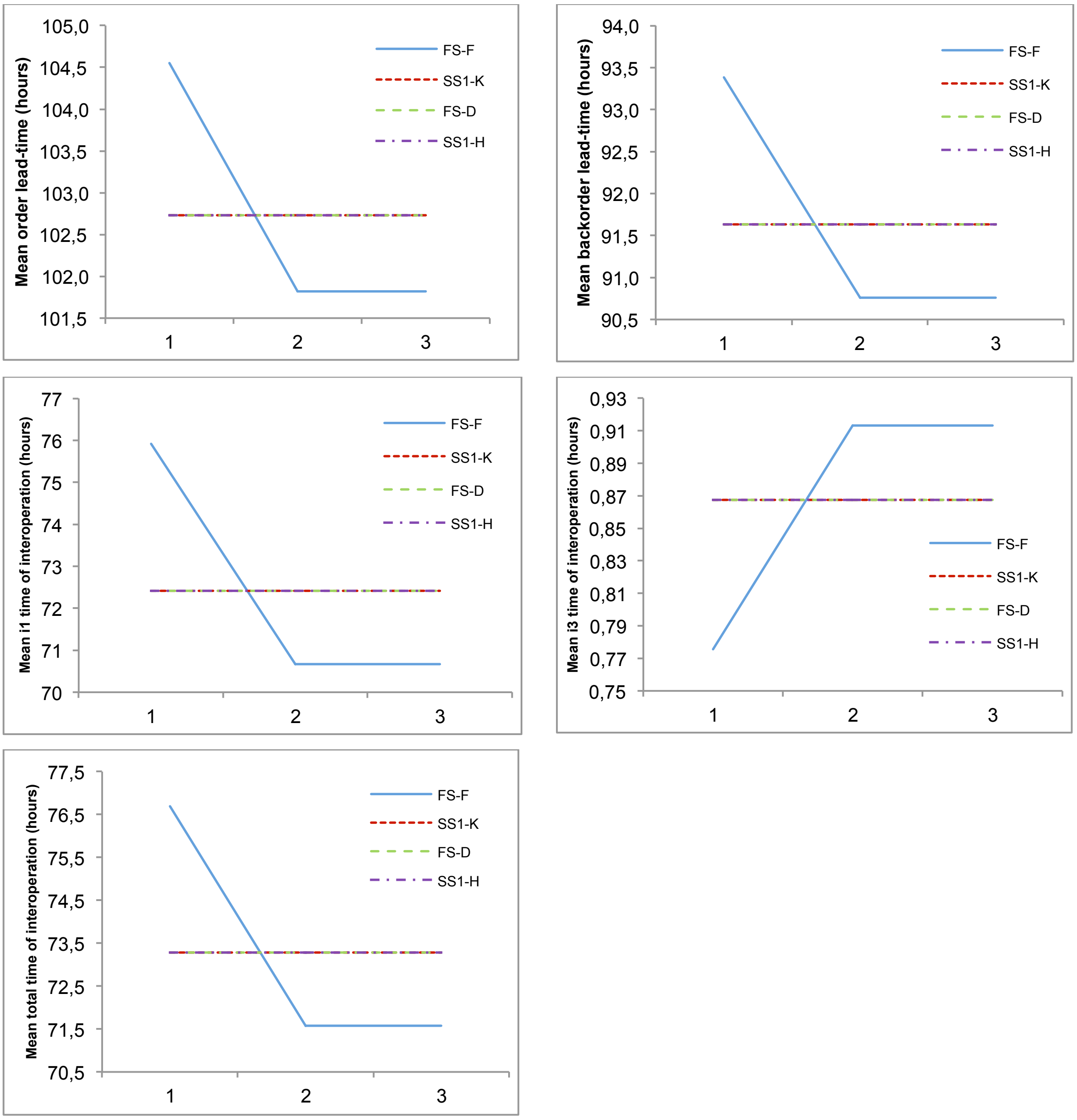


Figure 7.107. Effects plot for mean values of metrics.

The scenario configuration that has impact on the metrics is FS-F. Better values of OLT, OLTmissing, TI i1 and total TI are achieved by contracting a new employee to perform the purchasing activities. Though, increasing the number of employees on the purchasing section results in the increase of the time of interoperation to solve backorder. Nevertheless, this impact is considered low (about 8 minutes more).

In sum, the optimal configuration for the impact of i1 in i3 is given by FS-F(2), SS_1-K(1), FS-D(1) and SS_1-H(1).

Comparing the results for each individual interface optimization with the "as-is" were obtained the results presented in Table 7.58, Table 7.59, Figure 7.108, Figure 7.109 and Figure 7.110.

Table 7.58. Alternative comparison for combination of i1 with i3.

Alternatives	Order lead-time (OLT)	OLTmissing	Conversion time (Cv)	Time of interoperation in purchasing (TI)
	(hours)	(hours)	(hours)	(hours)
"as-is"	118,120	128,964	13,704	124,251
D1CS1	100,704	114,839	8,925	80,407
D1CS3	121,005	124,964	9,366	122,107
D1CS1 and D1CS3	104,084	109,525	8,509	77,563

Table 7.59. Improvement percentage of each alternative compared with the "as-is".

Alternatives	OLT improvement	OLTmissing improvement	Cv improvement	TI improvement	Total
	(%)	(%)	(%)	(%)	(%)
D1CS1	14,74	0,04	57,07	34,62	106,47
D1CS3	-0,51	4,15	39,15	13,19	55,98
D1CS1 and D1CS3	13,80	7,17	96,22	45,73	162,92

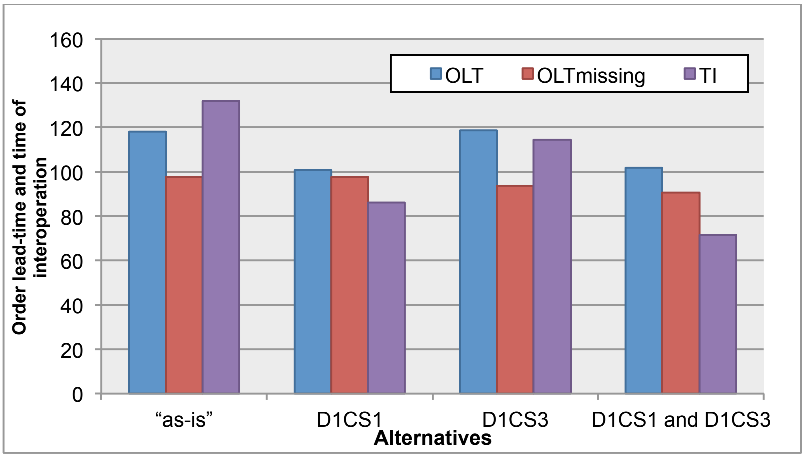


Figure 7.108. Influence of each alternative in order lead-time and in time of interoperation.

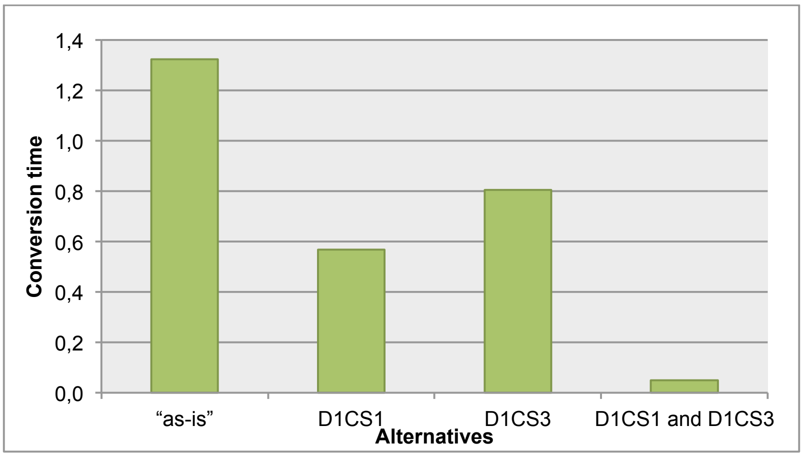


Figure 7.109. Influence of each alternative in conversion time.

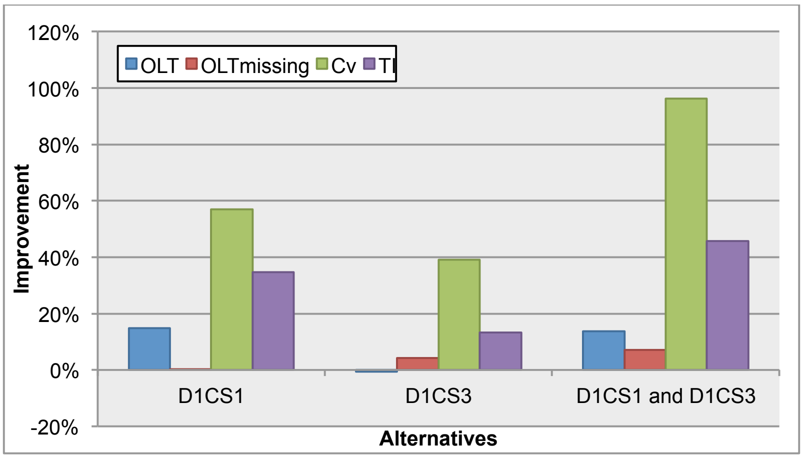


Figure 7.110. Improvement percentage of each alternative towards the “as-is”.

Combining the interfaces with their optimal values improves the dyad performance in about 13,80, 7,17, 96,22 and 45,73 per cent in OLT, OLTmissing, Cv and TI, respectively. Comparing with the separate improvements of the interfaces, combining the new designs of the interaction allows better interoperability performance. The resulting design matrix for the interactions between i1 and i3 is presented in Figure 7.111.

						DPs												
						3												
						1												
						1			2			3						4
						1	2	3	1	2	3	1			2		3	
												1	2	3	1	2		
FRs/DPs	3	3	1	1														
				2														
				3														
				4				x										
			2	1														
				2														
				3														
				4							x							
			3	1	1													
					2													
					3													
				2	1													
					2													
				3	1													
					2													
			4															

PVs												
3												
1												
1			2			3						4
1	2	3	1	2	3	1			2		3	
						1	2	3	1	2		
										x		

Figure 7.111. Detail on the "to-be" mappings between i1 and i3.

Dependencies in the mapping from functional to physical, and from physical to process domains were, mostly, eliminated due to the performed improvements. Improvements in SS_1's sales and logistics process sequence, the elimination of manual conversion processes by implementing compatible systems, and new resource distribution and quantification led to a more desirable interoperability solution that the initial one ("as-is").

7.7.3. Influence of D1CS2 in D1CS3

The influence of the delivery-reception interface in exceptions handling is the last aspect to analyse in dyad 1. Figure 7.112 details the "as-is" interoperability conditions mapped between those two interactions. On the mapping between functional, physical and process domains, there are some dependencies regarding process sequence and organisational alignment.

FRs/DPs	DP 3.2.1.1	DP 3.2.1.2	DP 3.2.1.3	DP 3.2.1.4	DP 3.2.1.5	DP 3.2.2.1	DP 3.2.2.2	DP 3.2.2.3	DP 3.2.2.4	DP 3.2.2.5	DP 3.2.2.6	DP 3.2.3.1	DP 3.2.3.2	DP 3.2.3.3	DP 3.2.4
3.3.1.1						x									
3.3.1.2															
3.3.1.3															
3.3.1.4											x				
3.3.2.1															
3.3.2.2															
3.3.2.3															
3.3.2.4					x										
3.3.3.1.1															
3.3.3.1.2															
3.3.3.1.3															
3.3.3.2.1															
3.3.3.2.2															
3.3.3.3.1															
3.3.3.3.2															
3.3.4															

FRs/DPs	PV 3.2.1.1	PV 3.2.1.2	PV 3.2.1.3	PV 3.2.1.4	PV 3.2.1.5	PV 3.2.2.1	PV 3.2.2.2	PV 3.2.2.3	PV 3.2.2.4	PV 3.2.2.5	PV 3.2.2.6	PV 3.2.3.1	PV 3.2.3.2	PV 3.2.3.3	PV 3.2.4
3.3.1.1															
3.3.1.2															
3.3.1.3															
3.3.1.4											x				
3.3.2.1															
3.3.2.2															
3.3.2.3															
3.3.2.4					x										
3.3.3.1.1															
3.3.3.1.2															
3.3.3.1.3															
3.3.3.2.1															
3.3.3.2.2															
3.3.3.3.1															
3.3.3.3.2															
3.3.4															

Figure 7.112. Detail on the "as-is" mappings between i2 and i3.

Regarding the FS's processes, any changes on i2's reception business process have impact on i3 final process. In the case of the "to-be" designs for the previous changes in the reception process, the final design should incorporate the new barcode system and the inspection procedures. The final BPM for reception is presented in Figure 7.113.

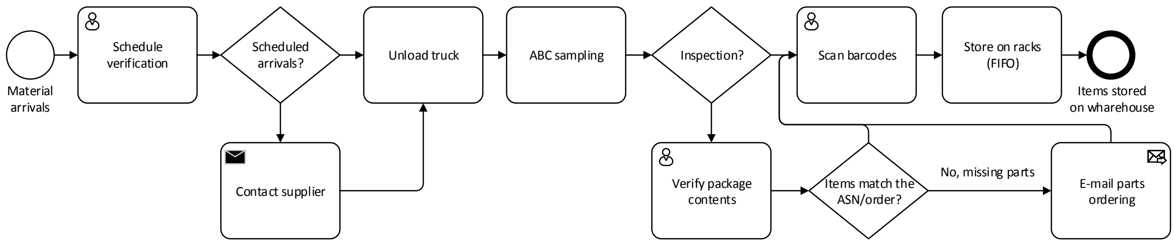


Figure 7.113. FS's reception process with changes from i2 and i3.

There is no resource dependency between the two interactions. The reception section has no resource limitation. Then, there is no dependency between DPs and PVs for the process sequence aspect. However, in the case of process alignment with organisational structure, there are both dependencies of FRs from DPs and of DPs from PVs. The proposed BPM for OS alignment is presented in Figure 7.14, and the resource quantity and distribution will be discussed ahead.

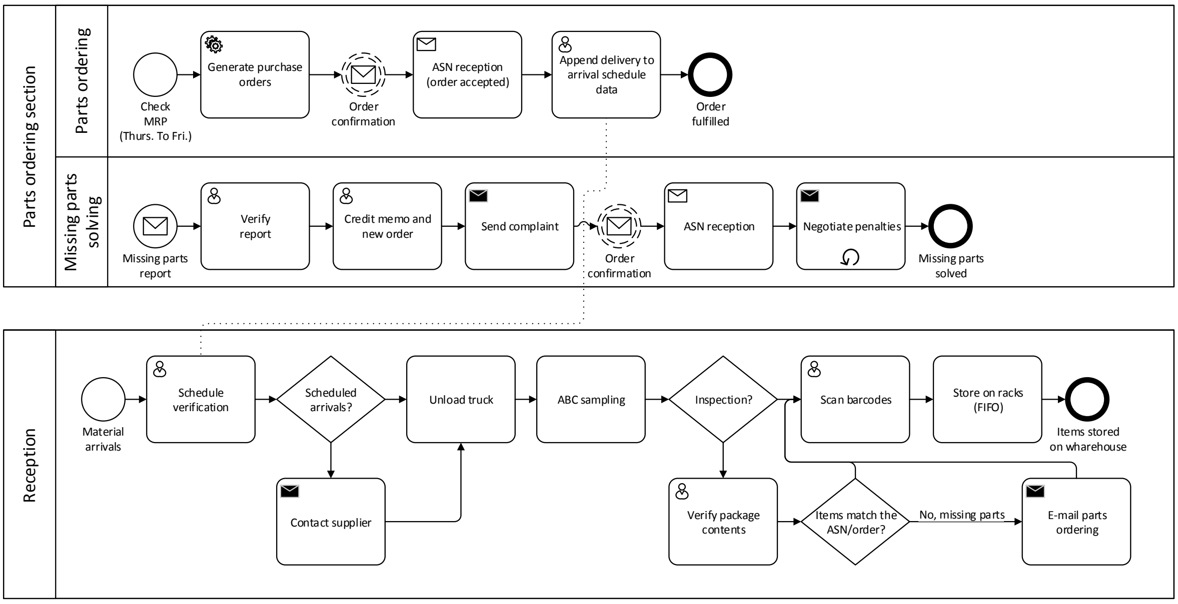


Figure 7.114. Final functional alignment of purchasing, missing parts solving and reception processes with FS's organisational structure.

In terms of work methods and resource dependency (registered in the PVs and in the matrices), the influence of i2 in i3, and vice-versa, is conditional. Only when orders with items missing are identified the exceptional procedures are performed. This may impact the performance of reception processes, increasing the time between order receptions and storing. Also, upon identification of faulty orders, the after-sales procedure in SS_1 is triggered. This one will have impact on the regular procedures for production and expedition in SS_1.

To study the impact of joining together i2 and i3, a simulation was performed considering the scenarios FS-F, SS_1-K, FS-D and SS_1-H studied on the previous section combined with the implementation of the FS's barcode system (i2). The applied Taguchi method is similar to the previously demonstrated, applying an L_9 array. The results are presented in Figure 7.115.

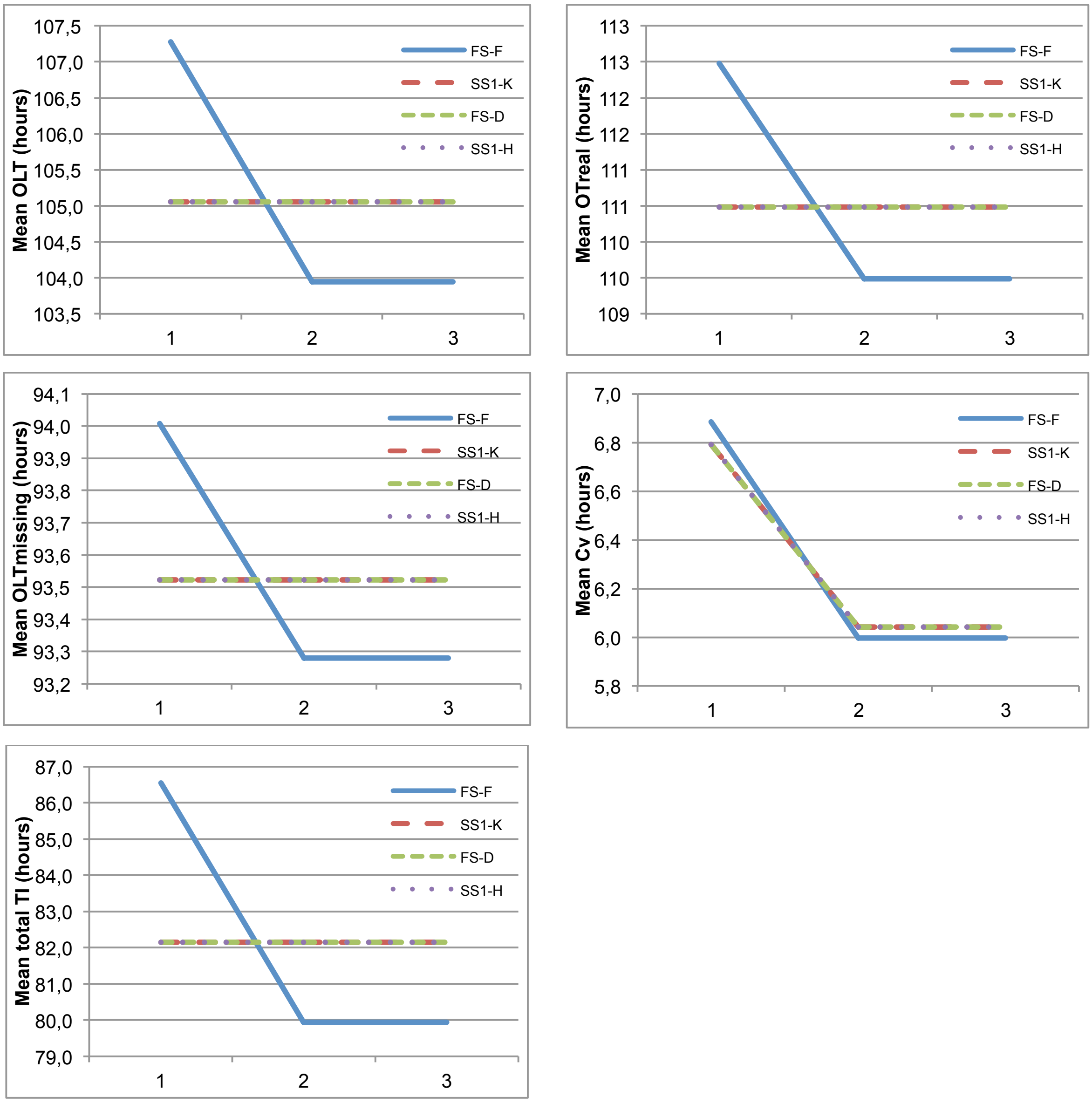


Figure 7.115. Effects plot for mean values of metrics.

In order to achieve higher interoperability performance in implementing the modifications from i2 and i3 (considering the impact of i1), FS-F scenario should be implemented with two employees (i.e., contract an additional employee for "parts ordering" section). Analysing the values from OLT and TI, one can affirm that this improvement is sufficient. Though, in terms of Cv, there significant improvements to the total value for this metric by adding one employee to the other scenarios. The gain is about 48 minutes per order. On the interoperability perspective, this change may be recommended if the goal is to lower the handmade data conversions. Still, a cost-based analysis is recommended to determine if the gain of 48 minutes in Cv is crucial for the dyad performance.

In terms of the dyad design for the mapping of interoperability conditions between i2 and i3, the design matrices remain unaltered. Although there are degrees of liberty for improvements between these two interactions, some interoperability problems in i2 weren't possible to solve. Due to limitations on the product size, some activities are still human-based rather than automated processes. Also, the improvement of Cv studied on the influence of these two interactions is indirect result. The studied scenarios affect directly the resources on i1 and i3. They produce an indirect effect on the expedition and reception business processes, due to solving order accumulation in the queues of the processes that are upstream relative to these expedition and reception processes.

Comparing the results for each individual interface improvement with the "as-is", were obtained the results presented in Table 7.60, Table 7.61, Figure 7.116, Figure 7.117 and Figure 7.118.

Table 7.60. Alternative comparison for combination of i2 with i3.

Alternatives	Order lead-time (OLT)	OLTreal	OLTmissing (OLTmissing)	Conversion time (Cv)	Time of interoperation in purchasing (TI)
	(hours)	(hours)	(hours)	(hours)	(hours)
"as-is"	118,120	128,964	97,770	13,417	28,880
D1CS2	121,005	124,964	97,701	9,077	24,528
D1CS3	118,726	128,642	93,713	12,480	11,230
D1CS2 and D1CS3	103,944	109,486	93,280	8,152	7,119

Table 7.61. Improvement percentage of each alternative compared with the "as-is".

Alternatives	OLT improvement	OLTreal improvement	OLTmissing improvement	Cv improvement	TI improvement	Total
	(%)	(%)	(%)	(%)	(%)	(%)
D1CS2	-2,44	3,10	0,07	32,35	15,07	32,96
D1CS3	-0,51	0,25	4,15	6,98	61,11	7,28
D1CS2 and D1CS3	12,00	15,10	4,59	39,24	75,35	110,57

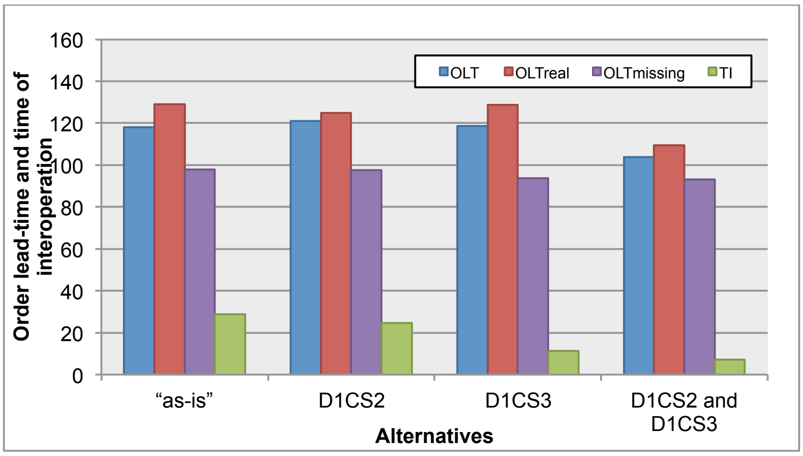


Figure 7.116. Influence of each alternative in order lead-time and in time of interoperation.

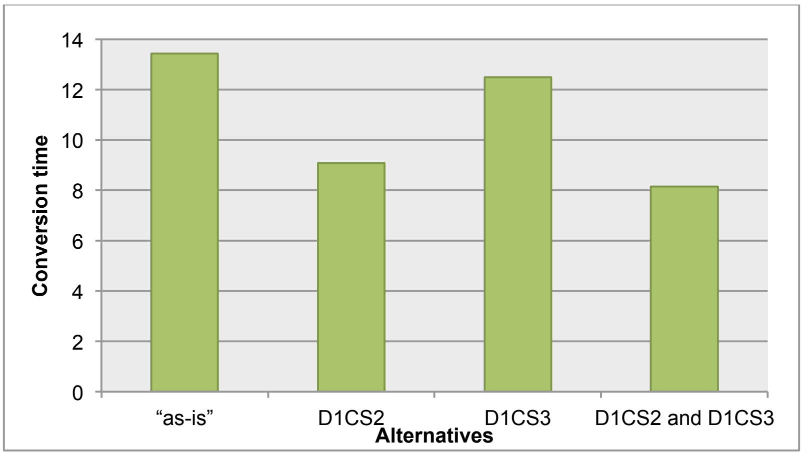


Figure 7.117. Influence of each alternative in conversion time.

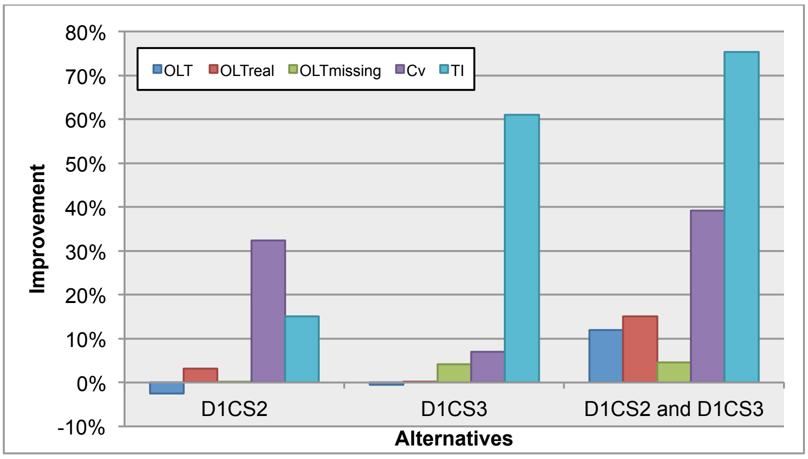


Figure 7.118. Improvement percentage of each alternative towards the "as-is".

Combining the interfaces with their optimal values improves the dyad performance in about 12, 15,1, 4,59, 39,24 and 75,35 per cent in OLT, OLTreal, OLTmissing, Cv and TI, respectively.

7.7.4. Interaction comparison

To determine the full contribution of the studied interactions (separated and combined), the order lead-time values were determined and time of interoperation and conversion time were recalculated to consider the impact of each scenario in the total values of TI and Cv. The results are presented in Table 7.62, in Figure 7.119 and in Figure 7.120.

Table 7.62. Alternative comparison for the full model.

Alternatives	Order lead-time (OLT)	OLTreal	OLTmissing (OLTmissing)	Conversion time (Cv)	Time of interoperation in purchasing (TI)
	(hours)	(hours)	(hours)	(hours)	(hours)
"as-is"	118,120	128,964	97,770	14,222	124,251
D1CS1	100,704	114,839	97,732	13,310	79,976
D1CS2	121,005	124,964	97,701	9,884	122,107
D1CS3	118,726	128,642	93,713	13,283	128,233
D1CS1 and D1CS2	104,084	109,525	97,724	9,027	77,563
D1CS1 and D1CS3	101,820	114,813	90,757	12,811	81,474
D1CS1 and D1CS2 and D1CS3	103,944	109,486	93,280	8,202	78,847

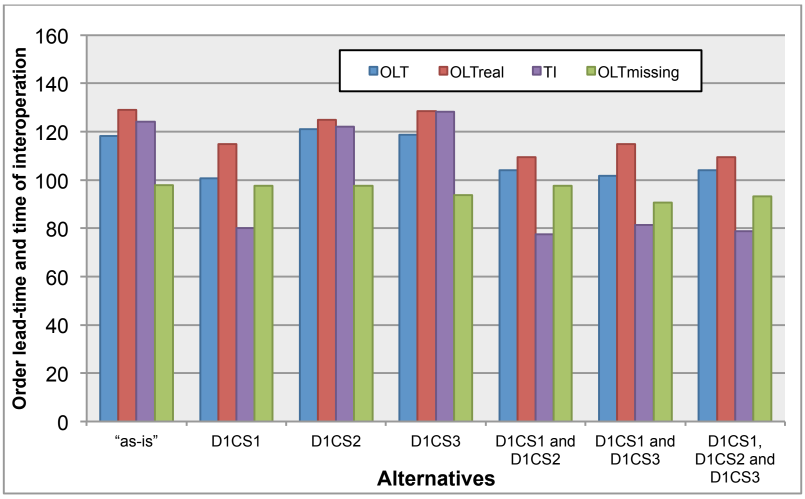


Figure 7.119. Influence of each alternative in order lead-time and in time of interoperation.

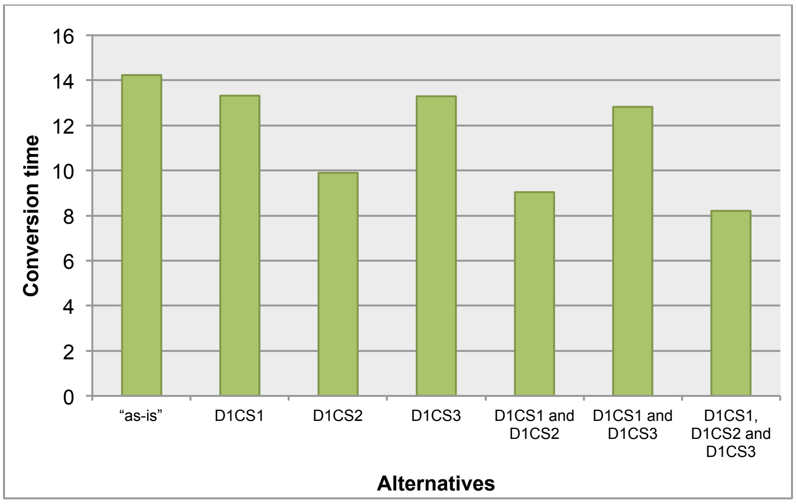


Figure 7.120. Influence of each alternative in conversion time.

The respective improvement percentage is presented in Table 7.63, in Figure 7.121.in Figure 7.122.

Table 7.63. Improvement percentage of each alternative compared with the "as-is".

Alternatives	OLT improvement (%)	OLTreal improvement (%)	OLTmissing improvement (%)	Cv improvement (%)	TI improvement (%)	Total (%)
D1CS1	14,74	10,95	0,04	6,41	35,63	67,78
D1CS2	-2,44	3,10	0,07	30,50	1,73	32,96
D1CS3	-0,51	0,25	4,15	6,60	-3,20	7,28
D1CS1 and D1CS2	11,88	15,07	0,05	36,53	37,58	101,11
D1CS1 and D1CS3	13,80	10,97	7,17	9,92	34,43	76,29
D1CS1 and D1CS2 and D1CS3	12,00	15,10	4,59	42,33	36,54	110,57

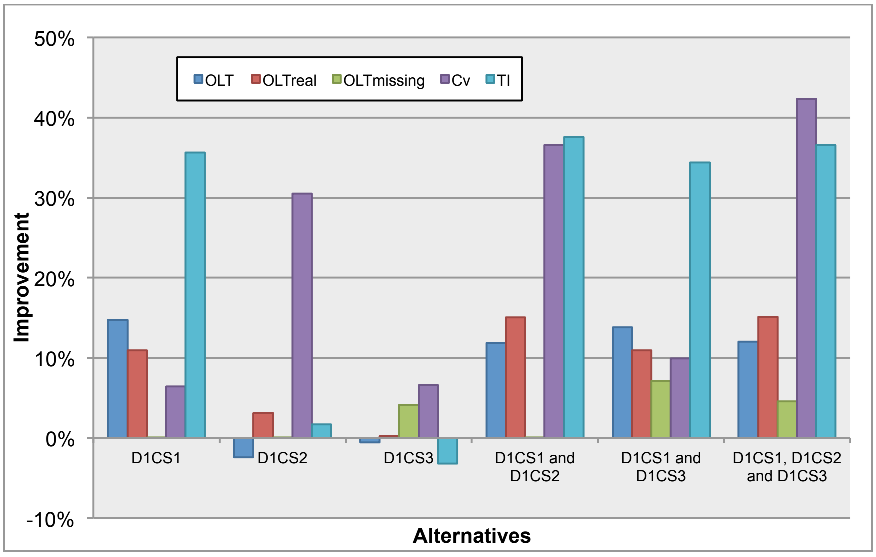


Figure 7.121. Improvement percentage of each alternative towards the "as-is".

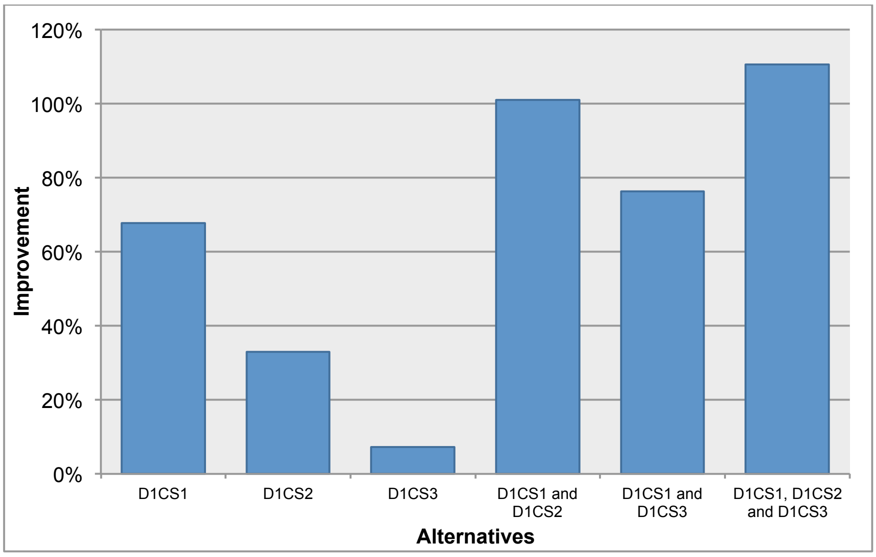


Figure 7.122. Sum of improvement percentages for each alternative.

Comparing all the studied alternatives, it is possible to conclude that the one that has higher impact on the dyad is i1 (the purchasing-selling interface). Improvements on this interface contribute to an improvement of 67,78 per cent. The interface that represents the lowest impact on the dyad is i3. This result is justified for being a conditional and occasional process, which is required when backordered items are identified. The implementation of all the studied improvements would contribute to an improvement of 110,57 per cent towards the "as-is" interoperability conditions. Improvements in order lead-time permit companies to have more degrees of liberty to reorganize another processes that are crucial to business, and are more time consuming like the deliveries and production. Improvements in terms of electronics use - in terms of time of interoperation and conversion time - permits to reduce the time required to perform a business process, resulting in less costs, and improving the workflows by eliminating the NVA processes.

7.7.5. Implications of the combined alternatives in the dyad design

The studied alternatives and scenarios resulted in the following design matrices (see Figure 7.123 and Figure 7.124).

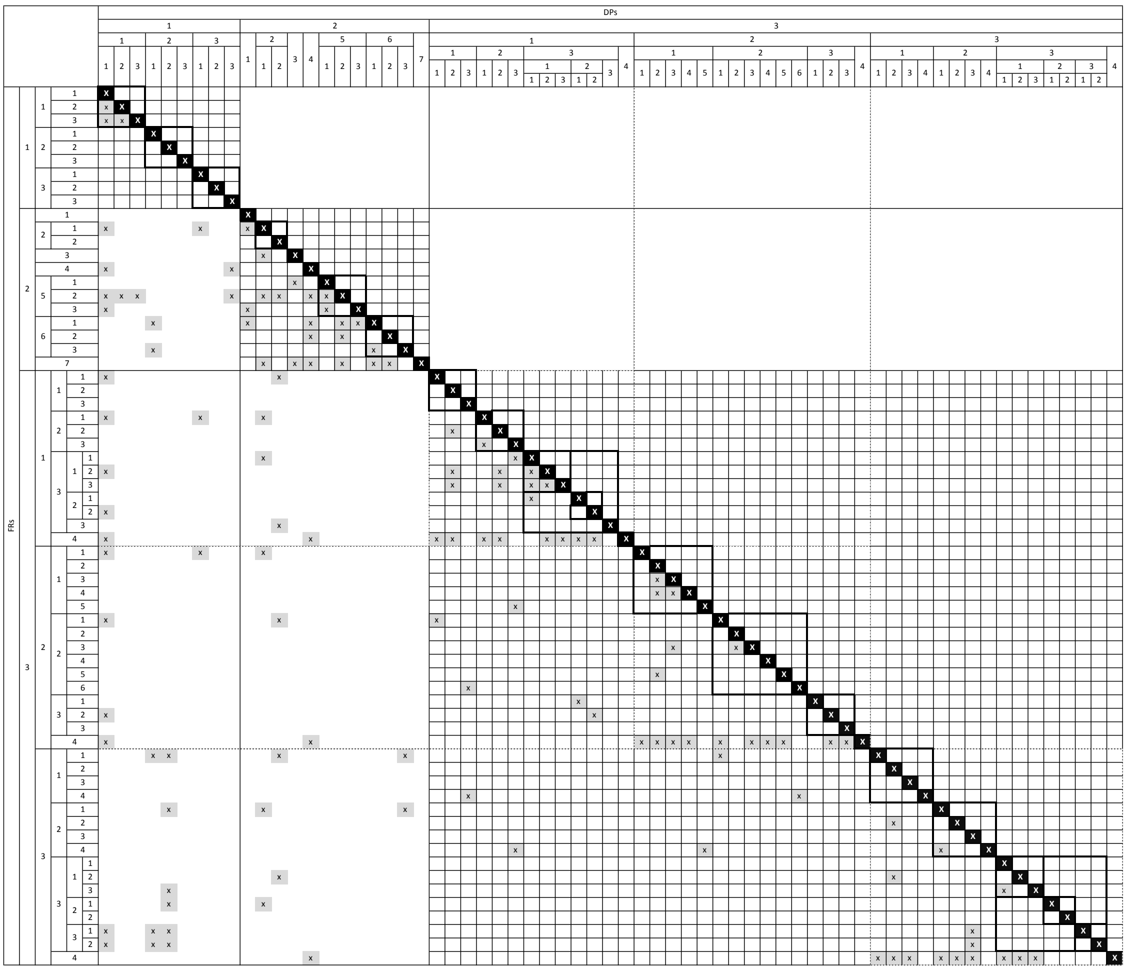


Figure 7.123. Design matrix for the "to-be" design of dyad (mapping between FRs and DPs).

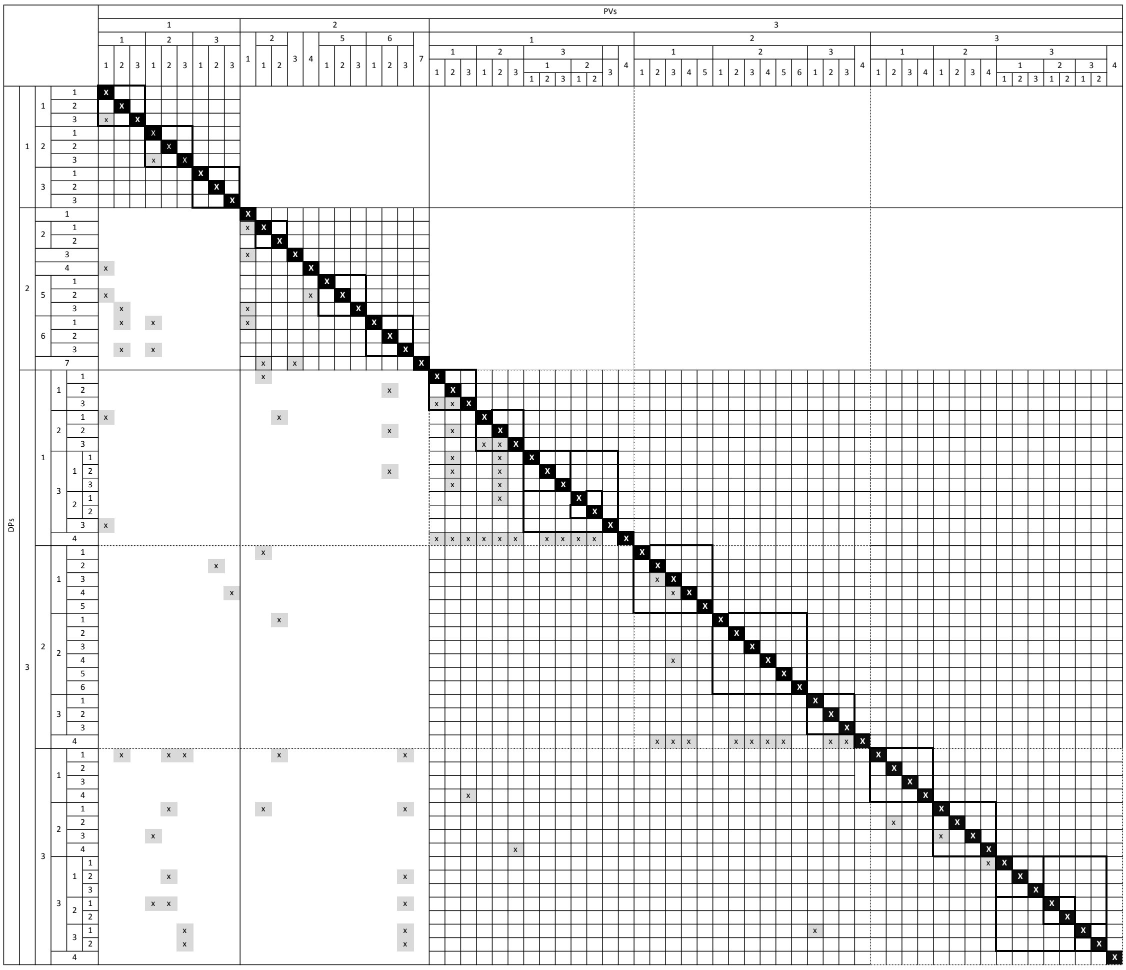


Figure 7.124. Design matrix for the "to-be" design of dyad 1 (mapping between DPs and PVs).

The overall improvements in the dyads business interoperability aspects business strategy (BS), relationship management (RM) and process interoperability (PI) lead to a design that satisfies best the independence axiom.

The methodology consisted in identifying the DPs and PVs that represent an interoperability performance problem, and study different conceptual solutions (presented in DPs) and/or a different set of process variables, that permit to improve the performance and turn the dyad's design close to an independent one.

The elimination of NVA processes by implementing interoperable applications and systems is a crucial point, leading to an improvement of 42,33 comparing with the actual interoperability configurations. This elimination was studied by suggesting new information systems that are compatible. For instance, in the case of the implementation of the EDI in the purchasing-selling interface, most of the manual conversion processes were eliminated, resulting in a reduction of 45 minutes in each order, which was wasted and didn't add any value to the ordering process.

The process re-design through new sequencing and alignment with the organisational structures were two other issues raised in every approached business process. By studying new process arrangement

with DSM was possible to infer about how a procedure should be performed by eliminating redundancies and unneeded interactions. Also, the SS_1's processes were reorganized in order to reduce the tasks performed by one section.
The mapping between the physical and process domains permitted to study, for a specific DPs conditions, what work methods and resource distribution and quantity guarantee optimal results. This aspect of the methodology was relevant because allows one to freeze the existing interoperability conditions, and study another forms to improve interoperability without changing the used information systems. In the case of i1, the improvement of the "as-is" resulted on a 44,82 per cent of the total improvement, just by re-sequence and organise the processes, and study different resource distribution and quantity.
The analysis of business strategy (BS) and relationship management (RM) components was also crucial to map the conditions that have impact on the process definition and execution. Although changes in these two interoperability components can not be tested, some hypothesis were formulated regarding how an interoperable business strategy may be achieved, and what changes in the RM should be implemented to correctly establish the business set up for the studied processes. In the case of the delivery-reception interface (i2), to implement the FS's barcode system on SS_1, a new contract must be agreed to establish the grounds for SS_1's implement procedures to label according to FS's requirements. Also, new responsibility assignment is required to shift the labelling responsibility from the customer to the supplier. Nevertheless, the implications of new responsibility assignment were studied by simulation, being possible to conclude that, although the dyad benefits from this new barcode system, FS is the company that benefits in terms of TI and Cv. SS_1 would suffer an increase of this values in order to obtain an higher interoperability performance for the dyad.

7.8. Result analysis and discussion

With the implementation of the presented cases studies was possible to demonstrate the applicability of the ADADOP method to identify and solve interoperability problems in an automotive buyer-supplier dyad in four different approaches. The first two approaches addressed two different interactions of the purchasing and sourcing operations: the buyer-seller interaction (D1CS1) and the expedition-reception interaction (D1CS2). The third approach focused on an exceptional procedure implemented in both actors to deal with incomplete orders that, in turn, is associated with previous interactions (D1CS3). The last approach dealt with the full scope of the FS-SS_1 operations reflected in the previous cases (D1CS4).
Through the execution of the case studies, the ADADOP method allowed the systematic approach of interoperability conditions, transposing them to physical and process levels. The establishment of an "as-is" design and models allowed testing the dyad using simulation, in an iterative process to study solutions adequate to the firms' interoperability conditions. The accompanying of the "as-is" to "to-be" benchmark with the AD framework permitted to keep track of each interoperability solution has

on other aspects reflected in FRs, DPs, PVs and in the design matrices. This proved useful to study solutions that don't compromise the integrity of the dyad's interactions, and to identify what measures should be implemented to achieve better performance results.

The adequate coding and reduction of data was achieved in the ADADOP method application. The method deals with qualitative interoperability measures (addressed in A stages), descriptive and modelling data (addressed in the D stages) and the inherent business-context, obtained in the firms' data, and from the SCM constructs and the SCOR model. The combination of those in the A+D stages, in the AD framework and in the modelling techniques, allowed narrowing down the information to traduce the BI conditions in the case studies. In turn, the iterations in the optimisation process repeated the same process for each studied scenario. So, the obtained "as-is" conditions, which have physical and practical representation, were confronted with the "to-be" conditions by providing, again, the conceptual, physical and process conditions that can be implemented on the dyad traduced by the interoperability solutions (DPs), PVs and the associated BPMs.

The application of the ADADOP method provided different results in the cases. In the first case (D1CS1), several problems were found in the execution of purchasing and selling activities, regarding process interoperability (PI), data interoperability (DI), software and systems interoperability (SSI), and human resources (HR). Tested solutions involved maintaining the same solutions and interoperability levels (addressed by the A stages from section 6.2.2) or scaling-up interoperability, providing a new interoperability solution. On the first approach, improvements were made without requiring changing the existing systems. Hence, human resource quantity and distribution, and process sequence and organisational alignment were addressed. The improvement in relation to the "as-is" scenario generated a gain in order lead-time (OLT) and in the time of interoperation (TI), reducing those values in 11,75 and 33,07 %. However, improving PVs to existing DPs doesn't provide improvements in situations were additional non-value added (NVA) activities are required. Incompatibility problems between systems and data formats could not be solved by those improvements, although was possible to reduce TI to handle user data processing faster. In opposition, the proposition of WebEDI and EDI to solve the incompatibility problems scaled-up interoperability, which affect mainly the DI and the SSI perspectives. Though, as proposed, improvements alone in interoperability scaling-up require adjusting the processes and the resources (users) involved in the business processes. That was confirmed having found best results after designing and modelling the systems implementation, and studying the adequate process sequence and alignments, and the adequate resources.

In case study 2, was studied the implementation of a new interoperable solution for copper wire rods identification and tracking in the dyad. This issue aimed at solving compatibility between AIDC systems used differently by the firms. The interoperability aspects involved in this scenario were mainly focused on business strategy (BS), relationship management (RM), PI, SSI and objects and hardware interoperability (OHI). Despite an overall gain was obtained in the "to-be" scenario, at the

individual firm level, a performance decrease, in terms of TI and wasted time in conversion (Cv), was noticed on SS_1. The proposed solution of shifting of responsibilities from FS to SS_1 proved to deliver better performance to the dyad as a whole though deteriorated the SS_1's individual performance.
Case study 3 presented an exceptional procedure created to handle incomplete orders. The identified problems concerned PI, DI, SSI and HR. The study of alternatives involved improving the existing conditions by studying new resources distribution and quantity in both firms, and the implementation of a new business process and procedures to handle the incomplete orders, the use of the existing SAP system to handle incomplete orders, and the implementation of an EDI to interface the SAP systems. The overall improvement was achieved by in the second alternative, having eliminated NVA conversion processes and streamlined the process sequence.
The last case study (D1CS4) considered the full scope of the FS-SS_1 dyad's operations involved in purchasing-delivery interactions. It was studied the joint influence of prior improvements and a full-scale improvement. Comparing the isolated improvements with the joint improvements was possible to conclude that making interoperability improvements in the three interaction perspective permits to achieve better performance results. Still, the full-scale approach requires that DPs and PVs be finely tuned to obtain best performances. Nevertheless, some individual cases have more influence in the dyad performance than others. That is the case of the purchase-selling interface (D1CS1) that, individually, produces better improvements and has more impact in the subsequently studied joint improvements. Comparing the four case studies, the utility in performing a multiple case study in the same dyad is recognized to providing insights in the application of the ADADOP method. It allowed to explore a wider range of the business interoperability (BI) perspectives, covering BS, RM, PI, DI, SSI, OHI and HR.

Chapter 8 - Conclusions

After having identified the main findings in research, and studied the propositions through a case study approach, this chapter has the objective of discussing those findings, relate them with the objectives and the research questions, to reflect about the research problem and draw the main conclusions. Then theoretical and managerial implications will be discussed, where the performed research is put in scope with the existing body-of-knowledge and its practical application. Last, recommendations for future research are presented to provide insights for new paths to explore in business interoperability.

Business interoperability (BI) has become an inherent necessity for firms that intended to achieve successful cooperation through electronic-based business. Nevertheless, BI has been seen in literature both as an ability and as a problem that needs to be solved when companies attempt to interact with each other to achieve value and collaborative advantage. This is a problem that affects supply chains (SC), more specifically the buyer-supplier dyad, which was the object in this thesis. In an attempt to study those problems, this thesis aimed at the following objectives:

- To propose a framework for interoperability perspectives and types under the concept of BI;
- To study the influence of BI in buyer-supplier dyads;
- To develop a method to assist problem identification and re-design of the interoperable buyer-supplier dyad.

Considering those objectives, the author aimed at the main value proposition:

"Provide an integrated methodology that systematizes the analysis and re-design of the interoperable buyer-supplier dyads to improve their performance and value-added to end-customer."

With the set objectives and the main value proposition, research was conducted having successfully developed a methodology that fulfils those objectives by aiding in the identification and solving of interoperability problems in the buyer-supplier dyads. The method allows to systematically analyse and re-design the dyad to accomplish higher performance and value-added to the final customer. The accomplishment of this result depended on the definition of the research method and the research questions (RQs). Those ones guided the investigation permitting to accomplish the main findings that, in turn, contributed to the proposals on this thesis. In the next section, the fulfilment of RQs and objectives is discussed, along with the research steps taken.

8.1. Main findings

Based on the set objectives, a main research question was proposed to address the scope of the research problem:

Main RQ:	*“How does the business interoperability problem identification and solving may be systematized in order to re-design buyer-supplier dyads, improving their performance and value?”*

The RQ was subdivided in two areas: the interoperability problem identification and characterization (A), and the integration of design, modelling and performance measurement in buyer-supplier dyads (B).

A. Interoperability problem identification and characterization

In this topic, two RQs were posed during the research:

- RQ A.1: In what perspectives may the buyer-supplier dyad be decomposed to reflect the business interoperability requirements and problems that have impact on their performance?
- RQ A.2: What are the criteria and methods that characterize the influence of BI in buyer-supplier dyad's performance?

To address RQ A.1, literature in BI was reviewed to determine how existing frameworks and models attempt to approach interoperability problems and the means to solve them. In the analysis of those works, it was possible to conclude that existing frameworks and models address interoperability in different perspectives and at different levels of detail, having some overlapping concepts and gaps. To solve this problem was proposed that the BI body-of-knowledge was organised using taxonomy. To accomplish that, it was studied how existing frameworks and contributions in BI attempted to characterize interoperability types and perspectives, and what were the decompositions proposed over time. By relating the identified aspects, was proposed the Business interoperability decomposition framework (see Figure 2.22 in section 2.4). In this framework were suggested two levels of detail in the BI decomposition. In the first level, interoperability is addressed in organisational interoperability (OI), knowledge interoperability (KI) and technical interoperability (TI). The second level decomposed BI further in business strategy (BS), relationship management (RM), cultural interoperability (CI), rules interoperability (RI), human resources (HR), process interoperability (PI), data interoperability (DI), software and services interoperability (SSI) and objects and hardware interoperability (OHI). The purpose of the framework is to provide a systematic view of the business interactions, allowing to detail the business interaction in each of those perspectives. This, in turn, contributed to organize the current BI body-of-knowledge, but also, facilitated the application of the Axiomatic Design Theory (AD) in the design of buyer-supplier dyads, which is addressed in the second part of research.

Moreover, literature in supply chain management (SCM) was revised with regards to buyer-supplier dyads. It was accomplished that, according to the collaborative perspective of supply chains (SCs), the same unifying dimensions as in the BI are advocated in supply chain collaboration (SCC) literature. Hence, was possible to identify the main SCM constructs that support buyer-supplier relationships (see Table 2.1 in section 2.2.2). These constructs help in answering RQ A.1, by setting the perspectives under the SCM scope that establish a common ground between SCM and BI. Those, in turn, can be used to detail further the interoperability perspectives in buyer-supplier dyads, providing a business-context and existing solutions comprehended outside the BI body-of-knowledge (BoK).

Furthermore, this shared perspectives permits to study the same phenomena under the scope of different bodies-of-knowledge (BoKs). That allows, in turn, complementing identified gaps in BI, and expanding both BI and SCM BoKs. As consequence, limitations were found in SCM constructs regarding formal approaches to SC processes, material and information flows and the information technologies (IT) that support the SC activities. In opposition, BI provides a comprehensive vision aiming at the same objectives, and addressing cooperation in areas introduced in the Business interoperability framework.

RQ A.2 aimed at exploring further the subject of identifying and characterizing interoperability. To answer the question, BI literature was explored to identify how the frameworks and models attempt to measure interoperability, and factors and criteria allow to achieve that characterization. It was accomplished that those methods focus on assessing interoperability descriptively, qualitatively, quantitatively, and using performance measurements. In addition, were identified criteria that act on the scope of the interoperability types identified previously on the BI decomposition framework (see Table 2.3 in section 2.6). Those criteria provide an additional decomposition of interoperability types, and can be used as means to characterize and measure interoperability and the impact interoperability has on business relationships and, specifically, in the case of the buyer-supplier.

In addition to the identified criteria, levels and maturity levels of interoperability were also identified (see Table 2.4 in section 2.6). They provide an integrated perspective of different aspects of interoperability.

Another aspect identified in interoperability literature is that the improvement in one perspective of interoperability may require the enhancement of another. According to IDEAS (2003), to achieve BI is necessary to achieve interoperability in all layers of interoperability. This notion is opposite to the one defended by (Legner & Wende, 2006), whereas optimal interoperability may be achieved by determining the adequate conditions for the business relationship. This thesis supports the second hypothesis, where the interdependency of interoperability perspectives is addressed by the BI decomposition framework and by the AD, and through the measurement of performance to determine optimal conditions for the buyer-supplier dyad.

With the previous findings under the scope of RQ A.1 and RQ A.2, a theoretical framework was proposed to support the establishment of interoperable buyer-supplier dyads (see Figure 6.1 in section 6.1). Strategically, the dyad aims at collaborative advantage, enforcing win-win relationships, mutual benefits and competitive synergy, with the purpose of becoming optimally interoperable, being interoperability reflected in improved performance and increased value to customer. To achieve this objective, the dyad depends on the BI perspective and SCM constructs that act as the main drivers for interaction.

B. The integration of design, modelling and performance measurement

The second part of the Main RQ was addressed by the RQ:

- RQ B: How to systemize the design of buyer-supplier dyad's in the improvement of their performance and value?

The higher aim in this question is to provide an integrated managerial tool that aids in analysing interoperability and in the re-design of buyer-supplier dyads, in order to achieve performance and increased value. Such integrated perspective was advocated in order to handle systematically the problem identification, impact measurement and the implementation of improvements that permit the dyad to achieve higher performance and value added. To achieve this objective one has to cope with the multidimensional and complex nature of BI, address different levels of detail without losing the dyad basic functionality, and to deal with the inherent context of the interaction. In that sense, three main areas were devised: design, modelling and performance measurement. With those areas, the objective was to conceal the different aims of those methods. In that sense, the RQs were set:

- RQ B.1: How to integrate design and modelling in the improvement of the buyer-supplier dyad's performance and value?
- RQ B.2: What methods allow representing the interoperability problems reflected in dyad's processes that affect performance and decrease value?
- RQ B.3: How to measure the impact of business interoperability in buyer-supplier dyad's performance?

In RQ B.1 were reviewed the main articles in interoperability that propose the design of interoperable relationships and systems, having accomplished that despite the found contributions, none of them provide a systematic and comprehensive approach the design addressing the full scope of BI. Hence, based on the challenges to design an interoperable system, the AD was proposed to address such challenges, permitting an integrated and systematic approach to design, permitting dealing with complexity and maintaining the basic systems functionality.

The need for modelling was addressed both in RQ B.1 and RQ B.2. The systematic design of an interoperable buyer-supplier dyad or interoperable system needs that the requirements be converted into the physical implications. Although AD provides the capability of mapping from conceptual to physical and process levels, in interoperability and computer sciences literature exists several modelling techniques that allow the representation of processes and operations in functional, decisional, information and business process points of view. With that in mind, to answer both RQ B.1 and RQ B.2 were reviewed the modelling techniques applied in the interoperability literature that deal with interoperability problems modelling. Based on those, the use of business process modelling notation (BPMN) and design structure matrix (DSM) were selected due to capturing different views of processes and business processes. The graphical notation of BPMN permits to understand the performance collaborations and business transactions between organizations. In turn, DSM captures the structure of interactions, interdependencies and interfaces.

Interoperability modelling literature addressing SCM suggest the use of the SCOR reference framework to address SC processes and operations. This one provides a standard for SC operations, and provides the main process patterns, practices, performance measures and training skills, allowing to enrich the addressed business-context, and also provided the main patterns for SC operations and processes.

In the last RQ, interoperability impact measuring was researched. Interoperability literature was revised to explore what metrics and methods are used to determine the impact of interoperability. From the several performance measurement methods, this thesis follows an approach similar to the one advocate by authors who propose performance measurement systems (PMS). It is defended that the interoperability monitoring should be done during the system testing operation. However, despite many contributions were found, there exist some limitations. The provided interoperability metrics focus on technical aspects, such as DI, SSI and OHI, rather than addressing interoperability at organisational and knowledge levels, which compose BI.

Acting on the limitations of interoperability metrics, supply chain performance measurement (SCPM) literature was reviewed. In this one, was explored the literature that aimed at the same unifying dimensions advocated by the SCC, buyer-supplier dyads and the BI perspectives. Based on those dimensions, contributions were found providing best practices for SCPM and performance metrics. SCM performance metrics were considered fit for the scope of the research problem, addressing performance in strategic, tactical and operational levels, and in the SCOR operations (see Table 5.4 in section 5.2.2).

The contributions of the ADADOP method for the RQs and research objectives

After having determined the relevant literature that permit to address the RQs, based on those findings the ADADOP method was proposed to solve a major gap in literature: the need for an integrated framework that allows to systematically identify, analyse and solve interoperability problems. On the findings from RQ A.1 and RQ A.2, a theoretical framework was proposed addressing the scope of the research problem (see Figure 6.1 in section 6.1). This framework represents the aim of this thesis, in relating the strategic fundament for collaborative advantage, the BI and SCM perspectives that buyer-supplier dyads' depended to achieve optimal interoperability. With this framework and previous findings in consideration, the ADADOP method was proposed (see Figure 6.3 in section 6.2). The method aims at solving the main RQ and accomplishing the value proposition, by permitting to systematically decompose the buyer-supplier dyad in to elements that represent the dyad's interaction in the BI perspectives and SCM constructs. That is achieved by the integration of the proposed A+D stages (see section 6.2.1), the proposed qualification of interoperability problems (A stages) (see section 6.2.2), the proposed AD framework (see section 6.2.3) and the modelling approach (D stages) (see section 6.2.4). RQ B.1 and RQ B.2 are herein answered by those problems, which permit to obtain a representation of the buyer-supplier dyad "as-is" conditions, where the main interoperability problems are identified. Also, they provide the means to integrate the design and modelling perspectives required for address the interoperable buyer-supplier dyads. While the AD framework focuses on setting the needs and requirements of the dyad, mapping them to physical and process levels, the modelling approach converts the physical and process implications into business process models (BPMs), design structure matrices (DSM) and simulation models.

Further, based on the representation of interoperability problems, the ADADOP provides an optimisation procedure that aimed at answering RQ B.3. The procedure aims at measuring the impact of interoperability in the buyer-supplier dyads, by proposing the interoperability performance measurement (IPM) framework (see Figure 6.11 in section 6.2.5.1), which combines the SCM metrics with interoperability metrics, covering the SCOR operations, and economic, internal and business relationships perspectives. Based on the IPM framework, performance metrics were proposed to support the optimisation procedure (see Table 6.23 in section 6.2.5.1). Those are based on existing SCM and interoperability metrics. In turn, interoperability metrics were adapted to fit the SCOR operations; the economic, internal and business relationships perspectives; and strategic, tactical and operational levels of measurement. Enclosing the optimisation procedure, an iteration procedure was proposed were, based on interoperability problem identification, new scenarios are generated (see section 6.2.5.2) and tested using the simulation models and the performance metrics. Studying those scenarios, and selecting the alternative that provides best performance for the buyer-supplier dyad and more value added, consequently leads to the achievement of optimal interoperability. This way, the development of the ADADOP method finally contributed to the achievement of RQ B, the main RQ and the higher proposition of this thesis.

Case studies findings

The selected research design strategy to test the empirical propositions was the case study approach. Here, the propositions and the proposed ADADOP method were tested in several application scenarios and case studies. The application scenarios contributed to a preliminary test of the method, validated with AD experts. Then, after having made the necessary adjustments to the method, four case studies were conducted in an automotive buyer-supplier dyad.

By implementing the ADADOP method through case studies, was possible to confirm its applicability in the determination of interoperability problems and systematic solving. The structuring of BI perspectives in the A+D stages permitted an easy to follow procedure in the determination of the dyad's BI conditions. There was a positive feedback in the early presentation and discussion of the ADADOP method with FS and suppliers. The interviewees were able to comprehend the BI perspectives transposed for the business-context they are inserted in, being possible to discuss easily some of the aspects. Also, the structuring of the method in the A+D stages permitted to systematically collect information with regards to previous perspectives.

The A stages permitted to identify quickly what kind of approach the companies perform to a specific interoperability requirement. The proposed interoperability levels were adapted in to the form of questionnaires, though, due to easiness in understanding each of the BI perspectives, data collected from interviews quickly fit into the proposed categories.

It was also possible to demonstrate and validate the buyer-supplier dyad decomposition in the BI perspectives using the A+D stages, AD framework and business process models, being admissible that those tools provide an adequate solution to provide the systematic detail on the dyad. Through the process of collecting data to design the "as-is" scenario, this data was constantly reviewed with firms' interviewees. The structure of the model provided an adequate framework to study the different aspects that rule firms' relationship. This was confirmed by the studied interoperable solutions, which were made consistently with the firms' and dyad structures. Subsequent, the suggested interoperable solutions were discussed with the interviewees, and the applicability of some of those improvements was confirmed.

The implementation of AD in the ADADOP method permitted to mimic adequately the business-context and the dyad's conditions. The systematic collection of data, the subsequent identification of problems and the study of interoperability solutions using simulation, conducted to improvements that fit the firms' structures. 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. Moreover, the application of the optimisation procedure permitted to test each scenario, and the re-design using the AD framework led to the required changes at the different BI perspectives. In the D1CS2, for instance, the adoption of the FS's barcode system in SS_1 would require responsibility shifting, changes in the firms' internal procedures, the implementation of new systems and appropriate employee skills to handle new procedures. Those perspectives are understood in different perspectives of BI. Namely, RM, PI, DI, SSI, OHI and HR. By performing the iterations in the optimisation procedure, the new studies solutions were validated formally in the AD framework, by studying the dependencies among FRs, DPs and PVs. Furthermore, the testing of the resulting processes using simulation permits to assess the proposed solutions to commit the interoperability solutions and improvements with the impact it has on the dyad. The final product (i.e. the "to-be" scenario) provides the necessary information in terms of DPs and PVs to draw an implementation procedure, where the relationships among BI perspectives are accounted.

With regards to the optimisation procedure, two approaches were followed: the improvement of existing interoperability conditions and the proposal on new interoperability solutions. The first approach permitted to improve the "as-is" conditions, without changing substantially the firm's conditions (i.e. the DPs). This kind of approach complies with solutions that require less effort in implementation, less investment and better resource use. In contrast, the second approach may require the scale-up in interoperability, if there are problems that require the implementation of new systems and more resources (technical and human). During the implementation of the case studies, several solutions were tested and analysed, being selected the ones that improve interoperability that comply with the first axiom, eliminate NVA activities, being traduced in better performance and value added to the final customer.

The selection of the best option in terms of interoperability allows obtaining higher interoperability and always adapting to the firms conditions. From the proposed alternatives, firms can select the ones that are more adequate (i.e. if require more or less effort, investment, resources, etc.). Nevertheless, for each selected scenario, by imposing the DP and PV changes in the AD framework, the re-design process permits to identify what are the main changes firms need to implement for each selected scenario.

8.2. Theoretical implications

The developed research of this thesis presents contributions to interoperability and BI BoK and to SCM literature. The proposed ADADOP method distinguishes from existing interoperability contributions by providing an integrated method to analyse and solve BI interoperability problems, providing the frameworks and tools that support the initial problem characterization and subsequent design of improvements.

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. In this research, a BI decomposition framework (see Figure 2.22 in 2.4) was proposed to reconcile the main interoperability perspectives that fit in BI. That allows a comprehensive view of interoperability permitting to relate aspects to existing literature, and also to address business interactions in different perspectives.

The proposed BI decomposition framework is also of a scalable nature, permitting to associate another relevant factors to address each interoperability type. That was particularly useful to associate the criteria that permit to address each type in additional levels of detail, and to integrate the business-context where the interoperability occurs.

Another contribution was the integration of the interoperability perspectives with the SCM constructs that rule buyer-supplier dyads. By finding similarities in these areas, both BoKs were expanded. In the BI BoK, the integration of existing SCM constructs allows to provide the context for the interoperability conditions and problems, and also to associate to existing solutions in practice on SC. In the other hand, the knowledge developed in this area provided an expansion in the SCM constructs, by providing perspectives referring to processes, data flows, information system and resources that, acting in the same strategic motivations, can be added to existing collaborative SCM practices.

The ADADOP method permitted to contribute also to the integration in terms of analysis and design, with the ability of designing, modelling and measuring the impact of interoperability. That distinguishes from existing literature, which attempt to perform those tasks in an isolated manner, or combine only two of those perspectives. The integrated view of BI defended in this thesis, allows one to characterize interoperability problems in buyer-supplier dyads, identify problems and devise the solutions having in consideration the impact those have in the dyad. That contributes to see BI not only as an ability or a problem, but also as a requirement or utility that, well used, can contribute to achieve collaborative advantage, competitive synergies, win-win relationships with mutual benefits, which are reflected in optimal interoperability through higher performance and value added to final customer.

The proposed AD framework allowed to relate BI perspectives according to dyad's specific conditions. This approach can be adapted to study the subject under other perspectives. The feature of maintaining systems basic functionality permits that other issues may be addressed in depth, while others not. In that way, the framework can accommodate issues addressed in different perspectives, but keeping the dependencies to others.

The inclusion of interoperability performance measurement in the ADADOP method provided metrics that contributed to measure the impact of interoperability on buyer-supplier dyads that act on SCs. The contribution herein was to provide the adequate metrics for SCOR operations that can reflect the impact of interoperability. In Table 6.23 metrics are suggested to support the ADADOP method, but that could also be fit to address buyer-supplier relationships in different objectives.

8.3. Managerial implications

With regards to management contributions, the propositions in this thesis provide a managerial tool that helps managers in the decision-making during business set-up and in the improvement of interoperability conditions. The ADADOP method systematically analyses the business relationship design, and the implications of other aspects that drive or constrain the interactions.

The method also 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, using the A+D stages and the AD framework. Those together 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 and PVs, subsequently affected conditions would require changes in order to keep the systems functionality, without problems.

Further, the method provides managers with a procedure to optimise interoperability conditions. By integrating the BPM and simulation with the AD framework, solutions can be tested using simulation to determine which scenario delivers better performance results. That, in turn, is helpful in order to

exclude several alternatives that can be detrimental for the individual company and for the dyad as a whole. It also allows to test those solutions without interfering with the real systems.
The optimisation procedure can also be combined with another reasoning factors that may provide different insights in the selection of the best interoperable solution. The method provides two solutions that act on the current "as-is" system to improve it, or to implement new interoperable solutions. It is possible to reconcile the method with a cost-benefit analysis or the introduction of constrains, such as technology limitations, resources or investment. That factors can narrow the studied hypothesis, concentrating on the alternatives that, despite not delivering the best possible results, provide the optimal results for the existing firms' conditions complying with the constrains.

8.4. Recommendations for future research

Based on the existing findings and on the limitations of my presented research, it is suggested that future research should expand the ADADOP method to explore other areas that fit the interaction of dyads. The current method makes an approach with processes as the core for business interaction. Other alternatives are admissible for the method. For instance, the method can be explored to measure the impact of BI in business strategy. The integration of causal performance measurement models as balanced scorecard can be integrated to study strategic performance in parallel with the provided perspectives. Another option could be to give detail to technical interoperability aspects. A more detailed approach can detail further the interoperability problems reflected through the systems interaction.
Other path to explore is the development of performance measurement systems (PMS) to support the proposed method, and to measure interoperability performance during the execution of procedures. That would permit to assess interoperability in real-time, and provide inputs for decision-making.
From the outputs of the ADADOP methods, upon the determination of the "to-be" scenario, several interoperability solutions and PVs are provided. This output can be transformed into an implementation procedure by using project management tools, to structure the implementation project that allows achieving the interoperable buyer-supplier dyad, and related systems. The migrating of databases, purchasing of another software, training of employees, studying new procedures, etc. are several possibilities that, from the results of the AD framework, can be converted.
Expanding further the applicability of the ADADOP, may be possible in the future to create knowledge-base with previous studied scenarios that can be implemented in similar dyads' and firms' conditions. For instance, storing previous designs, which are associated with a specific set of interoperability conditions and models, those solutions can be used to address similar patterns.
A cost-benefit analysis can be combined with ADADOP to study the feasibility of the proposed improvements.

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Annexes

Annex A Application scenario 1

LARG Interoperable Supply Chains: from Cooperation Analysis to Design

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Abstract. Innovative strategies such as Lean, Agile, Resilient and Green emerged as a response to global competition situation, requiring high levels of cooperation and of great complexity. However, the strategic alignment of operations with partners in supply chains is affected by lack of interoperability. The present work provides two decision-models to enhance SC competitiveness and performance by assessing interoperable SCM Practices applied in automotive industry and a methodology to design cooperation using the systematic approach of Axiomatic Design.

Keywords. Business Interoperability, SCM, AHP, Fuzzy Sets, Axiomatic Design.

Introduction

Competition between supply chains (SC) is a challenge of great importance in the global market situation. Supply Chain Management (SCM) has become a tactical asset providing strategies such as Lean, Agile, Resilient, and Green (LARG), which, combined, constitute an important paradigm and powerful tool to strive for more competitive and efficient management of SC. The greatest competitiveness is achieved by being able to respond to the demands of customers and unexpected disturbances with agility and effectiveness, and to join this to environmental responsibility and the elimination of processes that add no value. To do this, companies must implement a set of LARG SCM practices in order to manage efficiently and effectively the SC on the one hand, and measure their influence on the SC performance on the other. However, the difficulty of aligning operations with partners is affected by lack of interoperability. Lack of interoperability is reflected from top strategy to the transactional IT interface of business. Therefore, companies must strive to align interoperability issues, such as Business Strategy, Collaborative Business Processes, External Relationships, Employees and Work Culture, Business Semantics and Information Systems.

To successful overcome this difficulties, the present work provides two methods: the first to analyse and identify where interoperability is currently lacking (making use of a combination of MCDM models Fuzzy Sets and AHP); and an Axiomatic Design solution to systematize the identified issues with proper design parameters to cooperation.

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This paper is structured as follows: section one gives an overview of the literature regarding LARG paradigms and the trade-offs among them. Section two provides a brief review of business interoperability, and the main frameworks that contribute to the measurement and analysis of interoperability in the dyadic perspective. Section 3 presents two models to assist managers in decision-making and one model to design the cooperation. The applicability of the proposed models through two different case studies in a real manufacturing company is presented in Section 4. Limitations of the study and paths for future work are given in the last section.

1. LARG Supply Chain Management: trade-offs and contribution to Business Interoperability

Supply Chain Management (SCM) is based on the incorporation of all activities that add value to customers, since product design to delivery, integrating suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide cost while satisfying service level requirements [1]. Top SCM strategies like Lean, Agile, Resilient and Green, struggle to maximize competitivity and performance of SC in different perspectives. Lean argues that products should be designed to minimize the waste increasing the added value for the customer [2]. In the other hand, Agile argues that the production should be more responsive to customer. Resilience and Green, instead of focusing directly on the customer and production issues, are more focused on the environment or external agents. Resilience refers to the impact of external agents in the SC and Green concerns with the effects of SC's activity on environment [3]. However, in a SC contradictions occur between the disparate management approaches. For instance, Resilience is not always desirable if an organization strategy is to be lean, where for reducing inventory cost, they must have a low inventory level, which makes it less resilient [4].

To accomplish an interoperable supply chain, it is necessary to develop a deep understanding of the trade-offs between the Lean, Agile, Resilient and Green paradigms, exploring and researching their contribute for the sustainable competitiveness of the overall production systems in the supply chain, to help companies and supply chains to become more efficient, streamlined, and sustainable. Previous works have explored the influence of Lean, Agile, Resilient and Green on the performance of a SC, exploring contradictions and synergies [4–6]. The contribution of these papers in the present work focuses on providing a set of SCM's practices where it is likely that there are interoperability issues.

Research contributions from [5] provide a set of performance measures classified in: operational, economic, and environmental. Operational performance focuses on measuring quality, customer service, delivery time, and inventory levels; Economic performance focuses on costs, efficiency, environmental revenues, and environmental costs; and Environmental performance focuses on green image, business wastage, and emissions.

SC competitiveness is seen as an extent of business strategy, whereas the objective is to create sustainable competitive advantages and to position the firm opposite the competition [7]. In the research developed in [8] and [9], various dimensions of SC competiveness were identified, namely: competitive pricing, value-to-customer quality, dependable delivery, production innovation, customer service, and time-to-market.

2. Interoperability in Supply Chains

Business Interoperability has been introduced by [8], having defined it as "the organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business with the objective to create value". Far from the technical perspective initially defined by IEEE [9], this concept has evolved from syntactic and semantic perspectives, to a more pragmatic subject, concerning not only interactions with information system systems, but also concerning the organizational point of view.

2.1. Measurement of Interoperability

The measurement of interoperability is part of the identification and analysis of interoperability problems stressed by Legner & Lebreton (2007) as a goal that each company should strive for. Interoperability and Business interoperability frameworks outline the steps of analysis and evaluation from the areas of information technology to the organizational landscape of B2B relationships. Initiatives like ATHENA [11], [12], European Interoperability Framework (EIF) [13], ECOLEAD [14], Levels of Information Systems Interoperability (LISI) [15], Levels of Conceptual Interoperability Framework (LCIF) [16] and IDEAS traced the path to achieve "optimal interoperability" [12] in electronic systems and business. The state-of-the-art in business interoperability measurement is introduced by [17], [18] where business Interoperability Parameters (BIP) were defined suitable for multipurpose assessments in B2B perspectives. This set of parameters allows one to objectively assess interactions between companies at four levels of interoperability: business strategy, B2B relationships, organizational sharing, and information sharing, suitable to SC's relationships between actors.

2.2. Interoperable SCM Practices

SC performance is improved by implementation of a set of practices in the SC's entities and measures the impacts of those practices that can occur at the different entities. However, the activities between actors in supply chains are affected by interoperability. The coordination of strategic goals, operational activities, collaboration scenarios, and homogeneous exchange of information are the key objectives to achieve the interoperable LARG supply chain. Interoperable LARG SCM practices are considered to have four dimensions: supplier relationships, customer relationships, information sharing, and logistics integration. These dimensions encompass the upstream (supplier relationships) and downstream (customer relationships) perspectives of the supply chain, and the flow of information (information sharing) and material (supply chain integration) between actors [19]. This sub-constructs permitted to identify interoperable practices in [4–6]. The list of practices is presented in work developed by [19].

3. Methodology

3.1. Problem definition and scope

The ultimate SCM results in an effective and efficient integration of information, material, and seamless transactional flows across the supply chain, as an effective competitive asset. This is therefore reflected in overall SC competitiveness, which indirectly affects the individual organization performance and, consequently, the performance of the whole supply chain. The present work follows the conceptual framework proposed in Figure 1.

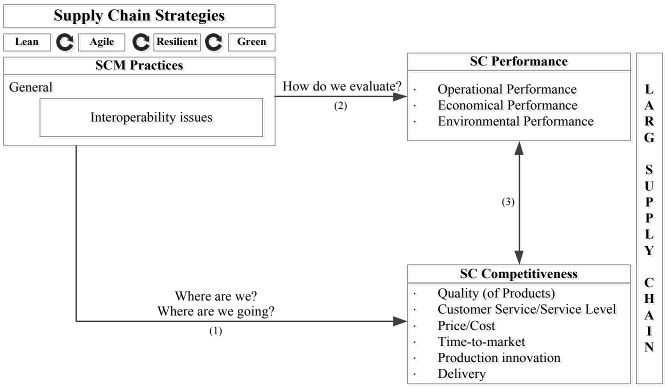

Figure 1. Conceptual framework (adapted from [19], [20]).

Supply Chain Competitiveness (featured in branch (1) of Figure 1) has various goals, which mark the SC position in the overall market vis-à-vis competitors' supply chains. For the purpose of the current work, the focus of competitiveness is the customer: quality, customer service/service level, price/cost, and delivery. Thus, it is considered that the management of supply chains is achieved by means of SCM practices that are defined as a set of activities undertaken by organizations to promote effective management of their supply chains. The practices of SCM are proposed to be a multi-dimensional concept, including the downstream and upstream sides of the supply chain. The framework proposes that SCM practices will have an impact on overall supply chain competitiveness, which influences directly and indirectly the supply chain performance.

3.2. Methodology to assess interoperability

The methodology proposed to assess interoperability comprises the steps shown in Figure 2.

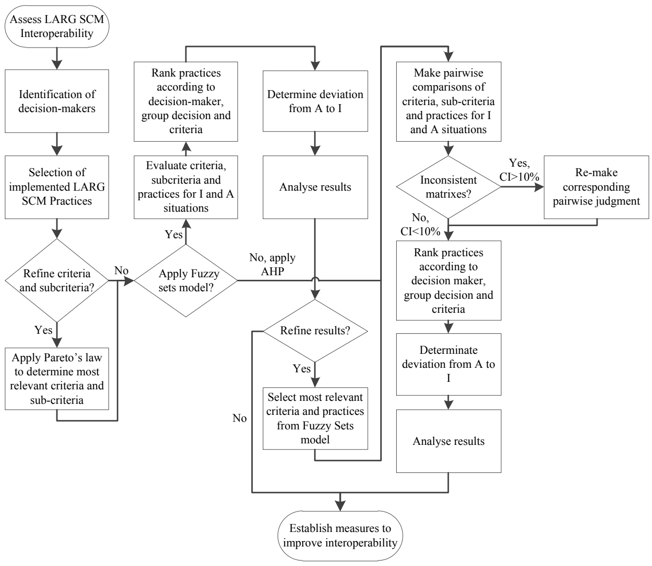

Figure 2. LARG SCM Interoperability assessment methodology application diagram (adapted from Espadinha-Cruz (2012)).

The first step is to identify the activities in the SC subject to interoperability – namely the interoperable SCM practices that fit the following sub-constructs: supplier relationships, customer relationships, information sharing and logistics integration [19]. Hence, in the LARG context, were identified 51 practices in the works from [4–6], being classified as interoperable LARG SCM practices.

Next, the identification of decision makers focuses on the SCM professionals belonging to the first tier of SC. In turn, these must be queried first in order to determine the degree of implementation of interoperable practices in the SCM and, using Pareto's law, most important practices should be addressed in interoperability assessment, from not implemented to fully implemented and relevant to companies objectives.

The next stage is to apply the assessment model (see Figure 3) that aligns SCM practices with the competitiveness objectives driven by interoperability criteria. This model is applied in two instances. Fuzzy Sets model [19], [20], which permits to evaluate practices interoperability in absolute scale and AHP model [19], [21], which ranks practices interoperability making pairwise judgments considering BIPs. For both models where considered two scenarios: Ideal scenario (I), which considers the desired level of interoperability; and Actual scenario (A), which evaluates the current situation of interoperability. The reason for presenting two alternatives for the assessment model is the question of quickness versus complexity in the application of models to practical situations. In one hand, fuzzy sets model is simpler and quicker to apply, because it depends on absolute scale evaluation resulting in less inputs than AHP which, in other hand, depends on comparison of terms, which can be more accurate, but harder to apply. The sequence of the assessment method refers to the quickness to determine, first, in which practices interoperability is lacking more and, applying the second model, the relative scale of AHP permits to enhance detail when evaluating the less interoperable practices.

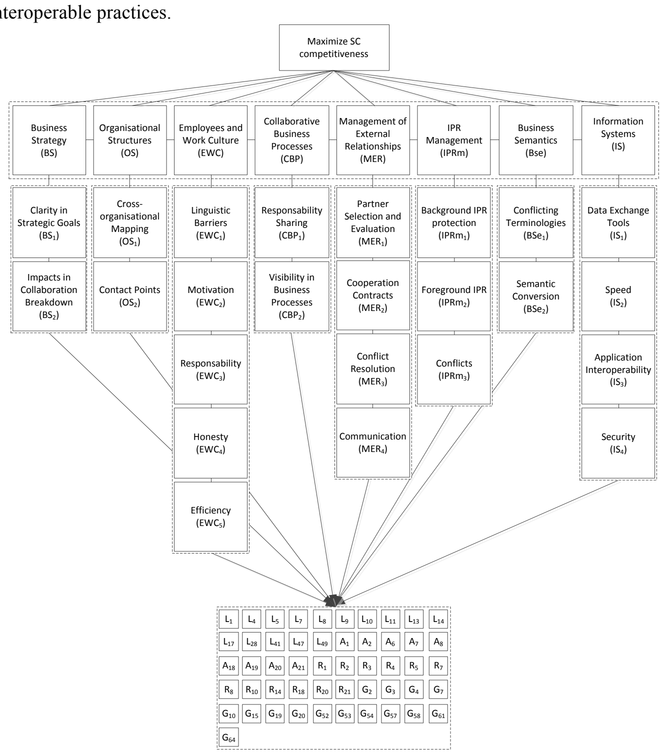

Figure 3. LARG SCM Practices interoperability evaluation model [19].

3.3. Designing cooperation using Axiomatic Theory

After identifying what are the main issues whereas interoperability is lacking when implementing SCM practices, it is applied the Axiomatic Design Theory (AD) [22] to systematically detail how to achieve a fully interoperable solution for the cooperation in SC.

The design of the SC cooperation using AD begins in the customer domain with the settlement of the customer needs (CNs). Mapping between the customer and the conceptual domains is used to find out the functional requirements (FRs) of the cooperation, from the strategic perspectives to the IT that supports the cooperation. Once this is done, another mapping allows for the translation of the FRs into design parameters (DPs), which are the set of properties that describe the design object in the physical domain. Lastly, mapping from the physical domain to the process domain leads to the process variables (PVs), which outline how the cooperation is established [22], [23].

4. Case Study

The following case study, with two application areas, was developed in an automobile manufacturer that currently employs 3,603 people, with a production of 133,100 cars in 2011, 98,9% of which were for export, representing 1% of the Portuguese Gross National Product (GNP). In terms of SC, the company has 671 suppliers, 660 of which are European, following the geographical distribution: Portugal – 12; rest of Europe – 581; rest of the world – 78.

4.1. LARG Practices Interoperability Assessment

The interoperability assessment in the focal firm was executed according to the methodology in Figure 2. The first model applied was Fuzzy Sets, in order to evaluate the overall scenario of interoperability. Representing both I and A situations graphically (see Figure 4), one sees the gap between these two states in most of the practices. For instance, the implementation of P_2 practice caresses interoperability. According to the automotive SC supervisor queried, implementing reverse logistics (P_2) requires a very high level of interoperability, calling for a well-defined strategy that seeks to define cooperation contracts and business models that prepare for the implementation of P_2.

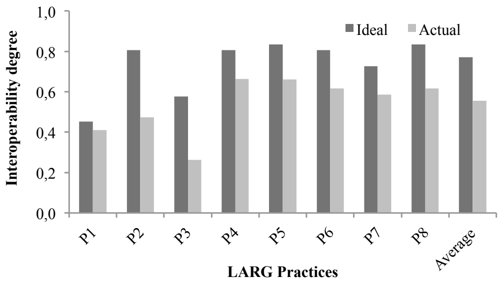

Figure 4. Comparison between ideal and actual levels of interoperability in the supply chain [19], [20].

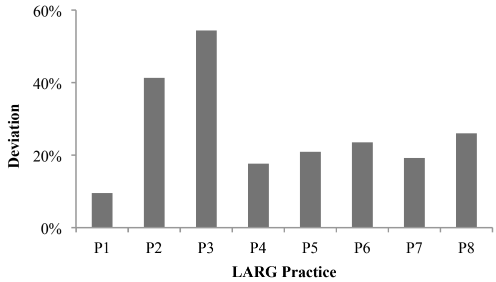

Figure 5. Distance to ideal interoperability for each SCM practice [19], [20].

To enhance definition of the interoperability criteria that rule implementation of P_2, it is possible to represent the results for this practice graphically, as in Figure 6.

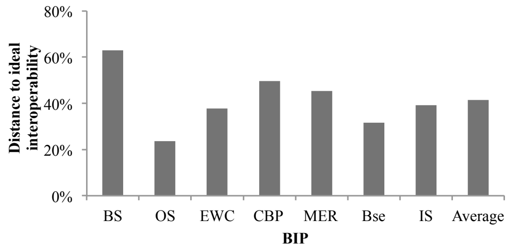

Figure 6. Distance to ideal interoperability for each BIP when applying reverse logistics (P_2).

The current data indicate in detail what kind of interoperability problems exist when implementing reverse logistics. Under the existing conditions, the company and its suppliers are provided with sufficient conditions to apply reverse logistics, when we refer to organizational structures (OS). In this matter, the distance to ideal interoperability is 24 per cent, indicating a certain proximity to optimal conditions. It means that in terms of cross-organizational role mapping and contact points between companies, the actual supply chain has the adequate conditions to perform reverse logistics. However, the lack of definition of a clear business strategy, common to SC's actors, leads to a non-definition of collaborative business processes (CBP) that would permit the implementation of P_2. As a consequence, other business (MER and EWC), knowledge (BSe), and technical (IS) parameters are neglected. For all of the BIPs, it is desirable that the interoperability level to be from high to very high but to the contrary, there is a major gap in interoperability, classifying it as low and average interoperable.

The next stage of evaluation is to apply the AHP model in order to enhance definition in the analysis of interoperability [19]. Graphically, the A perspective is presented in Figure 7.

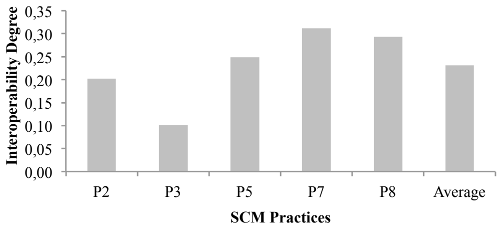

Figure 7. Interoperability degree of each practice considering A.

Considering the actual performance of P_2 implementation (see Figure 8), strategically, it is required an elevated degree of interoperability by clarifying the importance of reuse, and re-work and recycle materials to the objectives of SC. Internally, this practice requires and presents a high level of interoperability in the OS and EWC. The interviewee argued that company has the adequate OS and employee training, and no difficulty in locating the person responsible from each organization to deal with this subject. However, the difficulty is in the mechanism that governs the reverse flow of material, which is revealed in the low interoperability in collaborative sectors CBP and MER. Due to non-existent business processes prescribing how material is returned to suppliers (from 1^{st} to n^{th} tiers), no meaningful interactions occur leading to the accumulation of pallets in the focal firm.

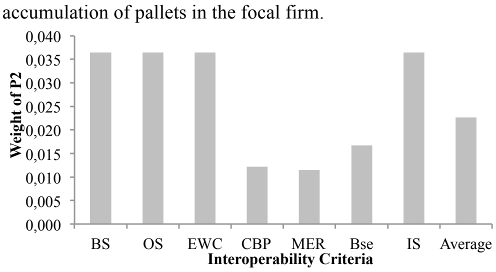

Figure 8. Weights of P_2 of each interoperability criterion.

4.2. Reverse Logistics (P_2) cooperation design with Axiomatic Theory

To work on a solution to the analysed practice P_2, the Reverse logistics cooperation establishment between the considered focal firm and a first tier supplier was designed systematically using AD. As a result, were obtained the Functional Requirements (FRs) and Design Parameters (DPs) presented in Table 1.

Table 1. Functional requirements and corresponding Design parameters to establish interoperable reverse logistics cooperation.

CN: Design a self-supported RL management between focal firm and 1st tier supplier	
FR_0: Ensure high levels of interoperability in the implementation of RL.	DP_0: Effective and efficient RL partnership establishment.
FR_1: Establish the cooperation objectives to implement RL with the selected supplier.	DP_1: Clarity on the objectives to implement RL, conflicts (of interests) and liabilities.
FR_2: Establish seamless business processes to ease reverse material flows.	DP_2: Business Process design, planning and coordination that fits the operational requirements of RL.
$F_{2.1}$: Establish clear RL collaborative business processes.	$DP_{2.1}$: Reconcile RL activities.
$F_{2.2}$: Define and ensure a correct responsibility assignment for RL implementation.	$DP_{2.2}$: Ease identification (and avoid gaps) of the actors responsible for each activity.
$F_{2.3}$: Coordinate RL processes between partners.	$DP_{2.3}$: Model and optimize material, process and information flows.
$F_{2.4}$: Ensure RL process visibility.	$DP_{2.4}$: Communicate effectively the process status between partners.
$F_{2.5}$: Ensure a required level of flexibility/adaptability in RL processes.	$DP_{2.5}$: Reconfigurable processes to accommodate material flows oscillations.
FR_3: Manage effectively and efficiently business relationships between partners, since RL cooperation initiation until termination.	DP_3: Interactive design of cooperation relationships, since initiation to termination.
$FR_{3.1}$: Monitor RL partnership.	$DP_{3.1}$: Continuous assessment of partnership (during the production process and output evaluation).
$FR_{3.2}$: Establish contract that spells conditions and liabilities and commits resources with responsibilities of RL.	$DP_{3.2}$: A written contract must assign actors with the RL responsibilities.
$FR_{3.3}$: Manage conflicts generated during RL cooperation.	$DP_{3.3}$: Establishment of mechanisms to prevent and/or mitigate the occurrence of conflicts in RL activities.
$FR_{3.4}$: Define effective and efficient communication paths for RL operations.	$DP_{3.4}$: Establishment of communication paths that enable information exchange between complementary cross-organisational activities.
FR_4: Manage human resources to perform RL activities.	DP_4: Adequate work environment and training to employee's characteristics.
$FR_{4.1}$: Avoid cultural and linguistic differences on employees performing RL.	$DP_{4.1}$: Mitigate the effect of cultural and linguistic differences.
$FR_{4.2}$: Identify and mitigate interpersonal conflicts when implementing RL.	$DP_{4.2}$: Define individual roles and responsibility assignment that correspond to individual capabilities and work expectations.
$FR_{4.3}$: Ensure employees adequate training to perform RL.	$DP_{4.3}$: Organizing training programs for worker continuous revision of the learnt contents.
FR_5: Adequate information needs to RL operations.	$DP_{5:}$ Select or design the adequate IT solution for RL activities.
$FR_{5.1}$: Design appropriate IT interface for RL operations.	$DP_{9.1}$: Reduce human dependent IT, by replacing manual interfaces with technology.
$FR_{5.2}$: Design in information systems able to exchange effectively and efficiently RL information.	$DP_{5.2}$: Enhance data synchronization to develop RL.
$FR_{5.3}$: Establish efficient databases and/or database interface that permit seamless information flows in RL.	$DP_{5.3}$: Use of common data resources.
$FR_{5.4}$: Design the appropriated IT application for RL information needs.	$DP_{5.4}$: Adapt IT to RL functional areas.

5. Conclusions and Future Work

The present work contributes to a pragmatic approach in interoperability, making use of the latest developments in business interoperability applied to innovative Lean, Agile, Resilient and Green Supply Chain Management strategies.

Settling on the problematic of dealing with complex networked collaboration environments subject to interoperability, the present work provides decision-models that help managers evaluating interoperability and a method for detailing the cooperation establishment in the identified issues.

For the purpose of demonstrating the application of the methods, a Portuguese Automaker was interviewed, where the two decision models (Fuzzy Sets and AHP) were applied to assess the implementation of SCM practices: reverse logistics (RL); supplier involvement in conception and design of products; use of IT to develop visibility to a clear view of upstream and downstream inventories; lead time reduction and flexible transportation. The application of the two models led to the conclusion that reverse logistics and the supplier involvement in conception and design of products currently lack interoperability. Detailed analysis from the two decision models, permitted to identify problems in strategic, operational and technical issues of the implementation of reverse logistics, which currently lacks more interoperability.

Therefore, to meet lack of interoperability issues to practical solutions to the current Automaker, Axiomatic Design theory permitted to decompose the problems into functional requirements (FR) and identify possible design parameters (DP) to re-design a new cooperation environment. For instance, the identification in Fuzzy Sets and AHP models that collaborative business process are failing on cooperation, permitted to identify the FR, which establishes the need for a seamless business process to ease reverse material flows (FR_2), fulfilled by a RL operations reconciliation ($DP_{2.1}$), material and information flows optimization ($DP_{2.2}$), seamless process status communication ($DP_{2.3}$) and flexible processes to overcome material flows oscillations ($DP_{2.4}$).

Future work will act in the assessment of the decomposed interoperability problems with the proposed decision models to achieve high detail of design solutions to cooperation.

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THE DESIGN OF AN INTEROPERABLE SELF-SUPPORTED REVERSE LOGISTICS MANAGEMENT SYSTEM

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ABSTRACT

Green Supply Chain Management (SCM) strategies emerged as a response to business competition with commitment to the environment. Reverse Logistics is part of this strategy that allows materials and products to be returned for re-use, re-manufacture or re-furbishing, requiring effective and efficient cooperation between supply chain (SC) firms. However, the lack of interoperability affects the alignment of operations with partners. This work presents a methodology to design the cooperation between partners using the systematic approach that is provided by Axiomatic Design Theory and a case study to demonstrate the application of this method to design a self-supported reverse logistics management system.

Keywords: reverse logistics, green supply chain management, business interoperability, Axiomatic Design.

1 INTRODUCTION

Due to the current market situation, the fierce competition between companies requires innovative strategies committed with the environment. Green Supply Chain Management (GreenSCM) strategies emerged as a response to environmental changes, guaranteeing environmental excellence in business activities [Srivastava, 2007]. In this context, Reverse Logistics (RL) arose as a solution to assign value to non-valued products or materials [Lau and Wang, 2009]. Therefore, this practice has the challenge of coordinating, effectively and efficiently, operations and material flows with regular business activities. For this reason, the latest achievements in business interoperability research combined with Axiomatic Design Theory allow us to describe how to establish reverse logistics cooperation, from top strategy issues to data transactions supported by information technology. This work presents a method to design an interoperable dyadic relationship with the purpose of applying reverse logistics between a first tier supplier and a focal firm that can manage alone the reverse logistics activities.

The work is structured in the following sections: section two contains a review of key topics (reverse logistics and business interoperability); section three describes the method and the background research that inspired the presented design; section four describes in detail the design of a dyadic reverse logistics relationship between a focal firm (manufacturer) and a first tier supplier; and, section five presents the final conclusions and comments related to the described design and outlines the main contributions and goals to achieve in future research.

2 LITERATURE REVIEW (KEY TOPICS)

2.1 REVERSE LOGISTICS

Reverse logistics (RL) refers to the physical flow of discarded materials that have lost their original value [Shi *et al.*, 2012]. It involves all the operational aspects related to collection, inspection, pre-processing and distribution associated with green manufacturing (reduce; recycle; production planning and scheduling; inventory management; remanufacturing, material recovery) and waste management (source reduction; pollution prevention; disposal) [Srivastava, 2007]. From a strategic point of view, RL has a high relevance to business. Srivastava [2007] stresses that investments in GreenSCM strategies like RL can be resource saving, waste eliminating and productivity improving. But, on other hand, the high cost of reverse logistics also compels firms to look at the issue seriously from a long-term strategic perspective [Lau and Wang, 2009].

The complexity of flows in RL leads to a diversity of return routes from end customer to raw materials suppliers (see Figure 1), making it hard to coordinate with forward logistics activities. Unlike the forward chain, there are many more sources of raw materials and they enter the reverse chain at a small cost or at no cost at all, and with high uncertainty of supply (collection) [Kot and Grabara, 2009]. In their work, Lau and Wang [2009] present three configurations for the RL networks: self-supported reverse logistics model;

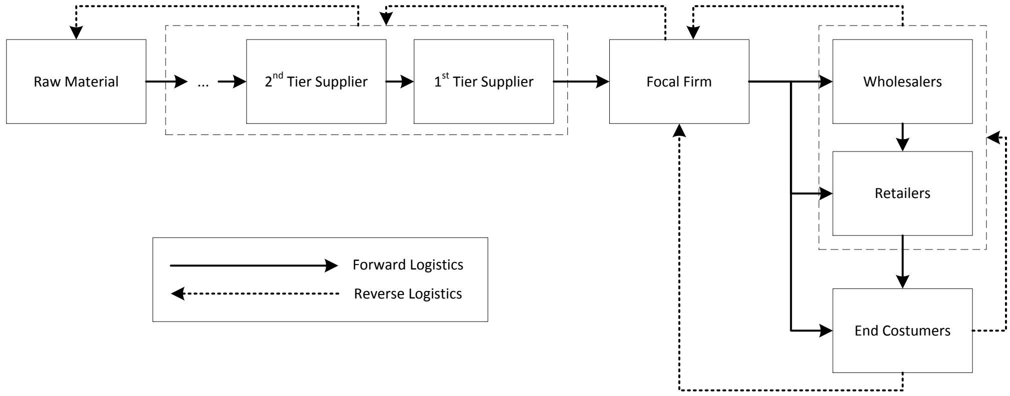

Figure 1. Forward and reverse logistics flows (adapted from Srivastava [2007]).

third-party reverse logistics (3PRL) model and collaborative reverse logistics model.

A self-supported RL management system helps firms collect valuable information about its products for continuous improvement ([Smith, 2005], cited by Lau and Wang [2009]). However, self-supported RL management systems involve significant capital investment [Lau and Wang, 2009]. On the other hand, a collaborative approach to manage and perform RL is less expensive, involves lower investment, and enables economies of scale through centralization [Lau and Wang, 2009].

A third conformation for RL network is suggested by the same authors. This approach allows a firm to focus on its core activities as well as to achieve more flexible reverse logistics operations and to transfer risk to third party [Lau and Wang, 2009].

2.2 Business Interoperability

Business interoperability was introduced by Legner and Wende [2006], who defined it as "the organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business with the objective to create value". Far from the technical perspective initially defined by IEEE [1990], this concept has evolved from syntactic and semantic perspectives to a more pragmatic position, concerning not only the interactions with the information systems, but also the organizational point of view. Initiatives like ATHENA [2007; Berre et al., 2007], the European Interoperability Framework (EIF) [IDABC, 2010], ECOLEAD [Consortium and others, 2006], Levels of Information Systems Interoperability (LISI) [DoD, 1998], Levels of Conceptual Interoperability Framework (LCIF) [Tolk and Muguira, 2003] and IDEAS have defined a possible path to achieve "optimal interoperability" [ATHENA, 2007] in electronic systems and businesses. Such frameworks provided data to achieve interoperability in three layers: business, knowledge, and information and communications technology (ICT) systems.

These three layers become a common concern in the context of the above-said frameworks, specifically in the definition of the business interoperability parameters (BIP), as proposed by Zutshi *et al.* [2012] and Zutshi [2010]: 1) business strategy (BS), 2) organizational structures (OS), 3) employees and work culture (EWC), 4) collaborative business processes (CBP), 5) management of external relationships (MER), 6) intellectual property rights management (IPRm), 7) business semantics (BSe) and 8) information systems (IS). These eight parameters represent the driving forces of collaboration between organizations, and allow analysing business-to-business (B2B) relationships that are suitable to SC's relationships between actors [Espadinha-Cruz *et al.*, 2012; Espadinha-Cruz, 2012]. The role of these parameters in the current work is to provide the main guidelines to decompose business activities into each BIP perspective.

3 METHOD AND AIM

The design herein depicted intends to provide solutions to problems identified by Espadinha-Cruz *et al.* [2012] and Espadinha-Cruz [2012] in a case that pertains to a Portuguese automaker. Those authors developed a business interoperability assessment methodology to analyse the implementation of reverse logistics with a first tier supplier. Their study unveiled some difficulties at the strategic, operational and information issues, since they found that it was lacking interoperability at some BIPs. Specifically, BS, EWC, CBP, MER, BSe and IS required a substantial revamping in order to take their interoperability to a condition that could be considered appropriate for the implementation of RL. The analysed automaker understands the importance of RL to the business goals, however some conditions are lacking. For instance, it is missing a business process to rule the RL activities. As consequence, issues like IS, MER, and EWC, have no guidelines to be established, and the occurrence of a rework, remanufacture or disposal is planned in each case.

Axiomatic Design (AD) Theory [Suh, 1990] provides an appropriate method to develop a systematic approach to fulfil the objectives of RL and the business interoperability requirements. This method permits us to describe in detail the dyadic relationship, committing design parameters (DP) to functional requirements (FR) along the diverse levels of the design decomposition: the business interoperability parameters. These parameters rule the interaction between two or more companies and should be included in the design of relationships, to reflect the design solution to each interoperability aspect. Although AD is often regarded just as one more engineering design tool, the literature shows that it can be used to design business platforms of diverse kinds. For instance, dos Santos *et al.* [2011] describe an Axiomatic Design approach to the design of a new business oriented to venture capital fundraising. This research led to interesting results, proving that AD is a useful approach to setup businesses focused on financial issues.

4 DESIGN OF SELF-SUPPORTED REVERSE LOGISTICS BETWEEN FOCAL FIRM AND 1ST TIER SUPPLIER

4.1 CUSTOMER NEEDS (CN) CHARACTERIZATION

The focus of this project is the dyad between a focal firm and a 1st tier supplier of an automotive supply chain. The customer is the focal firm that wants to establish a cooperation procedure and an IT system to allow the implementation of RL with a supplier for a specific product that represents most of the production value. However, as mentioned in section 2.1, there are three possible configurations for the RL networks. So, for this relationship three possible case studies are considered: CS_1 - self-supported reverse logistics model; CS_2 - collaborative reverse logistics model and CS_3 - third-party reverse logistics (3PRL) model. For the present design, it is assumed the situation of CS_1, in which the focal firm can manage alone the RL operations constraint, and support its costs, only needing to assign the re-manufacturing activities to the supplier. On the other hand, the supplier can guarantee the re-manufacturing of slightly damaged products.

4.2 PROCESS DESCRIPTION

The RL process is made of 5 main activities: collection, inspection, pre-processing, location and distribution and re-manufacturing. In the presented scenario, the focal firm has the ability to manage RL. Thus, is responsible for the first 4 activities, performing the collection of items, inspecting them in order to evaluate and deciding how and whom will recover the items. Additionally, in the pre-processing, the focal firm makes the preparation of the item to be recovered or disposed. In other words, it repairs and disassembles the components and processes waste before disposal. The supplier is only responsible for re-manufacturing and receiving the disassembled component.

The main concerns of the business correspond to the frontier of the responsibility. The effectiveness material and information flows and the coordination of activities rule the performance of RL. Figure 2 illustrates the generic processes (material flows) of the supplier and focal firm, referring to the interface activities between these actors.

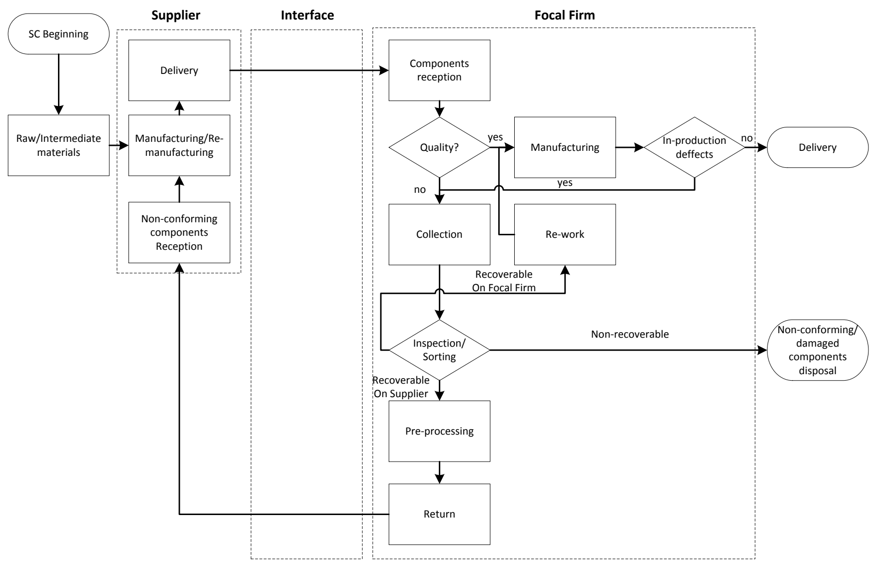

Figure 2. RL generic activities inherent to a self-supported RL management configuration.

The project of this relationship acts precisely at the interface between the two companies, addressing materials, data and currency flows, as well as human collaboration.

4.3 Definition of Highest Level Design Objectives

In the perspective of AD, the functional requirement of order zero (FR_0) is to ensure interoperability in the implementation of reverse logistics, which is achieved if the level 1 functional requirements are fulfilled. For this design, the following was selected as the highest level FR:

FR_0: Ensure interoperability in the implementation and management of reverse logistics.

In order to fulfil FR_0, the design parameter DP_0 will be:

DP_0: RL partnership.

The RL partnership (DP_0) success will be achieved if the measures of success, such as recovery, return, defect and scrap rates, cycle times, inventory turns, repair, remanufacturing and refurbish costs, etc. are satisfied.

4.4 Definition of Top Level FRs and DPs

The strategic focus of RL is translated by clarity in the cooperation goals for both companies. It stresses the main objectives, agreements and contracts that settle the arrangement on formal conditions. For this business perspective, the needed requirements fit in the following:

FR_1: Establish the cooperation goals to implement RL with the selected supplier.

The management of business processes is related to the development of the business activities, in order to ease material flow between partners. Thus, the main requirements in this subject are translated in:

FR_2: Establish business processes to ease reverse material flows.

Business relationships must be of concern from contract initiation until termination. The efficient management of interests and partnership behaviour will allow the growth of a trustworthy relationship that will bring the most advantages to RL performance. Hence, the functional requirement for this set of requirements is:

FR_3: Manage business relationships between partners, from RL cooperation initiation until termination.

Employees and their inherent work culture must also be managed. The activities developed in RL are performed mostly by human resources, and their failures are not easy to assess and model. So, to effectively run RL there must be the appropriate conditions to avoid human failures, conditioned by cultural differences, idiosyncratic factors (personality, motivation and responsibility) and suitable training for the RL roles. Hence, the main requirement that translates the presented need is:

FR_4: Manage human resources to perform RL activities.

At last, the fifth requisite concerns the information systems. Information systems provide the main data exchange infrastructure that will allow easing the access to the relevant data across organisations, regardless of if the activities are transactional or operational. As a consequence, the main FR for this matter is:

FR_5: Establish the information systems that provide the data required to run the RL process.

To fulfil the above FRs, the following DPs are proposed:

DP_1: The list of objectives (to implement RL), conflicts (of interests) and liabilities
DP_2: Description of a business process design, planning and coordination that fits the operational requirements of RL
DP_3: Description of the Interactive design of cooperation relationships, since initiation to termination
DP_4: Description of the work environment and training program that is suitable to the employee's characteristics
DP_5: Description of an IT solution suitable to support RL activities

Table 1 illustrates the design matrix of this level of the project.

Table 1. Design matrix for level 1.

	DP_1	DP_2	DP_3	DP_4	DP_5
FR_1	X	0	0	0	0
FR_2	X	X	0	0	0
FR_3	X	0	X	0	0
FR_4	X	0	0	X	0
FR_5	0	X	0	0	X

The present design is decoupled, requiring that the FRs are fulfilled in the specified order.

4.5 Definition of Level 2 FRs and DPs

The first FR fully describes the necessary detail to satisfy the strategic objectives of RL. Hence, this FR its not decomposed.

Other requirements must be fulfilled in order to achieve FR_2: clarify the business processes, the responsibility sharing definitions, the business process coordination, the business process visibility and the business process flexibility. Therefore, the sub-FRs for FR_2 will be:

$FR_{2.1}$: Establish clear RL collaborative business processes
$FR_{2.2}$: Define and ensure a correct responsibility assignment for RL implementation
$FR_{2.3}$: Coordinate RL processes between partners
$FR_{2.4}$: Ensure RL process visibility
$FR_{2.5}$: Ensure a required level of flexibility/adaptability in RL processes

To fulfil these requirements, the corresponding DPs are the following:

$DP_{2.1}$: Description of the reconciliation of the RL activities
$DP_{2.2}$: Identification (avoiding gaps) of the actors responsible for each activity
$DP_{2.3}$: Description of the model and of the material's optimization, process and information flows
$DP_{2.4}$: Definition of the way for communicating the process status between partners
$DP_{2.5}$: Description of how to reconfigure the processes to accommodate material flows oscillations

The relations between FRs and DPs for FR_2 are presented in Table 2.

Table 2. Design matrix for FR_2 (level 2).

	$DP_{2.1}$	$DP_{2.2}$	$DP_{2.3}$	$DP_{2.4}$	$DP_{2.5}$
$FR_{2.1}$	X	0	0	0	0
$FR_{2.2}$	X	X	0	0	0
$FR_{2.3}$	0	0	X	0	0
$FR_{2.4}$	X	X	X	X	0
$FR_{2.5}$	0	0	X	0	X

The design matrix for FR_2 is also decoupled, having only degrees of freedom for $FR_{2.1}$ and $FR_{2.3}$ that can be achieved independently.

FR_3 is related to the partnership monitoring, the establishment of cooperation contracts, the conflict management and the establishment of communication paths. Thus, the sub-FR's for this level are:

$FR_{3.1}$: Establish contract that spells conditions and liabilities and commits resources with responsibilities of RL
$FR_{3.2}$: Define communication paths for RL operations
$FR_{3.3}$: Monitor RL partnership
$FR_{3.4}$: Manage conflicts generated during RL cooperation

To satisfy these FRs, the following DPs were defined:

$DP_{3.1}$: A written contract must assign actors with the RL responsibilities
$DP_{3.2}$: The established communication paths that enable data exchange between complementary cross-organisational activities
$DP_{3.3}$: Description of the continuous assessment of partnership (during the production process and output evaluation)
$DP_{3.4}$: Description of the mechanisms to prevent and/or mitigate the occurrence of conflicts in RL activities

The relationships between the DPs and FRs for FR_3 are the following in the uncoupled design matrix (Table 3):

Table 3. Design matrix for FR_3 (level 2).

	$DP_{3.1}$	$DP_{3.2}$	$DP_{3.3}$	$DP_{3.4}$
$FR_{3.1}$	X	0	0	0
$FR_{3.2}$	0	X	0	0
$FR_{3.3}$	X	0	X	0
$FR_{3.4}$	X	X	X	X

The sub-FR's for FR_4 are:

$FR_{4.1}$: Avoid cultural and linguistic differences between employees performing RL
$FR_{4.2}$: Identify and mitigate interpersonal conflicts when implementing RL
$FR_{4.3}$: Ensure employees adequate training to perform RL

The corresponding DPs are the following:

$DP_{4.1}$: Description of the methods to mitigate the effect of cultural and linguistic differences
$DP_{4.2}$: Definition of individual roles and responsibility assignment that correspond to individual capabilities and work expectations
$DP_{4.3}$: Definition of the training programs for worker continuous revision of the learnt contents

The relationships between the DPs and FRs for FR_4 are the following (Table 4):

Table 4. Design matrix for FR_4 (level 2).

	$DP_{4.1}$	$DP_{4.2}$	$DP_{4.3}$
$FR_{4.1}$	X	0	0
$FR_{4.2}$	X	X	0
$FR_{4.3}$	0	0	X

To fulfil FR_4, the training of employees ($FR_{4.3}$) can be defined at any time, but to fulfil an efficient mitigation of interpersonal conflicts ($FR_{4.2}$), first one needs to address the cultural and linguistic issues ($FR_{4.1}$) of the employees.

Other conditions must be met in order to satisfy FR_5. For instance, the design of the IT interface must fit the needs of RL and simultaneously minimize the effect of human failure. Other concerns include security issues, data synchronization, interactions between databases and the IT application required to manage RL. Hence, the sub-FR's for this category are:

$FR_{5.1}$: Design the IT application for RL information needs
$FR_{5.2}$: Design the IT interface for RL operations
$FR_{5.3}$: Design information systems that are able to exchange RL data
$FR_{5.4}$: Establish the databases and/or the database interfaces that allow the data flows related to RL

To achieve these requirements, the following DPs are proposed:

$DP_{5.1}$: Description of the adopted IT to RL functional areas
$DP_{5.2}$: Description of the IT interfaces that replace manual interfaces in order to reduce human dependency
$DP_{5.3}$: Description of the data synchronization required to achieve RL
$DP_{5.4}$: Selected common data resources

The relationships between this set of FRs and DPs are presented in Table 5.

Table 5. Design matrix for FR_5 (level 2).

	$DP_{5.1}$	$DP_{5.2}$	$DP_{5.3}$	$DP_{5.4}$
$FR_{5.1}$	X	0	0	0
$FR_{5.2}$	X	X	0	0
$FR_{5.3}$	X	0	X	0
$FR_{5.4}$	0	0	X	X

This design matrix is uncoupled, and requires that the FRs are achieved in the specified order.

Figures 3 and 4 summarize the descriptions above. Figure 3 depicts the system architecture, while Figure 4 contains the corresponding complete design matrix.

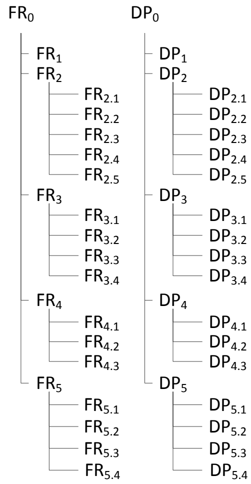

Figure 3. The RL system architecture.

	DP1	DP2	DP3	DP4	DP5	DP2.1	DP2.2	DP2.3	DP2.4	DP2.5	DP3.1	DP3.2	DP3.3	DP3.4	DP4.1	DP4.2	DP4.3	DP5.1	DP5.2	DP5.3	DP5.4
FR1	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR3	X	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR4	X	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR5	0	X	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2.1	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2.2	0	0	0	0	0	X	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2.3	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
FR2.4	0	0	0	0	0	X	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0
FR2.5	0	0	0	0	0	0	0	X	0	X	0	0	0	0	0	0	0	0	0	0	0
FR3.1	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0
FR3.2	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0
FR3.3	0	0	0	0	0	0	0	0	0	0	X	0	X	0	0	0	0	0	0	0	0
FR3.4	0	0	0	0	0	0	0	0	0	0	X	X	X	X	0	0	0	0	0	0	0
FR4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0
FR4.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	0	0	0	0	0
FR4.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0
FR5.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0
FR5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	0	0
FR5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	X	0
FR5.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X

Figure 4. Complete design matrix of self-supported reverse logistics between focal firm and 1st tier supplier.

5 CONCLUSIONS AND FUTURE WORK

This article proposes a design solution to establish a reverse logistics (RL) relationship between a focal firm and a 1st tier supplier, in which the focal firm manages and coordinates the activities of RL.

The application of the Axiomatic Design allowed us to systematize the reverse logistics definitions, considering the business interoperability parameters, making it possible to decide in which sequence the activities must be fulfilled. For instance, in the management of external relationships during cooperation (FR_3), first one needs to formalize a contract ($FR_{3.1}$). Next, one should define the communications paths ($FR_{3.2}$) that allow the partnership monitoring ($FR_{3.3}$). This will allow us to manage the conflicts generated during RL cooperation ($FR_{3.4}$). However, there is no precedence over $FR_{3.2}$, a fact that allows us to perform this task before $FR_{3.1}$.

Although it was possible to demonstrate the potential of Axiomatic Design to describe how to achieve an interoperable reverse logistics relationship between a supplier and a focal firm that manages the RL operations, some difficulties arise from this method (for example, the decomposition of the reverse logistics design aspects into interoperability requirements). There are several approaches to implement reverse logistics, in both the literature and the practice. All those approaches require an in depth knowledge about the models that rule the green supply management (for instance transaction cost economics and resource-based view).

Future work will focus on detailing the present model and developing other scenarios that could fit the presented situation, namely, the collaborative RL model (CS_2) and the third-party RL model (CS_3). These achievements will make it possible to apply the Information Axiom, allowing us to determine which design fits best to the needs of the focal firm.

Research will also be conducted in the field of computer simulation and business process modelling, and will address the testing and validation of the design. Also, the effect of interoperability variables in the RL metrics will be studied using the response surface methodology and design of experiments.

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Annex C Application scenario 3

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BUSINESS INTEROPERABILITY: DYADIC SUPPLY CHAIN PROCESS DECOMPOSITION USING AXIOMATIC DESIGN

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ABSTRACT

In today's competitive environment, companies must strive to cooperate in order to survive. Supply chain cooperation has become a strong asset relying on large integration and coordination of its well-structured processes. However, supply chain operations are conditioned by interoperability, for which until now is missing a tool that helps managers to identify and solve its problems. This article presents the supply chain process redesign supported by the Axiomatic Design Theory.

Keywords: business interoperability, axiomatic design, supply chain management, process interoperability.

1 INTRODUCTION

The fierce competition between companies requires networked cooperation such as supply chains (SC), in order to face the current market situation. In this context, business interoperability is an enabler that makes it possible to execute SC operations such as planning, sourcing, delivering, producing and returning, in a seamless fashion, permitting a suitable process alignment and information flow and guaranteeing high performance and competitiveness [Huhns, Stephens, & Ivezic, 2002]. However, the lack of interoperability is an emerging issue in information technology (IT) based cooperation.

In this work we present a method to decompose the processes between two supply chain actors. The paper is structured as follows: section two makes a brief review on the key topics (business interoperability and supply chain operations); section three describes the methodology for analysing and re-designing the supply chain dyadic cooperation; section four presents an example of the process decomposition between two SC actors supported by Axiomatic Design Theory (AD); and, section five presents the conclusions.

2 BUSINESS INTEROPERABILITY

2.1 BUSINESS INTEROPERABILITY DECOMPOSITION

Legner & Wende [2006] defined business interoperability as "an 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". Since the original concept introduced by [IEEE, 1990], interoperability has grown into a wider subject, integrating several organizational, operational and technological areas, currently becoming a complex subject [Rezaei *et al.*, 2013]. IDEAS [IDEAS, 2003], INTEROP Framework [Chen *et al.*, 2008; Chen, 2006], ATHENA Interoperability Framework (AIF) [ATHENA, 2007], ATHENA Business Interoperability Framework (BIF) [ATHENA, 2007] and European Interoperability Framework (EIF) [IDABC, 2010; F. B. Vernadat, 2010] are examples of frameworks and researches that present different perspectives, which reflect the issues that one must tackle to achieve higher levels of interoperability, that is, to get close to the concept of "optimal interoperability" [Legner & Lebreton, 2007]. Accordingly, and based on the definition of Legner & Wende [2006], we propose the Business Interoperability Components as depicted in Figure 1.

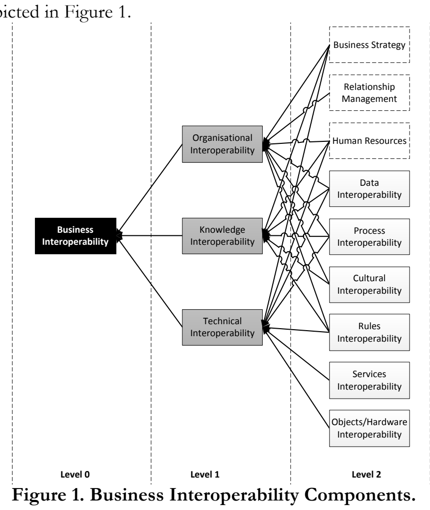

Figure 1. Business Interoperability Components.

These components portray individual perspectives of interoperability that, in each way, contribute to the concept of

Business Interoperability. This approach to the decomposition of business interoperability aims at systematizing the design of dyadic relationships using AD. This approach allows looking at the interoperability components to see how they guarantee an interoperable dyadic relationship.

2.2 PROCESS MODELLING AND THE SUPPLY CHAIN OPERATIONS

Modelling supply chain processes stems in the concept of process integration and coordination [F. Vernadat, 1996]. The supply chain operations reference model (SCOR), as introduced by [Supply Chain Council, 2010], provides a cross-industry standard in the definition and configuration of supply chain management processes. However, the SCOR model does not show how to proceed to achieve interoperability.

According to [Chen, 2006], process interoperability (PI) refers to the way internal processes from different companies interact with each other. The identification [ATHENA, 2005], sequencing [Chen, 2006; Chen *et al.*, 2008] and alignment [ATHENA, 2007; Tolk, 2003] of these processes are critical issues when designing the SC operations between two or more firms. Those authors stress the relevance of coordinating the internal processes into an interface or public process.

3 THE METHODOLOGY TO ANALYSE AND RE-DESIGN DYADIC COOPERATION

Figure 2 presents the method that is proposed to deal with the analysis and re-design of supply chain dyads.

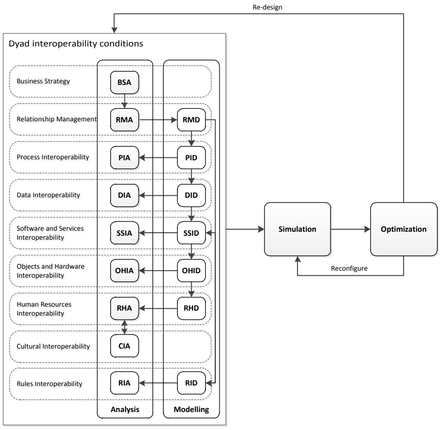

Figure 2. Methodology to analyse and re-design dyadic cooperation.

In this method, the first step is to analyse and model the dyad interoperability conditions in terms of the business interoperability components that represent the "as-is" situation. Next, one simulates the "as-is" model and one identifies the various scenarios that may lead to a more interoperable situation. At last, in the optimization stage, one finds which one of those scenarios has the best performance in terms of interoperability and in terms of supply chain performance.

3.1 STAGES OF ANALYSIS AND DECOMPOSITION

As mentioned in the previous section, the first step of the method is to determine the dyad interoperability conditions. This is achieved by interleaving the interoperability and the performance analyses, and modelling the interoperability components in a process that we call analysis and decomposition stages (A+D stages) (see Figure 2). The sequence of these stages has to do with the relationship between the business interoperability components. On the top of the method are the managerial and governance aspects, such as the business strategy and the management of the relationships that impact subsequent components. For instance, in business strategy analysis (BSA), the cooperation objectives are addressed and the dyad is analysed to verify if these ones are clear-cut to both companies and if the individual aspects are aligned into a cooperation business strategy. Managerial and governance aspects have impact in operations. Process interoperability decomposition (PID) and process interoperability analysis (PIA) are ruled by the prior aspects of interoperability, thus constituting the focus of this method. All the following stages are associated to the operations taken place in the dyad. For instance, data interoperability decomposition (DID) and data interoperability analysis (DIA) concerns to exchange of data between the firms that perform the processes. Issues like semantic alignment, communication paths and data quality are addressed in this stage in order to ensure that the data is properly interpreted, that there are sufficient contact points to exchange data, and that data is usable.

In terms of interoperability, the process resources are the information technology assets (software and systems interoperability, as well as objects and hardware interoperability) and the human resources. These resources enable processes and data exchange. As in the case of data interoperability, these resources are connected to the process interoperability.

3.2 PROCESS INTEROPERABILITY DECOMPOSITION (PID) AND ANALYSIS (PIA)

As stated before, process interoperability is the core of the method. Governance and management impact interoperability and two main elements rule the interaction between enablers and resources: the modelling and the analysis of the processes. The first element is the so-called process interoperability decomposition (PID), where individual and interface process identification, sequencing, and monitoring are addressed by using Design Structure Matrix (DSM) [Eppinger & Browning, 2012], Business Process Modelling Notation (BPMN) [Fettke, 2008] and supply chain practices implementation, in order to find which are the aspects that drive cooperation towards better effectiveness and efficiency. Figure 3 describes the method for decomposing a process in a dyad. For each actor in the SC dyad, we propose the characterization of each process (PI_1), the sequencing (PI_2) and the identification of the monitoring resources (PI_3). Next, the processes are aligned with the organisational structure of the company (PI_6). At last, after representing the company's internal processes, the interface process is created by aligning individual processes into a collaborative process (PI_5).

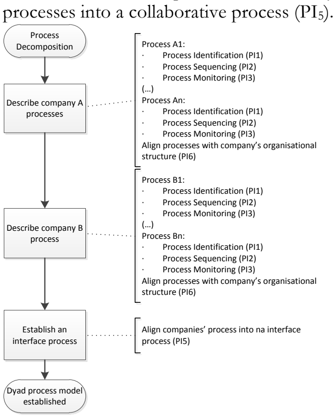

Figure 3. Process interoperability decomposition (PID) method.

Process interoperability analysis (PIA) is done after decomposing the process, and we suggest assessing the alignment and the visibility, as well as the appropriateness of the organisational structures to the processes. Both the process and the organisational alignment are addressed in qualitative and modelling standpoints. On the one hand, one makes a qualitative evaluation of the actors of the dyad; on the other hand, one verifies these two factors for better workflow arrangement and distribution through the companies' sections by using the DSM approach with optimization algorithms.

4 EXAMPLE: AUTOMOTIVE SUPPLY CHAIN DYAD

As an example, a 2nd tier raw material supplier (company A) and a 1st tier supplier (company B) constitute the dyad under analysis. On the AD perspective, the costumer in this case is the dyad. Hence, the top-level costumer need (CN) is to ensure high level of interoperability that should be achieved by the design of the sourcing and the delivery operations.

The interoperability conditions in terms of business strategy and process interoperability are specified in the design of Table 1.

Table 1. The dyad business strategy and process interoperability conditions.

FR$_0$: Ensure interoperability on sourcing and delivery operations.	**DP$_0$: Systematic design of the dyad.**
FR$_1$: Establish the cooperation goals and conditions for the dyad.	**DP$_1$:** The negotiation of a contract.
FR$_{1.1}$: Establish purchasing requirements.	DP$_{1.1}$: The company B's purchasing model.
FR$_{1.1.1}$: Settle an agreement for lead-time.	DP$_{1.1.1}$: The standard lead-time is one week.
FR$_{1.1.2}$: Define the deadline to reject orders.	DP$_{1.1.2}$: The supplier (company A) has five days to reject an order.
FR$_{1.1.3}$: Establish the payment conditions.	DP$_{1.1.3}$: The payment is authorized only after receiving the invoice and the materials.
FR$_2$: Manage internal and interface processes of the cooperation.	**DP$_2$:** The role assignment, the process design and the coordination of the sourcing and delivery activities.
FR$_{2.1}$: Define the company B processes.	DP$_{2.1}$: Company B is the buyer and performs the purchasing and reception operations.
FR$_{2.1.1}$: Define the purchasing process.	DP$_{2.1.1}$: The features of the purchasing process.
FR$_{2.1.1.1}$: Define the inventory policy.	DP$_{2.1.1.1}$: The inventory level is defined every week by the materials resource plan (MRP).
FR$_{2.1.1.2}$: Define the procedure to place an order.	DP$_{2.1.1.2}$: The purchasing is performed by sending the order schedule and waiting for order fulfilment.
FR$_{2.1.1.3}$: Define the order validation method.	DP$_{2.1.1.3}$: The orders are considered accepted except in case of delays and rejection.
FR$_{2.1.2}$: Define the payment procedure.	DP$_{2.1.2}$: The payment is made after receiving the invoice and the products physically.
FR$_{2.1.3}$: Sequence company B's individual tasks.	DP$_{2.1.3}$: The design of the process, material and information flows on purchasing process (see "Figure 4.").
FR$_{2.2}$: Define the company A processes.	DP$_{2.2}$: Company A is the supplier and is responsible for receiving orders and deliver materials to company B according to the pre-established lead-time.
FR$_{2.2.1}$: Define order reception procedure.	DP$_{2.2.1}$: Company A receives an order schedule and checks the inventory level to fulfil orders.
FR$_{2.2.2}$: Define the order validation procedure.	DP$_{2.2.2}$: Order validation performed by checking stored materials and production availability.
FR$_{2.2.3}$: Sequence company A's individual tasks.	DP$_{2.2.3}$: The design of the process, material and information flows on delivery process (see "Figure 5.").
FR$_{2.3}$: Align companies' internal processes.	DP$_{2.3}$: Interface process.

The corresponding design matrix is depicted in Table 2. The dependency between FRs and DPs, which comes from the chosen DPs, conditions the design of the processes. For instance, the establishment of a deadline to cancel orders ($DP_{1.1.1}$) has direct influence in the definition of the method to validate orders on the purchasing process ($FR_{2.1.1.3}$).

PID method is applied to FR_2. Process identification (PI_1) is portrayed by $FR_{2.1}$, $FR_{2.1.1}$, $FR_{2.12}$, $FR_{2.2}$, $FR_{2.2.1}$ and $FR_{2.2.2}$. Process sequencing (PI_2) is applied to $FR_{2.1.3}$ and $FR_{2.2.3}$. Finally, the companies' internal processes alignment (PI_5) is applied to $FR_{2.3}$.

Table 2. Design matrix for the supply chain dyad.

	DP1	**DP2**	**DP1.1**	**DP2.1**	**DP2.2**	**DP2.3**	**DP1.1.1**	**DP1.1.2**	**DP1.1.3**	**DP2.1.1**	**DP2.1.2**	**DP2.1.3**	**DP2.2.1**	**DP2.2.2**	**DP2.2.3**	**DP2.1.1.1**	**DP2.1.1.2**	**DP2.1.1.3**
FR1	X																	
FR2	X	X																
FR1.1			X															
FR2.1			X	X														
FR2.2					X													
FR2.3				X	X	X												
FR1.1.1							X											
FR1.1.2							X	X										
FR1.1.3							X		X									
FR2.1.1							X			X								
FR2.1.2							X				X							
FR2.1.3										X	X	X						
FR2.2.1													X					
FR2.2.2														X				
FR2.2.3													X	X	X			
FR2.1.1.1																X		
FR2.1.1.2																X	X	
FR2.1.1.3								X										X

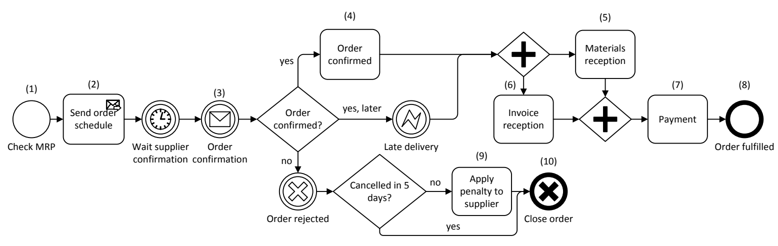

Figure 4. Company B's purchasing business process model ($DP_{2.1.3}$).

As for FR_2, stating the main operations and the procedures that must be used to achieve the sourcing and delivery goals specifies the process considerations. $FR_{2.1.3}$ corresponds to the alignment of the tasks of company B with the business process flow. The existing conditions of company B are presented in Figure 4. The process sequence is a direct consequence of the FR and DP decomposition. For instance, purchasing condition $DP_{1.1.3}$, establishes that the payment activity is preceded by a set of parallel activities: invoicing and reception of materials, which are requirements for making payments. Delays in any one of those activities will delay the payment to company A. Also, the condition $DP_{1.1.2}$ results in an additional process (see (9) in "Figure 4.") that, in case of order rejection delay, will result in negotiation of penalties.

In turn, the process of company A is presented in Figure 5, which portrays the sequence of the business procedures that should be performed to receive ($FR_{2.2.1}$) and validate orders ($FR_{2.2.2}$).

The next step in the proposed method is to align these processes with the company's organisational structure. In this example we are dealing only with one company section. Hence, the next step is to design the interface processes. Here, data, material and currency flows are mapped to interconnect the business processes. The result for the existing conditions is presented in Figure 6.

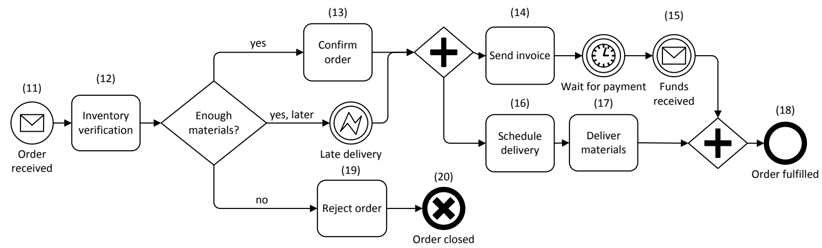

Figure 5. Company A's business process model ($DP_{2.2.3}$).

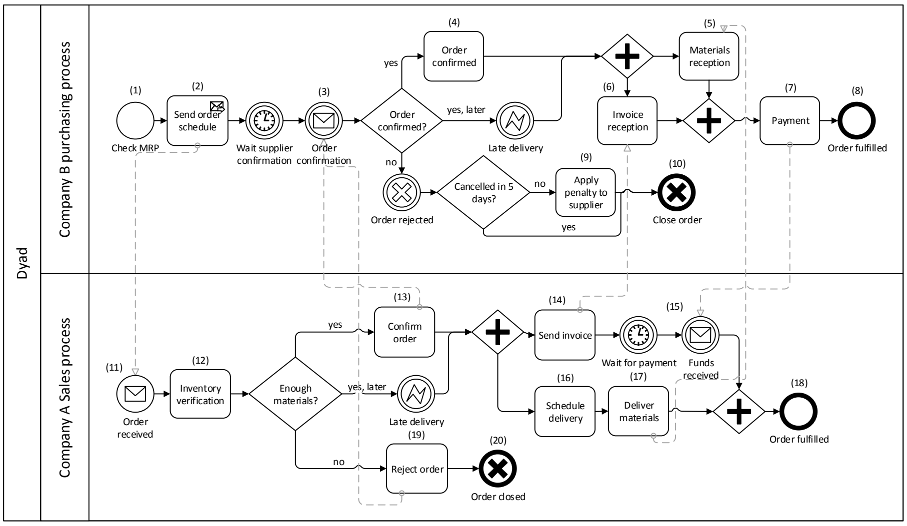

Figure 6. Dyad sourcing and delivery operations.

Representing the internal and the interface activities in a DSM (see Figure 7) allows visualizing the interactions between processes. The numbered activities of Figure 7 correspond to the numbers shown in Figure 6.

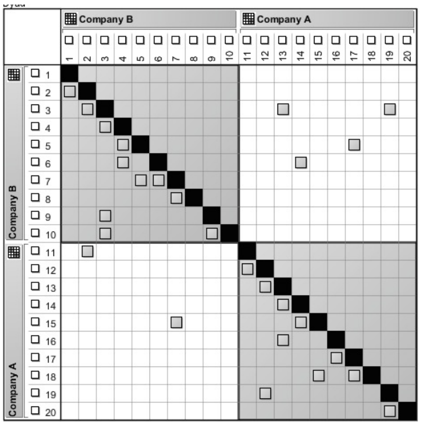

Figure 7. A DSM representation of the dyad (DSM made using the software "Cambridge Advance Modeller" developed by [Wynn, Wyatt, Nair, & Clarkson, 2010]).

One should notice that there are six interactions in the interface of the two companies. We must act on those ones in order to identify and solve the interoperability problem. For example, both BPMN and DSM representations show a strong dependency between the purchasing and the sales processes. Checking the MRP and placing an order initiate the purchasing process. After placing the order, the procedure stops until company B confirms or rejects it. In the perspective of company B, the order placement is what triggers the sales process. The process is almost fully executed and, if the order is confirmed, it stops again waiting for the payment of company A. However, company A only makes the payment when the invoice and the materials are received. The activities in both companies depend on each other in the interactions (14)-(6), (17)-(5) and (7)-(15) (see Figure 7). This complex operation deserves great attention in modelling and in applying the subsequent A+D stages. The effectiveness of the process depends on the features of each one of the interactions and on the available resources. The effectiveness is studied through simulation as a means to check if the procedures generate delays on each other. The result of this study may require the re-configuration of the dyad in terms of information systems that enable the interactions (2)-(11), (13)-(3), (19)-(3), (14)-(6) and (7)-(15); or the material flow on (17)-(5).

5 CONCLUSION

The present research contributes to developing an integrated tool to assess and re-design IT-supported cooperation, using a systematic approach to identify interoperability problems, as well as to select optimisation tools to eliminate or to mitigate them.

The method presented in section 3 allows guiding the axiomatic design application by interleaving the analysis and the decomposition stages, while keeping the integrity of the business interoperability issues that are related to the industry sector under analysis.

The proposed method for process decomposition allows linking the governance and managerial issues to the operational reality of business. This is useful in dyad analysis and design because it allows keeping track of previously defined aspects when advancing the design. The presented example demonstrates that the cooperation objectives are very relevant in the process design, such as in the case of order cancelling deadline that influences the order validation process in both companies.

The Business Process Model Notation (BPMN) and the Design Structure Matrix (DSM) have particular relevance in modelling processes. BPMN allows easy forms of representing process, material, information, and currency flows and provides suitable symbols to represent information technology assets, users, communication, etc. As for the DSM approach, it allows to go deeper in the interaction between processes. As illustrated by Figure 7, the interactions that occur in the interface between the two companies become evident and it is possible to check where a process begins and ends. On more complex processes (*e.g.*, representing all the supply chain operations, such as production, planning, sourcing, delivery and returning) it is possible to allocate processes to organisational sectors (as proposed in section 3.2), and to verify the process alignment and distribution through clustering algorithms.

Future work will concentrate on applying the next stages of the proposed methodology. For example, after defining the process interfaces, data exchange will be modelled and analysed in order to identify information barriers, such as semantics faults, or database heterogeneity. At last, using simulation tools it will be possible to study various scenarios without interfering with the actual system, thus providing the solution that results in less cost and time.

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Annex D Application scenario 4

A simulation approach to select interoperable solutions in Supply Chain dyads

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Abstract. Business Interoperability has become an indisputable reality for companies that cooperate and struggle for competitiveness. Supply Chain Management is one kind of industrial cooperation which relies on large integration and coordination of processes. Though, supply chain operations are ruled and conditioned by interoperability factors, which until now misses a tool to identify and solve its problems. In this context, this article proposes a simulation approach to study the effects of interoperability solutions on the performance of supply chain dyads.

Keywords: Business interoperability; SCM; dyadic relationships; simulation; performance measurement.

1 Introduction

Business interoperability (BI) is an organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop information technology (IT) supported business with the objective to create value [1]. In the context of supply chain management (SCM), business interoperability is an enabler that makes possible to execute the SC operations seamlessly, easing their alignment and the information flow, guaranteeing high performance and competitiveness [2]. However, lack of interoperability is an emerging issue in IT based cooperation [3]. Most of the existing research on interoperability areas concentrates in forms to classify and identify interoperability problems and barriers, and forms to measure and remove them.

On our research, we aim at the research question "How to achieve high levels of interoperability in supply chain dyads?", addressing one-to-one relationships in supply chains. To approach this issue, we address three topics: characterization and analysis of interoperability problems; cooperation re-design; and the study of the interoperability impact in the dyad performance. The present article proposes a method to study of interoperability impact on the dyad performance (in terms of SCM and interoperability performance), as a support to decision making in the dyad design and in the selection of suitable information systems to eliminate or mitigate interoperability problems.

adfa, p. 1, 2011.

The article is structured as follows: section two makes a brief review on the key topics (business interoperability, supply chain operations and performance); section three describes the methodology for analyzing and re-designing the supply chain dyadic cooperation; section four presents a case study on an automotive supply chain dyad; and section five presents the conclusions.

2 Business interoperability

2.1 Business interoperability decomposition

BI is a concept that evolved from the technical perspective of interoperability incorporating several aspects of organization interactions. Frameworks and researches like IDEAS [4], INTEROP Framework [5], [6], ATHENA Interoperability Framework (AIF) [7], ATHENA Business Interoperability Framework (BIF) [7] and European Interoperability Framework (EIF) [8], [9] traced the evolutionary path that led to the exiting notion of business interoperability. In previous work from [10], several kinds of interoperability that contribute to the current definition of business interoperability were identified and related (see Figure 1). In level 1 three interoperability types were suggested to contribute singly to the BI definition. Interoperability types shown in level 2 can provide input to more than one type of interoperability at level 1.

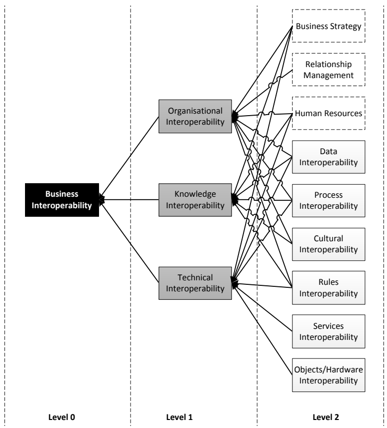

Fig. 1. Business Interoperability Components [10].

The different perspectives of interoperability reflect the issues that one must attend to achieve higher levels of interoperability or, as it was defined by [12], achieve "optimal interoperability".

2.2 Business interoperability measurement and performance metrics

Interoperability measurement and quantification is a branch of research dedicated to interoperability quantification in a qualitative or quantitative manner. Qualitative approaches to interoperability measurements are associated with subjective criteria that permits to assign a certain level of interoperability (e.g. [13]–[15]), or a maturity level (e.g. [16,17]), to a specific kind of interoperability.

On the other hand, quantitative approaches make an attempt to characterize the interoperations, proposing measurements (e.g. [18]) and scores [19] to convert interoperability issues into numeric values. The main problem with these approaches is that most of the numeric values that are obtained are as subjective as the interoperability issues that are analyzed.

Another branch of interoperability quantitative assessment is dedicated to performance measuring. Approaches to performance measurement as [7], [20]–[22] suggest ways to measure the impact of interoperability on metrics such as costs, time and quality. However, it is not known a direct way of relating interoperability issues, or the companies' decisions, with the interoperability metrics [7], [20]–[22].

3 Methodology to analyze and re-design dyadic cooperation

The proposed method to analyze and re-design the supply chain dyads is depicted by Figure 2.

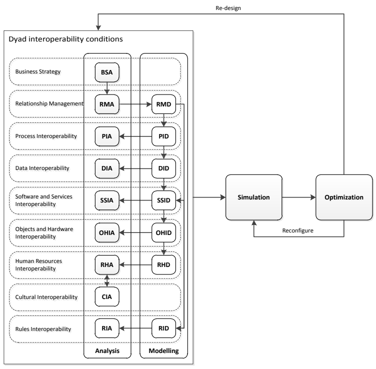

Fig. 2. Methodology to analyze and re-design dyadic cooperation [10].

In this method, the first phase is to analyze and model the dyad interoperability conditions in terms of the business interoperability components that represent the "as-is" situation. On the second stage, one simulates the "as-is" model and one identifies the various scenarios that may lead to a more interoperable situation. In this matter, we propose two kinds of approach: an improvement of the current scenario by addressing the interoperability variables that one can change in order to reconfigure the relationship (for instance, the human resources quantity on a specific process); or the redesign of certain aspects of interoperability, such as the process design or the selection of another information system that permits improving the dyad performance. In the last stage (optimization stage), one finds which one of those scenarios has the best performance in terms of interoperability and in terms of supply chain performance.

3.1 Stages of analysis and decomposition

As mentioned in the previous section, the first step of the method is to determine the dyad interoperability conditions. This is achieved by interleaving the interoperability and the performance analyses, and modeling the interoperability components in a process that we call analysis and decomposition stages (see Figure 2). The sequence of these stages has to do with the relationship between the business interoperability components. On the top of the method are the managerial and governance aspects, such as the business strategy and the management of the relationships that impact subsequent components. For instance, in business strategy analysis (BSA), the cooperation objectives are addressed and the dyad is analyzed to verify if these ones are clear-cut to both companies and if the individual aspects are aligned into a cooperation business strategy. Managerial and governance aspects have impact in operations. Process interoperability decomposition (PID) and process interoperability analysis (PIA) are ruled by the prior aspects of interoperability, thus constituting the focus of this method. All the following stages are associated to the operations taken place in the dyad. For instance, data interoperability decomposition (DID) and data interoperability analysis (DIA) are stages acting on the exchange of data between the firms that perform the processes. Issues like semantic alignment, communication paths and data quality are addressed in this stage in order to ensure that the data is properly interpreted, that there are sufficient contact points to exchange data, and that data is usable.

In terms of interoperability, the process resources are the information technology assets (software and systems interoperability, as well as objects and hardware interoperability) and the human resources. These resources enable processes and data exchange. As in the case of data interoperability, these resources are connected to the process interoperability.

3.2 Modeling and measuring interoperability performance on supply chains

Modeling supply chain processes derives from the concept of process integration and coordination [23]. The supply chain operations reference model (SCOR) [24] makes a link between performance measures, best practices and software requirements to business process models [25]. However, the SCOR model does not show how to proceed to achieve interoperability. In the application of the method portrayed in Figure 2 we propose a systematic representation of the interoperability perspectives of the dyad. In this one, we address the supply chain operations that take place between the two firms. For instance, in [11] a buyer-seller interface was designed. To achieve this design, a mapping has been done since the strategic objectives to the process design decisions using Axiomatic Design Theory [26] combined with Business Process Notation [27] and Design Structure Matrix [28]. This procedure allowed to decompose the SC operations and to address the interoperability issues inherent to each activity. The interoperability impact study and the selection of the appropriate design is the contribution of this article, and allows to demonstrate how the findings from [10] and [11] are modeled using computer simulation.

The course between an actual ("as is") to a desired more interoperable state ("to be") is supported by the decisions taken place during the re-design and reconfiguration activities of Figure 2. These decisions are formulated according to the identified interoperability barriers and tested through simulation. Here, in this part of the methodology the performance measurement becomes an essential aspect to achieve an interoperable dyadic relationship. Supply chain performance metrics and interoperability metrics portray a relevant part to strive, both, for a competitive and interoperable supply chain dyad.

In the next section we present a case study that is currently being developed on an automotive supply chain. Here is addressed the interaction between two firms in the context of purchase and delivery operations. These two operations were decomposed into interoperability aspects, and the business processes were modeled in order to help in the design of a simulation model. To evaluate the two companies three performance metrics were selected: order lead-time [29]–[33], time of interoperation and conversion time [7], [20,21], [34], [35].

4 Case study: automotive supply chain dyad

The present case study was implemented in a dyad constituted by a 2nd tier rubber parts supplier (company A) and a 1st tier automotive engine gaskets supplier (company B). The application of this method was made through several interviews in both companies and by analyzing companies' documentation. The internal and interface processes are presented in Figure 3.

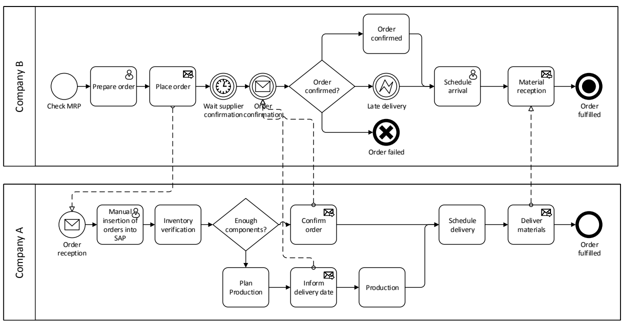

Fig. 3. Collaboration and internal activities business process model.

The interoperability conditions for both are presented in Table 1.

Table 1. Interoperability conditions on the dyad.

Interoperability aspect	Interoperability conditions
Business Strategy	A contract was signed specifying the agreed lead-time of 7 days. The cooperation strategy was defined, but is not aligned with individual objectives.
Relationship Management	A long-term relationship was established.
Human Resources	Company A has 6 employees (5 responsible for inserting orders manually on SAP and 1 to validate orders). Company B has 2 employees to treat the orders.
Process interoperability	In company A, 5 users insert manually orders into SAP. One HR verifies the inventory and confirms or calls for production. In company B, the ordering process is performed by 2 operators that check MRP data on SAP system and send the purchase orders to the supplier by e-mail and, then, wait for supplier response to validate the order and, then, wait for its fulfillment.
Data interoperability	There are compatibility issues between the formats of the orders in both companies. Data must be treated manually in both cases.
Software and systems interoperability	In both companies, SAP system and the E-mail system are not interoperable. This requires manual interaction between systems.

The first improvement to test on the current approach for the collaboration is to study the use of the resources that enable cooperation. For simplification purposes, we only address the human resources quantity as variable to improve the "as-is" scenario. Other aspects featured on Figure 1 should, if possible, be addressed in the performance analysis.

The results regarding the variation of human resources quantity are presented in Figure 4.

Regarding order preparation from company B, currently there are 2 employees responsible for preparing, manually, the orders by accessing the Material Resource Plan on SAP system and send the needed orders by e-mail. On the "as-is" configuration, the average value of the order lead-time (OLT) is 163 hours (7 days), which satisfies the agreed lead-time. Decreasing the number of employees to one permit reducing the OLT to 155 hours (6 days) and the time of interoperation (TIP). However, the conversion time increases from 0,3 to 8,7 hours for each order to be prepared. In counterpart, increasing the number of employees doesn't have effect on the metrics.

In respect to company A's activities, the number of employees on the manual insertion of orders on SAP could be decreased to a minimum of 3 in order to maintain

Table 2. Comparison between "as-is" and the implementation of EDI scenario (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99% and an error of 1,05%).

Scenario	OLT (hours)	TIP (hours)	Cv (hours)	Human resources (number of employees)
"as-is"	162,58	22,32	0,32	8
EDI implementation	163,44	22,59	0,08	3
Difference	+1%	+1%	-76%	-5

In turn, the two compared solutions are based on the same interoperability conditions in terms of human resources quantity. From the first improvement, we had concluded that if we increase operators on the inventory verification activity we can decrease the lead-time in about one day. We can test the number of employees influence for the EDI implementation. The results are presented in Figure 5.

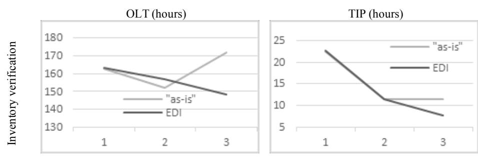

Fig. 5. Influence of human resources quantity on OLT and TIP for Inventory verification process for each scenario (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99% and an error of 1,05%).

If the companies decide to eliminate or mitigate the systems incompatibility (SAP and E-mail) by implementing an EDI, best results can be achieved if the number of employees on the inventory verification is increased to 3. However, if due to technical limitations the EDI implementation is not possible, the company A should add another employee to the inventory verification activity (by contracting a new employee) or remove one employee from manual insertion to inventory verification.

5 Conclusions

The presented research contributes to the development of an integrated framework to assess and re-design supply chain dyadic cooperation. It provides a method to study the interoperability impact on the performance of the dyad. This method allows one

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the test various scenarios without affecting the real system and providing the solution that may result in an improvement for the dyad.

Future work will concentrate on the integration of other interoperability aspects by implementing Design of Experiments and Taguchi methods. This will allow us to deal with the complexity of Business Interoperability by systematizing the influence of interoperability aspects on performance.

6 Acknowledgements

The authors would like to thank Fundação para a Ciência e Tecnologia for providing a research grant to Pedro Espadinha da Cruz through the project PTDC/EME-GIN/115617/2009.

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the same OLT. Though, the minimum conversion time (Cv) is achieved with 4 employees.

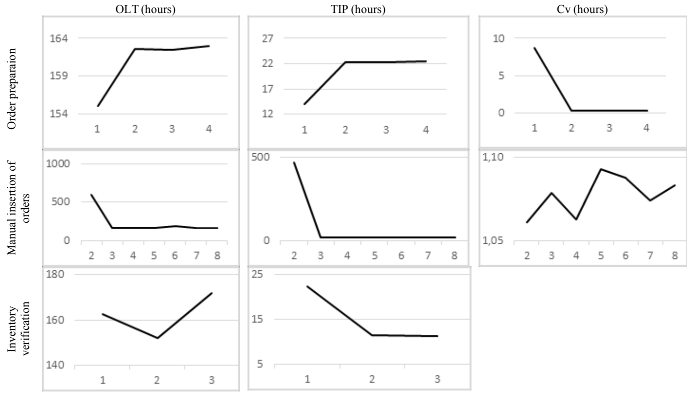

Fig. 4. Influence of human resources quantity on OLT, TIP and Cv for each process (obtained on Rockwell Arena Software in 20 replications with a confidence interval of 99% and an error of 1,05%).

Still in company A, increasing the employees to 2 permits to decrease the OLT to 152 hours (6 days) and TIP to 11,54 hours. This last improvement enhances the response time to the company B's requests. Instead of waiting 22 hours to obtain the order confirmation, the increase of 1 employee permits to fulfill this in half of the time. For this activity there are no Cv values because there is no conversion process involved.

The second improvement we propose is the implementation of an Electronic Data Interchange (EDI) system to replace the order placement communication path. This measure will enhance compatibility of data between the ICT and the order management system, reducing the time for order preparation in company B and eliminating the manual insertion process of company A. The obtained results are presented in Table 2.

Comparing the metrics for the "as-is" and the EDI implementation scenario, both OLT and TIP increase by 1 percent. In counterpart, there is a reduction of 76% of the time to prepare the orders to send to company A.

In terms of human resources, the "as-is" scenario counts with 2 employees on company B and 6 employees (5 on manual insertion and 1 on inventory verification) on company A. The implementation of the EDI reduces the company A to 1 operator required to deal with company B's orders.

Annex E Proposta de caso de estudo

FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

UNIDEMI R&D Unit in Mechanical and Industrial Engineering

BIXLARGIE
PTDC/EME-GIN/115617/2009

Proposta de Caso de Estudo

A Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, através da Unidade de Investigação e Desenvolvimento em Engenharia Mecânica e Industrial (UNIDEMI), está a desenvolver um projeto de nome "Business Interoperability for Collaborative Platforms with Axiomatic Design Theory for Lean, Agile, Resilient and Green Industrial Ecosystems", PTDC/EME-GIN/115617/2009, financiado pela Fundação para a Ciência e Tecnologia. Este projeto tem uma duração de três anos e uma equipa de investigação de 5 membros, liderada pelo Professor António Grilo. Pretendemos com esta nota apresentar uma proposta de realização de casos de estudo para validação dos modelos desenvolvidos nos sectores da indústria Aeronáutica, Automóvel, Elétrica e Electrónica.

O objectivo da investigação a desenvolver é a implementação de uma metodologia que permita estudar os mecanismos de colaboração entre pares de empresas e a utilização de plataformas de tecnologias de informação que as suportam. Esta metodologia visa a identificação sistemática de pontos de falha de colaboração e a optimização da performance da mesma, através da reconfiguração de parâmetros de negócio, obtidos através de modelos de simulação propostos pelo projeto.

Nesse sentido, vimos por este meio apresentar a nossa proposta de realização de caso de estudo com a «Nome», no qual gostaríamos de contar com a Vossa participação, visto serem uma das maiores empresas do sector da «NomeSector», destacando-se pela performance económica e produtividade a nível nacional.

Como participar?
A participação nesta investigação requer uma recolha de dados que permita caracterizar a «Nome» e a sua relação com os seus parceiros diretos no âmbito da cadeia de abastecimento (fornecedores, empresa focal montadora e fornecedores logísticos). Esta caracterização visa a identificação de falhas de colaboração, nomeadamente em interações que envolvam fluxos de material e de informação, com vista a estabelecer um conjunto de recomendações que permitam melhorar a performance da relação em termos de tempo, custos e qualidade.

Quais os benefícios da Sua participação?
A realização do caso de estudo visa proporcionar benefício mútuo para todas as partes envolvidas. Por um lado, os investigadores terão a oportunidade de recolher os dados necessários para a validação dos modelos teóricos desenvolvidos, e por outro lado as empresas receberão os resultados do estudo bem como as recomendações feitas tendo em conta os resultados obtidos. Com base nas recomendações feitas, as empresas poderão tomar medidas a nível de implementação dos mecanismos que possam melhorar as suas formas de colaboração, melhorando assim a eficácia e eficiência na implementação das práticas de gestão colaborativas.

Quais as garantias oferecidas?
No desenvolvimento da investigação deste caso de estudo garantimos total confidencialidade dos dados recolhidos, bem como dos resultados da investigação. Todo o material recolhido e os resultados da investigação serão entregues em formato de relatório e o material científico produzido detalhados à Vossa empresa. A publicação dos resultados de investigação será apenas feito após a Vossa aprovação.

Agradecemos desde já atenção dispensada, e a oportunidade de nos encontrarmos pessoalmente para discutir de que forma poderemos desenvolver esta colaboração colaboração.

Monte da Caparica, Dezembro de 2013

Prof. António Grilo

Annex F Case study description and planning

Business Interoperability for Collaborative Platforms with Axiomatic Design Theory for Lean, Agile, Resilient and Green Industrial Ecosystems

Caso de Estudo na NOME_DA_EMPRESA

Descrição e Planeamento do Caso de Estudo

Pedro Espadinha da Cruz

UNIDEMI
R&D Unit in Mechanical
and Industrial Engineering

outubro de 2016

Índice

1 Resumo

O presente documento visa apresentar uma descrição do projeto "Business Interoperability for Collaborative Platforms with Axiomatic Design Theory for Lean, Agile, Resilient and Green Industrial Ecosystems", e do caso de estudo proposto à NOME_DA_EMPRESA.

O documento está estruturado em 4 secções. A secção 2 apresenta uma descrição do projeto e dos membros da equipa. A secção 3 apresenta o detalhe da metodologia proposta pelo Bolseiro de Investigação Pedro Espadinha da Cruz. Na secção 4 é apresentado o planeamento do caso de estudo a desenvolver na NOME_DA_EMPRESA, abordando quais as fases de desenvolvimento e os dados necessários em cada fase. Por último, na secção 5, são enunciados os dados a recolher da NOME_DA_EMPRESA.

2 Apresentação do projeto BIXLARGIE

O projeto nomeado de "Business Interoperability for Collaborative Platforms with Axiomatic Design Theory for Lean, Agile, Resilient and Green Industrial Ecosystems" (BIXLARGIE), PTDC/EME-GIN/115617/2009, liderado pelo Professor António Grilo, tem como objectivo o desenvolvimento de uma metodologia integrada que permita o estabelecimento ou melhoria de relações de negócio no contexto da interoperabilidade de negócio (*Business Interoperability*).

O conceito de interoperabilidade de negócio é por nós definido de "capacidade de cooperação em relações de negócio suportadas por sistemas de informação". Este conceito teve origem técnica, sendo definido pelo *Institute of Electrical and Electronics Engineers* (IEEE, 1990) como a capacidade de dois ou mais sistemas ou componentes de trocar informação e utilizar essa informação. Desde essa década o conceito evoluiu passando a integrar as perspectivas de negócio (Estratégico, Táctico e Operacional), de conhecimento e de tecnologia.

Relativamente às relações de negócio, estão abrangidas as seguintes cooperações industriais: Gestão da Cadeia de Abastecimento (SCM), Inovação, Gestão das relações com os clientes e *Outsourcing*. No contexto abordado no caso de estudo com a NOME_DA_EMPRESA, pretende-se analisar a relação com os fornecedores, no contexto da SCM. O objectivo é a análise sistemática de factores que regem a interação entre empresas, de forma a decompor a relação para identificar e resolver problemas de cooperação, e optimizar o seu desempenho em termos de cadeia de abastecimento e em termos de interoperabilidade. Neste contexto, é proposta a aplicação da metodologia desenvolvida pelo Bolseiro de Investigação Pedro Espadinha da Cruz (ver secção 3) que visa a análise de pares de empresas a operar na cadeia de abastecimento.

2.1 Membros do projeto

A equipa do projeto BIXLARGIE é composta pelos seguintes membros:

- **Investigador principal:**

Prof.º António Carlos Bárbara Grilo

- **Investigadores:**

Prof.º Virgílio da Cruz Machado

Prof.º António Manuel Flores Romão de Azevedo Gonçalves Coelho

Prof.º António José Freire Mourão

Prof.º Ricardo Luís Rosa Jardim Gonçalves

Prof.ª Maria do Rosário de Meireles Ferreira Cabrita

- **Bolseiros de Investigação Mestres:**

Izunildo Fernandes Cabral

Pedro Emanuel Botelho Espadinha da Cruz

2.2 Abordagens de projeto

O projeto BIXLARGIE segue dois ramos de estudo: a análise do efeito de rede e análise das relações um-para-um. Na primeira abordagem, o Bolseiro Izunildo Cabral encara as relações num ecossistema industrial como um todo, analisado qual o efeito que a interação entre duas empresas tem em terceiros. A segunda abordagem é realizada pelo Bolseiro Pedro Espadinha da Cruz, cujo o objectivo é analisar em detalhe todas as decisões estratégicas tomadas para construir a base da relação de um-para-um na cadeia de abastecimento; quais os processos e fluxos de material, informação e monetários; e qual a eficiência de cada um dos aspectos inerentes à relação e que efeito isso tem no desempenho da mesma.

3 Descrição da metodologia de análise e redesenho de colaborações na cadeia de abastecimento

A metodologia de análise e redesenho de colaborações na cadeia de abastecimento foi desenvolvida pelo Bolseiro Pedro Espadinha da Cruz e faz parte integrante da proposta do caso de estudo a desenvolver na NOME_DA_EMPRESA. Esta metodologia incide em quatro etapas distintas: analise, modelação, simulação e optimização. Concluída a última etapa, procede-se à reconfiguração ou ao redesenho da relação de um-para-um (ver Figura 3.1).

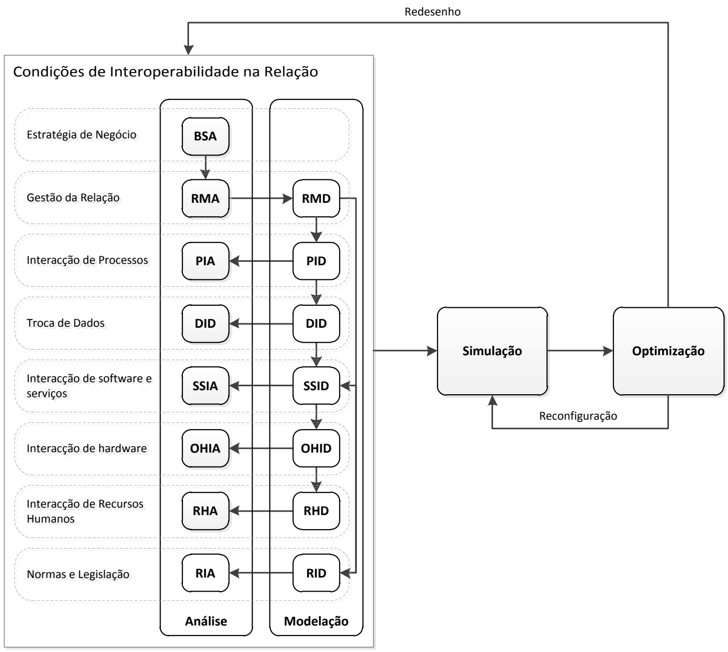

Figura 3.1. Etapas da metodologia para análise e redesenho de colaborações na cadeia de abastecimento.

Na primeira etapa, o objectivo é avaliar cada aspecto que rege a interação entre empresas. Teoricamente, é considerado que uma relação entre empresas é composta pelos factores:

4

estratégia de negocio, gestão das relações, interação de processos, recursos humanos, troca de dados, interação entre normas e legislação, influências culturais, interação entre software e serviços, e interação entre hardware. A análise da relação passa por avaliar qual a configuração de interoperabilidade existente entre cada par de empresas em cada um destes aspectos.

A etapa seguinte corresponde à modelação dos fluxos de material, informação e monetário. Esta etapa ocorre parcialmente em simultâneo com a primeira etapa. O processo de analise e modelação é orientado pelos princípios:

1. Análise da estratégia de negocio (BSA);
2. Analise da gestão das relações (RMA);
3. Decomposição da gestão das relações (RMD);
4. Decomposição de processos (PID);
5. Avaliação dos processos (PIA);
6. Decomposição da troca de dados (DID);
7. Avaliação da troca de dados (DIA);
8. Decomposição de software e serviços (SSID);
9. Avaliação de software e serviços (SSIA);
10. Decomposição da interação entre hardware (OHID);
11. Avaliação da interação entre hardware (OHIA);
12. Decomposição de normas e legislação (RID);
13. Avaliação das normas e legislação (RIA);
14. Decomposição dos recursos humanos (RHD);
15. Avaliação dos recursos humanos (RHA);
16. Avaliação das influências culturais (CIA).

A terceira etapa corresponde a simulação do sistema real em ambiente simulado de forma a medir o desempenho da relação e, posteriormente, realizar optimização da relação na quarta etapa.

4 Planeamento do caso de estudo

O caso de estudo possui 3 componentes: recolha, tratamento e validação dos dados com a NOME_DA_EMPRESA. A componente de recolha corresponde à primeira e segunda fase da metodologia que decorrem interactivamente. A recolha é orientada pelos princípios de análise de decomposição da metodologia apresentados na secção anterior, de acordo com as fases apresentadas na Figura 4.1.

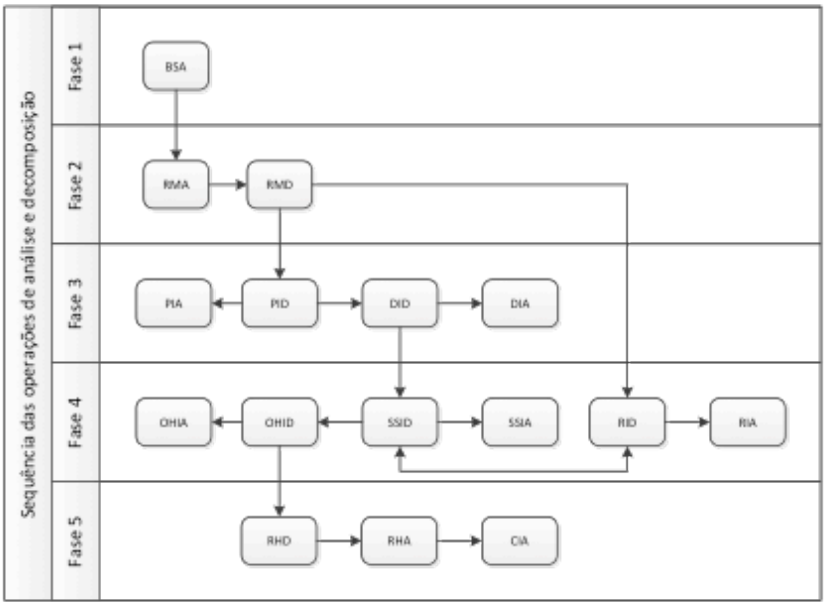

Figura 4.1. Sequência dos princípios de análise de decomposição distribuídos por fases da recolha de dados do caso de estudo.

O processo de tratamento de dados resulta da aplicação dos princípios de análise e decomposição, tal como é apresentado na secção 1, e da construção de um modelo de simulação dos processos de negocio da NOME_DA_EMPRESA com fornecedores com os dados recolhidos. A integração de dados num modelo só, utiliza um modelo baseado na teoria axiomática, que relaciona todos os dados recolhidos de acordo com relações de dependência. Esta dependência rege a criação do cenário atual daquilo que é a relação atual da NOME_DA_EMPRESA com os fornecedores. Através da simulação e reconfiguração dos dados recolhidos são criados vários cenários que poderão melhorar o desempenho da relação em termos de custos, tempo e níveis de serviço. Esta ultima etapa resulta da optimização utilizando desenho de experiencias, método Taguchi e/ou método da superfície de resposta.

4.1 Benefícios

Em cada uma das fases de investigação serão elaborados relatórios intermédios entregues à NOME_DA_EMPRESA, à medida que as fases de implementação são desenvolvidas. No fim da investigação, é entregue um relatório final detalhado e material científico para apreciação. Só após o parecer da NOME_DA_EMPRESA é que os resultados são publicados, garantindo total anonimato das empresas envolvidas.

No fim do caso de estudo, as soluções que permitem melhorar o desempenho da relação são apresentadas à NOME_DA_EMPRESA de formar a validar e fornecer a informação de que permite melhorar a relação com os fornecedores escolhidos.

4.2 Garantias

No decorrer deste caso de estudo, é garantida total confidencialidade dos dados recolhidos bem como do tratamento de dados posterior. Nenhum dos dados recolhidos será divulgado entre empresas (NOME_DA_EMPRESA e fornecedores) nem publicado sem garantir devidamente o anonimato dos intervenientes.

5 Resumo de dados a recolher

Os dados necessários para operacionalizar a metodologia estão associados às fases do caso de estudo apresentado na secção anterior. Contudo, alguns dados preliminares são necessários de forma a caracterizar a empresa selecionada e as suas parceiras de negócio. Nesse sentido, a secção descreve a fase 0 como uma fase preliminar e discrimina os dados necessários.

Na descrição das fases seguintes, ressalva-se que estas apenas constituem linhas de orientação para o diálogo com os profissionais da NOME_DA_EMPRESA e fornecedores. O desenvolvimento do caso de estudo levará a que muitas destas questões sejam esclarecidas através do diálogo e não por entrevista direta.

5.1 Fase 0 – Dados preliminares da relação de negócio

De forma a estabelecer a relação de negocio base para aplicação da metodologia é necessário identificar quais os fornecedores da NOME_DA_EMPRESA e qual o seu papel na relação. Para o efeito, é necessário recolher os dados:

- Nome do fornecedor
- Componentes ou materiais fornecidos
- Produto da NOME_DA_EMPRESA que está associado a esses componentes ou materiais
- Posição na cadeia de abastecimento (fornecedor de 1ª, 2ª ou Nª linha).

De forma a caracterizar cada um dos fornecedores sugere-se a seguinte classificação:

1. Qual a relevância do fornecedor para o negocio?

☐	☐	☐	☐	☐
1	2	3	4	5
Pouco relevante		Relevante		Muito relevante

2. Com que frequência ocorrem falhas em pedidos?

☐	☐	☐	☐	☐
1	2	3	4	5
Pouco frequente		Frequente		Muito frequente

3. Com que frequência ocorrem atrasos em entregas?

☐	☐	☐	☐	☐
1	2	3	4	5
Pouco frequente		Frequente		Muito frequente

4. Possui um fornecedor alternativo caso este falhe?

☐	☐
Sim	Não

5. Qual o nível de confiança com o fornecedor?

☐	☐	☐	☐	☐
1	2	3	4	5
Muito baixo		Indiferente		Muito alto

6. Até que nível considera as competências deste fornecedor adequadas ao negocio?

1	2	3	4	5
Muito fracas	Fracas	Médias	Boas	Muito boas

5.2 Fase 1 – Avaliação da Estratégia de Negócio (BSA)

Na primeira fase é realizada a avaliação da estratégia de negocio (BSA), onde se pretende verificar que objectivos foram previamente acordados. Para o efeito, é solicitado uma **cópia das condições gerais para fornecimento da NOME_DA_EMPRESA**, de forma a verificar quais os aspectos que são preestabelecidos.

De forma a avaliar a estratégia da relação, tanto a NOME_DA_EMPRESA como os fornecedores são inquiridos nos seguintes aspectos:

1. Qual o grau de detalhe dos objectivos estabelecidos para a colaboração? (selecione a opção mais adequada)
   - Nenhum. As encomendas são planeadas caso-a-caso.
   - Contrato verbal.
   - Foi assinado um contrato com todas as condições especificadas pela NOME_DA_EMPRESA.
   - Todos os objectivos foram previamente acordados.
   - Foram revistas todas as competências e capacidades de forma a estabelecer uma relação de vantagem mútua.

2. De que forma considera que os objectivos são claros para ambas as partes?
   - Não foram definidos objectivos.
   - Falhas frequentes.
   - Falhas ocasionais devido à falta de definição de alguns aspectos. Existe um potencial conflito de interesses.
   - Claro para ambas as partes.
   - Foi realizada uma revisão abrangente do acordo de forma a evitar um conflito de interesses.

3. Considera que os objectivos da colaboração estão devidamente alinhados com os objectivos individuais de cada empresa?
   - Objectivos isolados. Trabalhamos para objectivos individuais.
   - Parcerias ocasionais.
   - Os parceiros partilham a mesma estratégia.
   - Objectivos completamente alinhados. Os parceiros partilham da mesma estratégia e revêm continuamente as competências para lutar por uma parceria competitiva.

5.3 Fase 2 – Avaliação da gestão da relação (RMA)

Nesta fase é pretendido verificar até que ponto a relação com os fornecedores foi definida, desde o seu inicio até ao fim do contracto. Nesse sentido, são propostas as questões:

1. Que tipo de critério foi utilizado para a escolha do fornecedor?
   - ☐ Nenhum. Foi selecionado o primeiro fornecedor disponível.
   - ☐ Foi recomendado por outras empresas.
   - ☐ Foi selecionado um fornecedor certificado.
   - ☐ Foram revistas todas as capacidades técnicas e recursos que satisfazem os requisitos materiais.
   - ☐ Foi realizada uma revisão extensiva de competências de forma a escolher um parceiro com o qual podemos beneficiar mutuamente e crescer a relação a longo prazo.
2. Qual a duração desta relação de negocio?
   - ☐ Curto prazo.
   - ☐ Médio prazo.
   - ☐ Longo prazo.
3. Com que frequência se reúne com o seu parceiro para rever o progresso da colaboração?
   - ☐ Nunca. Apenas quando formalizamos o contracto.
   - ☐ Anualmente.
   - ☐ Mensalmente.
   - ☐ Semanalmente.
   - ☐ Diáriamente
4. Como classifica a definição das responsabilidades na relação?
   - ☐ Mal definidas. Existem demasiadas lacunas de responsabilidade.
   - ☐ Definidas, mas com necessidade de melhoria.
   - ☐ Bem definidas. Não existem problemas relativamente à indefinição de responsabilidades.
5. O poder na relação está distribuído igualmente pelos dois parceiros?
   - ☐ Não. O nosso parceiro toma decisões que nos afectam directamente
   - ☐ Não, mas participamos na tomada de decisão
   - ☐ Sim. Ambas as empresas têm o mesmo poder na tomada de decisão.
   - ☐ Não, mas o nosso parceiro participa na tomada de decisão.
   - ☐ Não. Nós somos a empresa governante e as decisões que tomamos afectam o nosso parceiro.

5.4 Fase 2 – Decomposição da gestão da relação (RMD)

Na decomposição da forma como as relações são geridas, pretende-se descrever:

- A monitorização dos parceiros;
- A atribuição de responsabilidades (qual a empresa responsável por cada processo ou atividade, custos e penalizações);
- Os, eventuais, planos de contingência para falhas na colaboração que tenham por origem falhas nos sistemas de informação (de origem técnica ou de utilizadores).

5.5 Fase 3 – Decomposição dos processos (PID)

Nesta fase, pretende-se identificar e caracterizar os processos realizados internamente e na interface das relações que ocorram no âmbito da cadeia de abastecimento. Os dados requeridos para esta fase são:

- Descrição dos processos internos da NOME_DA_EMPRESA:
  - Fornecimento:
    - Procedimento para colocação de encomenda ao fornecedor
    - Frequência de encomenda
    - Horizonte de planeamento
    - Tempo de resposta do fornecedor e prazo de cancelamento da encomenda.
    - Procedimento para realização do pagamento.
    - Procedimento para recepção de componentes ou matéria prima.
    - Local de descarga da matéria prima.
    - Armazenamento (dias de stock).
  - Produção:
    - Tempo de produção
    - Frequência de produção
    - Razão de materiais/produto final (BOM)
    - Quantidade produzida (por unidade de tempo)
    - % desperdício.
- Descrição dos processos do fornecedor:
  - Entrega:
    - Tempo desde que a ordem foi colocada até ser expedida
    - Especificações de embalamento e acondicionamento de cargas
    - Especificações de etiquetagem
- Descrição dos processos de interface:
  - Transporte de componentes do fornecedor para a NOME_DA_EMPRESA
    - Tempo de transporte
- Desenho dos fluxos de material, informação e monetários e distribuição pelas secções internas da NOME_DA_EMPRESA (construção de modelo de processos de negocio)
- Desenho da interface de negocio.

5.6 Fase 3 – Avaliação dos processos (PIA)

Na avaliação de processos (PIA), pretende-se verificar a forma como estes estão definidos e devidamente alinhados com o fornecedor. As questões propostas são as que se seguem:

1. Considera que os processos da NOME_DA_EMPRESA estão devidamente alinhados com o seu fornecedor?
   - ☐ Mal alinhados. Existem demasiadas falhas na responsabilidade gerando conflitos.
   - ☐ Bem alinhados, mas com ocorrência ocasional de problemas.
   - ☐ Bem alinhados e visíveis para ambos os parceiros. Não ocorrem problemas por má definição de responsabilidade.
2. Como avalia a distribuição dos processos da cadeia de abastecimento ao longo das secções da NOME_DA_EMPRESA?
   - ☐ Ineficiente (existem demasiadas tarefas para um só sector ou demasiados sectores a lidar com a mesma tarefa).
   - ☐ Funcional. Cada sector lida com uma atividade especifica.
   - ☐ Eficiente. As tarefas estão distribuídas de forma eficiente pelos sectores tendo em conta os seus recursos e capacidade.
3. Relativamente ao seu fornecedor, tem noção do quão bem distribuídos estão estes processos pelas secções?
   - ☐ Mal definidos. Existe dificuldade em rastrear uma encomenda ao longo do nosso parceiro.
   - ☐ Definidos funcionalmente. Um sector para cada processo.
   - ☐ Bem definidos. O processo do fornecedor é totalmente visível e sabemos com quem contactar para cada situação.

5.7 Fase 3 – Decomposição da troca de dados (DID)

Para cada fluxo de informação desenhado em PID, é necessário detalhar os dados subjacentes a cada processo ou atividade, de forma a saber que dados são processados, transferidos e armazenados. Dessa forma, para cada fluxo de informação é necessário verificar:

- Informação de processos (estados dos processos, como por exemplo em que fase de produção se encontra um produto ou localização da entrega).
- Informação do produto (identificação electrónica, histórico de processos executados e onde foram executados, etc.).
- Informação comunicada nas operações da cadeia de abastecimento (por exemplo, quantidade encomendada, prazo, contexto de encomenda [normal ou urgente], etc.).
- Se a informação é protegida por encriptação.
- Procedimentos de comunicação para realizar encomenda, solicitação de factura e dados de pagamento, informação de processo (estado de encomenda, estado da produção, estado do transporte);
- Tempo de comunicação (exemplo, quanto tempo leva o fornecedor a confirmar uma encomenda).
- Formatos de dados trocados

- Existência de serviços de conversão de dados
- Existência de acordo quanto a formato de dados trocados
- Existência de acordo de terminologia utilizada

5.8 Fase 3 – Avaliação da troca de dados (DIA)

Na avaliação da troca de dados, pretende-se verificar até que ponto esta é bem sucedida nas atividades da cadeia de abastecimento. Nesse sentido, são propostas as questões:

1. Para cada fluxo de informação, verificar:
   a. Qual a percentagem de informação incorreta proveniente do seu fornecedor?

1	2	3	4	5
0 %	<10%	<20%	<30%	<40%

   b. Qual a percentagem de atrasos de informação por parte do seu fornecedor?

1	2	3	4	5
0 %	<10%	<20%	<30%	<40%

2. Avalie se os canais de comunicação existentes entre si e o seu parceiro estão bem definidos? (selecione a opção que mais se adequa).
   - ☐ Não definido. O processo de comunicação não foi definido e a comunicação é planeada caso-a-caso, optando por uma ou várias formas de comunicação não standard para realizar um pedido.
   - ☐ Mal definido. Embora existam canais de comunicação estabelecidos, muitas vezes são necessários contactos adicionais por outra via (telefone, e-mail, etc.)
   - ☐ Definido. Existe um processo standard para realizar o procedimento normal.
   - ☐ Bem definido. Existe um procedimento standard para a comunicação normal e procedimentos para lidar com situações excepcionais (como por exemplo planos de contingência).
3. Avalie a facilidade que tem em contactar com a pessoa responsável em cada secção.
   - ☐ Muito difícil. Não foram definidas as responsabilidades ou o nosso parceiro não nos comunica devidamente as alterações de pessoal.
   - ☐ Difícil. Foram definidas as responsabilidades, mas o nosso parceiro não nos comunica alterações de pessoal (por exemplo, férias, alterações de postos de trabalho, etc.), gerando atrasos.
   - ☐ Médio. Os pontos de contacto foram definidos.
   - ☐ Muito fácil. Pontos de contacto bem definidos. Todas as alterações nos responsáveis de secção são previamente comunicados.
4. Como avalia o armazenamento e troca de dados entre si e o seu parceiro? Escolha a opção que mais se adequa à situação da NOME_DA_EMPRESA.
   - ☐ Troca manual – As bases de dados são isoladas, e a informação é transferida manualmente.
   - ☐ Troca de dados electrónica – as bases de dados são isoladas, mas estão ligadas electronicamente (por exemplo EDI, e-mail, etc.).
   - ☐ É utilizada a mesma base de dados, mas com software diferente.
   - ☐ É partilhada a mesma base de dados e aplicações.
5. Os serviços de comunicação são rápidos o suficiente para as necessidades de comunicação com o seu parceiro?

- ☐ Muito lenta. o canal de comunicação é totalmente ineficiente face às necessidades do negócio
- ☐ Lenta – o tempo de espera face à resolução do problema afecta a performance da minha empresa reflectida em atrasos e custos.
- ☐ Mediana – Satisfaz as necessidades dos pedidos, mas ocasionalmente sou contactado para mais esclarecimentos ou mais informação.
- ☐ Rápida – a solicitação de um pedido de recuperação é atendida em tempo útil, não causando transtorno para a empresa.
- ☐ Perfeitamente sincronizada – O pedido é realizado com o mínimo de interação humana, sendo colocado logo no sistema de informação. Toda a informação necessária para a tomada de decisão é fornecida e só tenho de aguardar pela resolução do problema.

6. Quão frequentemente ocorrem falhas de comunicação?

- ☐ Nunca
- ☐ Uma vez por ano
- ☐ Uma vez por mês
- ☐ Uma vez por semana
- ☐ Diariamente

7. Têm necessidade de converter dados provenientes do seu fornecedor?

- ☐ Sempre. O nosso fornecedor utiliza um sistema totalmente diferente do nosso e necessitamos regularmente de converter a informação.
- ☐ Frequentemente.
- ☐ Ocasionalmente.
- ☐ Raramente. Só em situações pontuais.
- ☐ Nunca. Os formatos foram previamente acordados e, caso haja essa necessidade, o nosso fornecedor deve converter os dados antes de enviar.

8. Qual a percentagem de dados que são necessários converter?

☐	☐	☐	☐	☐
0 %	<10%	<20%	<30%	<40%

5.9 Fase 4 – Decomposição do software e serviços utilizados (SSID)

Após as fases PID e DID, pretende-se designar cada tipo de serviço/aplicação utilizada em cada processo de negócio e em cada fluxo de informação. Com esse intuito, os itens que devem ser verificados são:

- Identificação dos serviços e software utilizados para suporte das atividades (exemplos: EDI, ERP, CRM, e-MP, E-mail, Fax, telefone);
- Descrição dos serviços de segurança e privacidade;

5.10 Fase 4 – Avaliação de software e serviços utilizados (SSIA)

Para cada serviço e software identificado, são propostas as seguintes questões de avaliação:

1. O software utilizado é compatível com o software do fornecedor?

- ☐ Sem opinião
- ☐ Não. Existe necessidade de converter os dados antes de serem utilizados.
- ☐ Usamos aplicações distintas mas que são compatíveis.
- ☐ Sim, utilizamos aplicações semelhantes que utilizam os mesmos serviços e formatos de dados.
- ☐ Utilizamos uma solução integrada de software (por exemplo SAP, ERP's ou CRM's, etc.), logo não existe incompatibilidade.

2. Existem limitações internas da NOME_DA_EMPRESA devido a incompatibilidade de sistemas operativos?
   - ☐ Sem opinião
   - ☐ Não. Mantemos computadores com outras versões de sistemas operativos para garantir compatibilidade com software e equipamento mais antigo.
   - ☐ Não. O sistema operativo é semelhante para toda a NOME_DA_EMPRESA.
   - ☐ Não. O software utilizado é compatível com uma vasta gama de sistemas operativos.
3. Existem limitações relativamente ao uso de sistemas operativos diferentes entre a NOME_DA_EMPRESA e o seu fornecedor?
   - ☐ Sem opinião
   - ☐ Não. Temos de converter os dados na NOME_DA_EMPRESA antes de os usar nas nossas aplicações que funcionam em sistema operativo diferente.
   - ☐ Não. Solicitamos ao nosso fornecedor que converta os dados antes de nos enviar.
   - ☐ Não. A NOME_DA_EMPRESA requer aos fornecedores que adquiram SO compatível com o software.
   - ☐ Não. O software utilizado é compatível entre ambas as empresas.
4. Como avalia os serviços de segurança e privacidade utilizados entre a NOME_DA_EMPRESA e o fornecedor?
   - ☐ Não utilizamos serviços de segurança.
   - ☐ Serviços de segurança independentes. Cada empresa utiliza o seu serviço interno.
   - ☐ Segurança definida pela NOME_DA_EMPRESA ou clientes NOME_DA_EMPRESA.
   - ☐ Serviços definidos bilateralmente.
5. O software e serviços são geridos por:
   - ☐ Secção da NOME_DA_EMPRESA dedicada a informática.
   - ☐ Empresa externa.
6. Existem limitações à escalada tecnológica devido à utilização de equipamento informático antigo (por exemplo Windows XP para utilizadores ou Windows 95/98 devido a compatibilidade com alguns equipamentos)??
   - ☐ Sim.
   - ☐ Em alguns casos.
   - ☐ Não.
7. Qual(ais) o factor que tem(êm) mais peso na utilização de sistemas operativos e equipamentos mais antigos?
   - ☐ Custos
   - ☐ Compatibilidade com software
   - ☐ Compatibilidade com equipamento industrial
   - ☐ Compatibilidade com hardware
   - ☐ Formação dos funcionários

5.11 Fase 4 – Decomposição da interação entre hardware (OHID)

Para cada processo e fluxo de informação, é necessário designar:

- Cada tipo de equipamento ou hardware utilizado (por exemplo: computador, sistema de etiquetagem, equipamento de comunicação, etc.);
- Qual o tipo de interação entre os equipamentos indicados (de maquina-maquina, homem-maquina e homem-humano);
- Quais os requisitos para operacionalizar estes equipamentos (rede, software, sistema operativo, hardware, etc.).

5.12 Fase 4 – Avaliação da interação entre hardware (OHIA)

Para cada equipamento identificado sugere-se a avaliação:

1. Qual o nível de compatibilidade dos equipamentos utilizados?

   - ☐ Nenhum. O equipamento funciona isoladamente para um propósito único.
   - ☐ Parcial. É utilizável em software e hardware especifico.
   - ☐ Total. O equipamento interage com todo o tipo de hardware e software existente nas instalações.

5.13 Fase 4 – Decomposição das normas e legislação (RID)

A decomposição das normas e legislação aplicáveis na colaboração entre a NOME_DA_EMPRESA e fornecedores é realizada através da analise dos termos e condições disponibilizados no site da NOME_DA_EMPRESA.

5.14 Fase 4 – Avaliação das normas e legislação (RIA)

Para avaliar as normas e legislação aplicáveis na colaboração, é proposto avaliar:

1. Se as normas e legislação são compatíveis entre a NOME_DA_EMPRESA e o fornecedor?

   - ☐ Não. Existe sobreposição de normas entre ambas as empresas.
   - ☐ Sim. As normas de negocio foram discutidas e acordadas entre os parceiros.
   - ☐ As normas estão de acordo com a legislação em vigor.
   - ☐ As normas foram impostas por contrato.
   - ☐ As normas e legislação são totalmente compatíveis.

5.15 Fase 5 – Decomposição dos recursos humanos (RHD)

A decomposição dos recursos humanos refere-se à identificação dos os processos que são realizados por atividade humana, que envolvem a utilização dos sistemas de informação. Nesse sentido, pretende-se caracterizar este factor nos seguintes itens:

- Quantidade de recursos humanos por processos/equipamento/sistema de informação.
- Número de horas de trabalho
- Turnos de funcionamento (tempo por turno e quantidade de turnos por dia
- Pausas

5.16 Fase 5 – Avaliação dos recursos humanos (RHA)

Nesta fase pretende-se avaliar qual a eficiência dos recursos humanos a desempenhar as tarefas da cadeia de abastecimento. Nesse sentido, as questões propostas são:

1. Com que frequência os seus funcionários faltam ao trabalho (falta injustificada)?
   - ☐ Nunca.
   - ☐ Uma vez por ano.
   - ☐ Uma vez por mês.
   - ☐ Uma vez por semana.
   - ☐ Uma vez por dia.
2. Como avalia a preparação dos seus funcionários para operarem com os sistemas de informação da empresa?
   - ☐ Insuficiente.
   - ☐ Adequada.
   - ☐ Acima do expectável.
3. Qual a eficiência dos seus funcionários na utilização dos sistemas de informação da sua empresa?
   - ☐ 0 a 20%.
   - ☐ 20 a 40%.
   - ☐ 40 a 60%.
   - ☐ 60 a 80%.
   - ☐ 100%.

5.17 Fase 5 – Avaliação das influências culturais (CIA)

Por ultimo, pretende-se avaliar qual a influencia que factores culturais têm no desempenho de funções na cooperação. Com esse intuito, as questões propostas são:

1. Trabalham com funcionários dos vossos fornecedores nas vossas instalações?
   - ☐ Sim.
   - ☐ Não.
2. Como classifica as características culturais da sua organização?
   - ☐ Não existe uma cultura organizacional estabelecida. Cada individuo preserva a sua identidade cultural.
   - ☐ Existe uma cultura organizacional institucionalizada. Os funcionários conhecem e partilham os valores da organização.
   - ☐ Existe uma cultura extra-organizacional entre a nossa empresa e os parceiros, mantida através de encontros ocasionais entre funcionários das empresas.
3. Existem barreiras linguísticas na colaboração?
   - ☐ Sim.
   - ☐ Não.
4. Foi estabelecida uma língua secundária para a comunicação entre empresas?
   - ☐ Sim.
   - ☐ Não.

5. Com que frequência ocorrem conflitos entre funcionários das empresas devido a diferenças culturais?

- [ ] Nunca.
- [ ] Uma vez por ano.
- [ ] Uma vez por mês.
- [ ] Uma vez por semana.
- [ ] Uma vez por dia.

6 Referências

IEEE. (1990). IEEE Standard Glossary of Software Engineering Terminology.

FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

UNIDEMI R&D Unit in Mechanical and Industrial Engineering

BIXLARGIE
PTDC/EME-GIN/115617/2009

Questionário de identificação e enquadramento de fornecedores

O presente questionário tem o objectivo de identificar e caracterizar os fornecedores da NOME_DA_EMPRESA.
O conjunto de questões apresentado possui um formato estruturado de forma a introduzir manualmente os dados de acordo com o tipo de questão.
Qualquer informação que considere útil para cada uma das questões, poderá escrever no campo de comentários abaixo de cada questão ou enviar um ficheiro (por exemplo, um Print Screen, folha de excel, etc.) em anexo por e-mail junto deste questionário e escrevendo no campo de comentários o nome ou referência ao ficheiro.
Em caso de dúvida, contactar:

- Pedro Espadinha da Cruz
- E-mail: p.cruz@campus.fct.unl.pt
- Telemóvel: 963507251

A. Enquadramento da Empresa:

A.1. Nome da empresa: ______________________

B. Identificação de Fornecedores

B.1. Indique os seus fornecedores principais de material/componentes:

Nome do fornecedor	Componentes/materiais comprados	Produto relacionado	País
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Comentários (facultativo):

1

B.3. Como avalia os fornecedores identificados nos seguintes parâmetros:

1. Qual a relevância de cada fornecedor para o negocio (selecione um valor por cada fornecedor)?

Nome do fornecedor	Pouco relevante		Relevante		Muito Relevante
	1	2	3	4	5
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐
7	☐	☐	☐	☐	☐
8	☐	☐	☐	☐	☐
9	☐	☐	☐	☐	☐
10	☐	☐	☐	☐	☐

Comentários (facultativo):

2. Com que frequência os fornecedores falham os pedidos (selecione um valor por cada fornecedor)?

Nome do fornecedor	Pouco frequente		frequente		Muito frequente
	1	2	3	4	5
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐
7	☐	☐	☐	☐	☐
8	☐	☐	☐	☐	☐
9	☐	☐	☐	☐	☐
10	☐	☐	☐	☐	☐

Comentários (facultativo):

5. Até que nível considera as competências de cada fornecedor adequadas ao negocio (selecione um valor por cada fornecedor)?

Nome do fornecedor	Muito fracas 1	Fracas 2	Médias 3	Boas 4	Muito boas 5
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐
7	☐	☐	☐	☐	☐
8	☐	☐	☐	☐	☐
9	☐	☐	☐	☐	☐
10	☐	☐	☐	☐	☐

Comentários (facultativo):

3. Com que frequência os fornecedores se atrasam nas entregas (selecione um valor por cada fornecedor)?

Nome do fornecedor	Pouco frequente 1	2	frequente 3	4	Muito frequente 5
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐
7	☐	☐	☐	☐	☐
8	☐	☐	☐	☐	☐
9	☐	☐	☐	☐	☐
10	☐	☐	☐	☐	☐

Comentários (facultativo):

4. Qual o nível de confiança de cada fornecedor (selecione um valor por cada fornecedor)?

Nome do fornecedor	Muito baixo 1	2	Indiferente 3	4	Muito alto 5
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐
4	☐	☐	☐	☐	☐
5	☐	☐	☐	☐	☐
6	☐	☐	☐	☐	☐
7	☐	☐	☐	☐	☐
8	☐	☐	☐	☐	☐
9	☐	☐	☐	☐	☐
10	☐	☐	☐	☐	☐

Comentários (facultativo):

Annex H Phase 1 and phase 2 questionnaire

FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

R&D Unit in Mechanical and Industrial Engineering

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Questionário da Fase 1 e Fase 2

A. Enquadramento do par de empresa:

A.1. Nome da empresa focal: ____________________

A.2. Nome do fornecedor: ____________________

B. Avaliação da Estratégia de Negócio (BSA)

B.1. De que forma considera que os objectivos são claros para ambas as partes?

- ☐ Falhas frequentes.
- ☐ Falhas ocasionais devido à falta de definição de alguns aspectos. Existe um potencial conflito de interesses.
- ☐ Claro para ambas as partes.
- ☐ Foi realizada uma revisão abrangente do acordo de forma a evitar um conflito de interesses.

B.2. Considera que os objectivos da colaboração estão devidamente alinhados com os objectivos individuais de cada empresa?

- ☐ Objectivos isolados. Trabalhamos para objectivos individuais.
- ☐ Parcerias ocasionais.
- ☐ Os parceiros partilham a mesma estratégia.
- ☐ Objectivos completamente alinhados. Os parceiros partilham da mesma estratégia e revêm continuamente as competências para lutar por uma parceria competitiva.

C. Avaliação da Gestão da Relação (RMA)

C.1. Qual a duração desta relação de negocio?

- ☐ Curto prazo.
- ☐ Médio prazo.
- ☐ Longo prazo.

C.2. Com que frequência se reúne com o seu parceiro para rever o progresso da colaboração?

- ☐ Nunca. Apenas quando formalizamos o contracto.
- ☐ Anualmente.
- ☐ Mensalmente.
- ☐ Semanalmente.
- ☐ Diariamente

C.3. Como classifica a definição das responsabilidades na relação?

- ☐ Mal definidas. Existem demasiadas lacunas de responsabilidade.
- ☐ Definidas, mas com necessidade de melhoria.
- ☐ Bem definidas. Não existem problemas relativamente à indefinição de responsabilidades.

1

C.5. Como avalia o grau de conhecimento do seu parceiro para desempenhar funções?

- ☐ Inadequado. O nosso parceiro não tem conhecimento nem a formação necessários para desempenhar as funções nesta colaboração.
- ☐ Conhecimento e formação apropriados.
- ☐ Conhecimento e formação são um requisito da NOME_DA_EMPRESA, pelo que não é selecionado um parceiro sem as capacidades necessárias para estabelecer a relação de negocio.
- ☐ Conhecimento e formação satisfazem completamente as necessidades de negócio e permitirão, um dia, escalar o negócio para outro nível.

D. Decomposição da Gestão da Relação (RMD)

Aspectos a verificar:

- Planos de contingência para falhas na colaboração.

D.1. Possuem planos de contingência para falhas em:

- ☐ Sistemas de comunicação de dados
- ☐ Sistemas de armazenamento de dados
- ☐ Equipamento de etiquetagem (ex.º "*Bar code*")
- ☐ Equipamento informático da produção

Annex I Phase 3, 4 and 5 questionnaire

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Questionário das Fase 3, 4 e 5

A. Enquadramento da Empresa:

A.1. Nome da empresa: ______________________________

B. Decomposição dos processos (PID)

B.1. Descrição dos processos internos da NOME_DA_EMPRESA

- Fornecimento/compra:
  - Frequência de encomenda – histórico de dados, amostragem pessoal ou min, méd, máx.
  - *Lead-time* – verificar 1 semana, de acordo com o contrato.
- Recepção e armazém:
  - Procedimento de recepção de material
    - Se é armazenado, saber:
      - Dias de stock
      - Armazenado embalado (ex.º paletes) ou individualmente.
- Pagamentos:
  - Como são aplicadas as penalizações? Como crédito ou cobradas pontualmente?
- Produção:
  - Tempo de produção
  - Razão de materiais/produto final (BOM parcial)
  - Desperdício/não conformes (%)
  - Custos por unidade produzida
- Gestão de não conformes (Logística inversa):
  - Os produtos são armazenados imediatamente ou são descartados?
  - Os produtos não conformes são classificados antes de proceder à sua recuperação ou eliminação?
  - Qual o procedimento para solicitar o retorno de inventário? (caso-a-caso ou procedimento pre-definido)

B.2. Descrição dos processos físicos de interface:

- Transporte dos componentes do fornecedor para a NOME_DA_EMPRESA:
  - Tempo de transporte (min, méd, máx)

C. Avaliação dos processos (PIA)

C.1. Considera que os processos da NOME_DA_EMPRESA estão devidamente alinhados com o seu fornecedor?

Essex	Stewart EFI	Starlim	
☐	☐	☐	Mal alinhados. Existem demasiadas falhas na responsabilidade gerando conflitos.
☐	☐	☐	Bem alinhados, mas com ocorrência ocasional de problemas.
☐	☐	☐	Bem alinhados e visíveis para ambos os parceiros. Não ocorrem problemas por má definição de responsabilidade.

C.2. Como avalia a distribuição dos processos da cadeia de abastecimento ao longo das secções da NOME_DA_EMPRESA?

Essex	Stewart EFI	Starlim	
☐	☐	☐	Ineficiente (existem demasiadas tarefas para um só sector ou demasiados sectores a lidar com a mesma tarefa).
☐	☐	☐	Funcional. Cada sector lida com uma atividade especifica.
☐	☐	☐	Eficiente. As tarefas estão distribuídas de forma eficiente pelos sectores tendo em conta os seus recursos e

1

capacidade.

C.3. Relativamente ao seu fornecedor, tem noção do quão bem distribuídos estão estes processos pelas secções?

- ☐ Mal definidos. Existe dificuldade em rastrear uma encomenda ao longo do nosso parceiro.
- ☐ Definidos funcionalmente. Um sector para cada processo.
- ☐ Bem definidos. O processo do fornecedor é totalmente visível e sabemos com quem contactar para cada situação.

D. Fase 3 – Avaliação da troca de dados (DIA)

Na avaliação da troca de dados, pretende-se verificar até que ponto esta é bem sucedida nas atividades da cadeia de abastecimento. Nesse sentido, são propostas as questões:

D.1. Para cada fluxo de informação, verificar:

a. Qual a percentagem de informação incorreta proveniente do seu fornecedor?

	1 0 %	2 <10%	3 <20%	4 <30%	5 <40%
SUPPLIER1	☐	☐	☐	☐	☐
SUPPLIER2	☐	☐	☐	☐	☐
SUPPLIER3	☐	☐	☐	☐	☐

b. Qual a percentagem de atrasos de informação por parte do seu fornecedor?

1 0 %	2 <10%	3 <20%	4 <30%	5 <40%
☐	☐	☐	☐	☐

D.2. Avalie se os canais de comunicação existentes entre si e o seu parceiro estão bem definidos? (selecione a opção que mais se adequa).

SUPPLIER1	SUPPLIER 2	SUPPLIER3	
☐	☐	☐	Não definido. O processo de comunicação não foi definido e a comunicação é planeada caso-a-caso, optando por uma ou várias formas de comunicação não standard para realizar um pedido.
☐	☐	☐	Mal definido. Embora existam canais de comunicação estabelecidos, muitas vezes são necessários contactos adicionais por outra via (telefone, e-mail, etc.)
☐	☐	☐	Definido. Existe um processo standard para realizar o procedimento normal.
☐	☐	☐	Bem definido. Existe um procedimento standard para a comunicação normal e procedimentos para lidar com situações excepcionais (como por exemplo planos de contingência).

D.3. Avalie a facilidade que tem em contactar com a pessoa responsável em cada secção.

- ☐ Muito difícil. Não foram definidas as responsabilidades ou o nosso parceiro não nos comunica devidamente as alterações de pessoal.
- ☐ Difícil. Foram definidas as responsabilidades, mas o nosso parceiro não nos comunica alterações de pessoal (por exemplo, férias, alterações de postos de trabalho, etc.), gerando atrasos.
- ☐ Médio. Os pontos de contacto foram definidos.
- ☐ Muito fácil. Pontos de contacto bem definidos. Todas as alterações nos responsáveis de secção são previamente comunicados.

D.4. Como avalia o armazenamento e troca de dados entre si e o seu parceiro? Escolha a opção que mais se adequa à situação da NOME_DA_EMPRESA.

- ☐ Troca manual – As bases de dados são isoladas, e a informação é transferida manualmente.
- ☐ Troca de dados electrónica – as bases de dados são isoladas, mas estão

2

ligadas electronicamente (por exemplo EDI, e-mail, etc.).
- ☐ É utilizada a mesma base de dados, mas com software diferente.
- ☐ É partilhada a mesma base de dados e aplicações.

D.5. Os serviços de comunicação são rápidos o suficiente para as necessidades de comunicação com o seu parceiro?
- ☐ Muito lenta. o canal de comunicação é totalmente ineficiente face às necessidades do negócio
- ☐ Lenta – o tempo de espera face à resolução do problema afecta a performance da minha empresa reflectida em atrasos e custos.
- ☐ Mediana – Satisfaz as necessidades dos pedidos, mas ocasionalmente sou contactado para mais esclarecimentos ou mais informação.
- ☐ Rápida – a solicitação de um pedido de recuperação é atendida em tempo útil, não causando transtorno para a empresa.
- ☐ Perfeitamente sincronizada – O pedido é realizado com o mínimo de interação humana, sendo colocado logo no sistema de informação. Toda a informação necessária para a tomada de decisão é fornecida e só tenho de aguardar pela resolução do problema.

D.6. Quão frequentemente ocorrem falhas de comunicação?
- ☐ Nunca
- ☐ Uma vez por ano
- ☐ Uma vez por mês
- ☐ Uma vez por semana
- ☐ Diariamente

D.7. Têm necessidade de converter dados provenientes do seu fornecedor?
- ☐ Sempre. O nosso fornecedor utiliza um sistema totalmente diferente do nosso e necessitamos regularmente de converter a informação.
- ☐ Frequentemente.
- ☐ Ocasionalmente.
- ☐ Raramente. Só em situações pontuais.
- ☐ Nunca. Os formatos foram previamente acordados e, caso haja essa necessidade, o nosso fornecedor deve converter os dados antes de enviar.

D.8. Qual a percentagem de dados que são necessários converter?

☐	☐	☐	☐	☐
0 %	<10%	<20%	<30%	<40%

E. Fase 4 – Decomposição do software e serviços utilizados (SSID)

Após as fases PID e DID, pretende-se designar cada tipo de serviço/aplicação utilizada em cada processo de negócio e em cada fluxo de informação. Com esse intuito, os itens que devem ser verificados são:

- Identificação dos serviços e software utilizados para suporte das atividades (exemplos: EDI, ERP, CRM, e-MP, E-mail, Fax, telefone);
- Descrição dos serviços de segurança e privacidade;

F. Fase 4 – Avaliação de software e serviços utilizados (SSIA)

Para cada serviço e software identificado, são propostas as seguintes questões de avaliação:

F.1. O software utilizado é compatível com o software do fornecedor?
- ☐ Sem opinião
- ☐ Não. Existe necessidade de converter os dados antes de serem utilizados.
- ☐ Usamos aplicações distintas mas que são compatíveis.
- ☐ Sim, utilizamos aplicações semelhantes que utilizam os mesmos serviços e formatos de dados.
- ☐ Utilizamos uma solução integrada de software (por exemplo SAP, ERP's ou CRM's, etc.), logo não existe incompatibilidade.

F.2. Existem limitações internas da NOME_DA_EMPRESA devido a incompatibilidade de sistemas operativos?

- ☐ Sem opinião
- ☐ Não. Mantemos computadores com outras versões de sistemas operativos para garantir compatibilidade com software e equipamento mais antigo.
- ☐ Não. O sistema operativo é semelhante para toda a NOME_DA_EMPRESA.
- ☐ Não. O software utilizado é compatível com uma vasta gama de sistemas operativos.

F.3. Existem limitações relativamente ao uso de sistemas operativos diferentes entre a NOME_DA_EMPRESA e o seu fornecedor?

- ☐ Sem opinião
- ☐ Não. Temos de converter os dados na NOME_DA_EMPRESA antes de os usar nas nossas aplicações que funcionam em sistema operativo diferente.
- ☐ Não. Solicitamos ao nosso fornecedor que converta os dados antes de nos enviar.
- ☐ Não. A NOME_DA_EMPRESA requer aos fornecedores que adquiram SO compatível com o software.
- ☐ Não. O software utilizado é compatível entre ambas as empresas.

F.4. Como avalia os serviços de segurança e privacidade utilizados entre a NOME_DA_EMPRESA e o fornecedor?

- ☐ Não utilizamos serviços de segurança.
- ☐ Serviços de segurança independentes. Cada empresa utiliza o seu serviço interno.
- ☐ Segurança definida pela NOME_DA_EMPRESA ou clientes NOME_DA_EMPRESA.
- ☐ Serviços definidos bilateralmente.

F.5. O software e serviços são geridos por:

- ☐ Secção da NOME_DA_EMPRESA dedicada a informática.
- ☐ Empresa externa.

F.6. Existem limitações à escalada tecnológica devido à utilização de equipamento informático antigo (por exemplo Windows XP para utilizadores ou Windows 95/98 devido a compatibilidade com alguns equipamentos)??

- ☐ Sim.
- ☐ Em alguns casos.
- ☐ Não.

F.7. Qual(ais) o factor que tem(êm) mais peso na utilização de sistemas operativos e equipamentos mais antigos?

- ☐ Custos
- ☐ Compatibilidade com software
- ☐ Compatibilidade com equipamento industrial
- ☐ Compatibilidade com hardware
- ☐ Formação dos funcionários

G. Fase 4 – Decomposição da interação entre hardware (OHID)

Para cada processo e fluxo de informação, é necessário designar:

- Cada tipo de equipamento ou hardware utilizado (por exemplo: computador, sistema de etiquetagem, equipamento de comunicação, etc.);
- Qual o tipo de interação entre os equipamentos indicados (de maquina-maquina, homem-maquina e homem-humano);

- Quais os requisitos para operacionalizar estes equipamentos (rede, software, sistema operativo, hardware, etc.).

H. Fase 4 – Avaliação da interação entre hardware (OHIA)

Para cada equipamento identificado sugere-se a avaliação:

H.1. Qual o nível de compatibilidade dos equipamentos utilizados?

- ☐ Nenhum. O equipamento funciona isoladamente para um propósito único.
- ☐ Parcial. É utilizável em software e hardware especifico.
- ☐ Total. O equipamento interage com todo o tipo de hardware e software existente nas instalações.

I. Fase 4 – Decomposição das normas e legislação (RID)

A decomposição das normas e legislação aplicáveis na colaboração entre a NOME_DA_EMPRESA e fornecedores é realizada através da analise dos termos e condições disponibilizados no site da NOME_DA_EMPRESA.

J. Fase 4 – Avaliação das normas e legislação (RIA)

Para avaliar as normas e legislação aplicáveis na colaboração, é proposto avaliar:

J.1. Se as normas e legislação são compatíveis entre a NOME_DA_EMPRESA e o fornecedor?

- ☐ Não. Existe sobreposição de normas entre ambas as empresas.
- ☐ Sim. As normas de negocio foram discutidas e acordadas entre os parceiros.
- ☐ As normas estão de acordo com a legislação em vigor.
- ☐ As normas foram impostas por contrato.
- ☐ As normas e legislação são totalmente compatíveis.

K. Fase 5 – Decomposição dos recursos humanos (RHD)

A decomposição dos recursos humanos refere-se à identificação dos os processos que são realizados por atividade humana, que envolvem a utilização dos sistemas de informação. Nesse sentido, pretende-se caracterizar este factor nos seguintes itens:

- Quantidade de recursos humanos por processos/equipamento/sistema de informação.
- Número de horas de trabalho
- Turnos de funcionamento (tempo por turno e quantidade de turnos por dia
- Pausas

L. Fase 5 – Avaliação dos recursos humanos (RHA)

Nesta fase pretende-se avaliar qual a eficiência dos recursos humanos a desempenhar as tarefas da cadeia de abastecimento. Nesse sentido, as questões propostas são:

L.1. Com que frequência os seus funcionários faltam ao trabalho (falta injustificada)?

- ☐ Nunca.
- ☐ Uma vez por ano.
- ☐ Uma vez por mês.
- ☐ Uma vez por semana.
- ☐ Uma vez por dia.

L.2. Como avalia a preparação dos seus funcionários para operarem com os sistemas de informação da empresa?

- ☐ Insuficiente.
- ☐ Adequada.
- ☐ Acima do expectável.

L.3. Qual a eficiência dos seus funcionários na utilização dos sistemas de informação da sua empresa?

- ☐ 0 a 20%.
- ☐ 20 a 40%.
- ☐ 40 a 60%.
- ☐ 60 a 80%.
- ☐ 100%.

M. Fase 5 – Avaliação das influências culturais (CIA)

Por ultimo, pretende-se avaliar qual a influencia que factores culturais têm no desempenho de funções na cooperação. Com esse intuito, as questões propostas são:

M.1. Trabalham com funcionários dos vossos fornecedores nas vossas instalações?

- ☐ Sim.
- ☐ Não.

M.2. Como classifica as características culturais da sua organização?

- ☐ Não existe uma cultura organizacional estabelecida. Cada individuo preserva a sua identidade cultural.
- ☐ Existe uma cultura organizacional institucionalizada. Os funcionários conhecem e partilham os valores da organização.
- ☐ Existe uma cultura extra-organizacional entre a nossa empresa e os parceiros, mantida através de encontros ocasionais entre funcionários das empresas.

M.3. Existem barreiras linguísticas na colaboração?

- ☐ Sim.
- ☐ Não.

M.4. Foi estabelecida uma língua secundária para a comunicação entre empresas?

- ☐ Sim.
- ☐ Não.

M.5. Com que frequência ocorrem conflitos entre funcionários das empresas devido a diferenças culturais?

- ☐ Nunca.
- ☐ Uma vez por ano.
- ☐ Uma vez por mês.
- ☐ Uma vez por semana.
- ☐ Uma vez por dia.