Improving Industry 4.0 through Service Science

A Framework to improve the Portuguese Ornamental Stone Sector in BIM Procurement Context

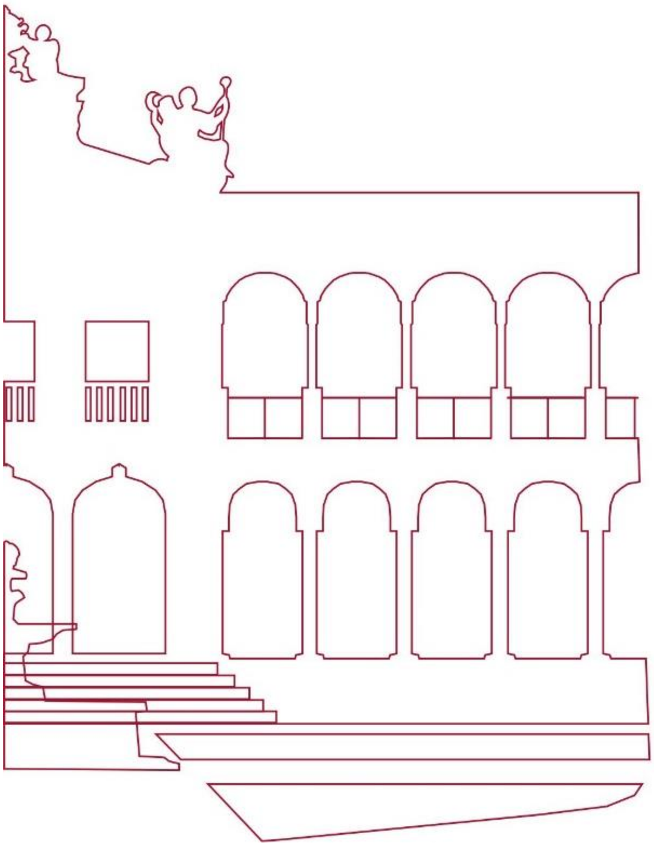
Doutorando

Agostinho Manuel Antunes da Silva

Orientadores
Prof. Doutora Andreia Teixeira Marques Dionísio
Prof. Doutor Luís Alberto Godinho Coelho

Tese apresentada à Universidade de Évora para obtenção do Grau de Doutor em Gestão

Évora, 2018



INSTITUTO DE INVESTIGAÇÃO E FORMAÇÃO AVANCADA

UNIVERSIDADE DE ÉVORA

Improving Industry 4.0 through Service Science

A Framework to improve the Portuguese Ornamental Stone Sector in BIM Procurement Context

Doutorando

Agostinho Manuel Antunes da Silva

Orientadores

Prof. Doutora Andreia Teixeira Marques Dionísio

Prof. Doutor Luís Alberto Godinho Coelho

Tese apresentada à Universidade de Évora para obtenção do Grau de Doutor em Gestão

INSTITUTO DE INVESTIGAÇÃO E FORMAÇÃO AVANÇADA

In this thesis, the citations and references follow the *American Psychological Association* 6th edition style

ABSTRACT

IMPROVING INDUSTRY 4.0 THROUGH **SERVICE SCIENCE**
A Framework to Improve the Portuguese Ornamental Stone Sector
in BIM Procurement Context

This thesis aims an exploratory evaluation of the Industry 4.0 (I4.0) impact on Portuguese Ornamental Stone (OS) firms' response to the Threats resulting from the Building Information Modelling (BIM) procurement.

The transition witnessed from the Third to the Fourth Industrial Age leads to the emergence of paradigms such as BIM, seeking efficiency in Architecture, Engineering and Construction (AEC) through a global approach and procurement oriented towards standardisable products and I4.0, where production comes to be supported by Cyber-Physical Systems (CPS).

Integrated in the AEC supply chain, the OS sector shows Portugal to be the eighth country in OS trade worldwide, and the second per capita, with its competitiveness based on the products customization. BIM represents threats for its sustainability, particularly in firms of the Cluster Portugal Mineral Resources (CPMR).

The literature review showed that Service Science (S-S) is an inter-disciplinary scientific field that combines Organisation with Tchnological Knowledge, with a view to categorizing, innovating and creating value for Service-Systems.

Guided by the pragmatic paradigm and using the mixed methodology of parallel convergence, this research focuses on conceptualization of a Service Science Framework (Inovstone4.0), to which was applied a representative sample of CPMR companies. This Framework has allowed to measure the evolution of Key Concern Indicators (KCI) indexed to stakeholders' concerns, when operations shifts from the current best practices to I4.0 operattions.

From the results, it has been found significant relief of stakeholder's concerns, regarding the time to deliver, costs, footprint and products conformity, when in BIM procurement context, the production evolves to I4.0, allowing to conclude that in technical terms, the impact of I4.0 on the threats arising from BIM procurement in CPMR tends to be positive.

Keywords: Service Science, Industry 4.0, Internet of Things, BIM, Cyber-Physical Systems, Ornamental Stone

RESUMO

DESENVOLVIMENTO DA INDÚSTRIA 4.0 PELA SERVICE SCIENCE
Modelo para a aumentar a Competitividade do Setor das Rochas Ornamentais Português em Contexto de Procurement BIM

O objeto de estudo desta tese é explorar o potencial impacto da Industria 4.0 (I4.0) como resposta às ameaças resultantes da generalização do *Building Information Modelling* (BIM), nas empresas de Rochas Ornamentais (RO) portuguesas.

Na transição da Terceira para a Quarta Era Industrial a que assistimos, emergem paradigmas como o BIM, que busca a eficiência na Arquitetura Engenharia e Construção (AEC) por via de uma abordagem global e de um modelo de *procurement* orientado para produtos standarizados e a I4.0, cuja produção passa a ser suportada por Cyber-Physical Systems (CPS).

Integrado na cadeia de abastecimento da AEC, o setor das RO coloca Portugal como o oitavo país no comércio mundial de RO e segundo per capita, cuja competitividade provém da customização. Do *procurement* BIM, resultarão ameaças à sua sustentabilidade, nomeadamente nas empresas do Cluster Portugal Mineral Resources (CPMR).

Da revisão de literatura verifica-se que a Service Science (S-S) é uma área científica interdisciplinar que combina organização e conhecimento tecnológico, com vista a categorizar, inovar e criar valor aos *service-systems*.

Guiada pelo paradigma pragmatista e utilizando a metodologia mista paralela convergente, esta investigação centrou-se na conceptualização de um modelo S-S, que foi aplicado a uma amostra representativa das empresas do CPMR, permitiu medir de forma exploratória, a evolução das preocupações dos *stakeholders*, operacionalizadas por via de *Key Concerns Indicators* (KCI), quando as operações passam do estado atual, para o *procurement* BIM e produção I4.0.

Dos resultados obtidos, verificou-se um alívio significativo das preocupações dos stakeholders quanto ao prazo de entrega, custo, sustentabilidade e qualidade dos produtos, quando as operações em contexto BIM evoluem para I4.0, permitindo concluir que em termos técnicos, o impacto da I4.0 sobre as ameaças resultantes do procurement BIM tende a ser positivo.

Palavras-chave: Service Science, Industry 4.0, Internet of Things, BIM, Cyber-Physical Systems, Ornamental Stones

ACKNOWLEDGEMENTS

First and foremost, I want to thank my advisors Andreia Dionisio and Luis Coelho. It has been an honour and a pleasure to me, to be their Ph.D. student. I have appreciated all their contributions, friendship, ideas and *pro bono* transfer of knowledge to make my Ph.D. experience, productive and stimulating. The joy, willingness and enthusiasm of the Ph.D. Program Coordinator Cesaltina Pires was contagious and motivational for me, even during tough times in the Ph.D. pursuit. I am also thankful for her friendship and pedagogical skills as professor.

To all professors involved in the Ph.D. Program, I want to thank for all they taught me. All of them have contributed immensely to my personal and academic good time at Évora University. Moreover, these professors have been a source of friendships as well as good advice and collaboration. To Rui Fragoso and Raquel Lucas a special thank you for the friendship. I am also grateful for the classroom mates, specially to Maria José, Teresa and Carlos.

My research was also supported by Cefage and Hercules reserchers, to whom I want to say thank you. My gratefully acknowledge to the IFFA and SAC, for the professional support. For the consistent enthusiasm, dedication to the Service Science cause and support, I want to say thank you to Almaden Research Center researchres, specially to Jim Spohrer.

I want to thank to all my customers and providers, to my partners and workfellows at CEI Group but also to competitors and authority representatives. A very special thanks to the Cluster Portugal Mineral Resources friends: Marta, Tânia, Cláudia and Luís Martins.

My life should not be the same without my friends José Barroso, António Marcos, Vasco Almeida, António Prata, Rui Carvalho, João Paulo, Neto Filipe, Inês Frazão, Joana Frazão, Samuel Delgado, Regina Vitório, Pedro Vazão, Filipe Miguel, António Aguiar, João Silva, Paulo Durão, Luis Lopes and José Mirão, among others. To all of them, my friendship and gratitude.

For the permanent inspiration coming from my father. Although no longer among us he keeps raising me with a love of science and supported me in all my daily pursuits. For the permanent love coming from my mother. For my beloved sisters Ana Maria and Elisabete. For my loving, encouraging, and patient wife Olivia, whose faithful support during the final stages of this Ph.D., is so appreciated. Most of all, for my son, João, the strength of my life. Thank you.

Agostinho da Silva
Évora, 2017

ABBREVIATIONS AND ACRONYMS

3D-BIM	BIM dimension indexed to the Product Geometry
4D-BIM	BIM dimension indexed to the Product Price
4V	Velocity, Voracity, Veracity and Volume
5D-BIM	BIM dimension indexed to the Product Time
6D-BIM	BIM dimension indexed to the Product Sustainability
7D-BIM	BIM dimension indexed to the Product Maintenance
8D-BIM	BIM dimension indexed to the Product Security
ACPMR	Cluster Portugal Mineral Resources Association
AEC	Architectural Engineering and Construction
AECSC	Architecture Engineering and Construction Supply Chain
ASSIMAGRA	Portuguese Federation of Marbles Granites and Related Industries
BIM	Building Information Modelling
CAD	Computer Aided Design
CAD-Customer	Customer that designs in CAD
CBP	Current Best Practices
CBP-OS-Provider	Ornamenatal Stone Provider in Current Best Practices Operation
CBP-Provider	Provider operating in Current Best Practices mode
CEMBUREAU	European Cement Association
CI	Conformity Index
Cockpit I4.0	Cockpit
CPMR	Cluster Portugal Mineral Resources
CPMR-OS	Cluster Portugal Mineral Resources Stone Companies
CPS	Cyber-Physical Systems
CPS-Body	Body of the CPS
CPS-Cockpit	Cockpit I4.0 of the CPS
CRM	Customer Relation Management
CSI	Customer Satisfaction Index
ESCN	National Scientific System (ESCN)
EU	European Union
FACAP	First Mobilizer Project to the Portuguese Footwear Sector
FATEC	Second Mobilizer Project to the Portuguese Footwear Sector

FP-I4.0	Fingerprint I4.0
G-D Logic	Goods Dominant Logic
GDP	Gross Domestic Product
I4.0-OS-Provider	Ornamenatal Stone Provider in Industry 4.0 Operation
I4.0-Provider	Provider operating in I4.0 mode
IC	Industry of Construction
ICSD	Intelligent Connectivity of Smart Devices (ICSD)
ICT	Information and Communication Technologies
IFC	Industrial Foundation Class
IIoT	Industrial Internet of Things
Inov4.0|F	Inovstone4.0 Conceptual Framework
INOVSTONE	Second Mobilizer Project to the Portuguese OS Sector
IO	Innovation Outcomes
IoT	Internet of Things
ISO	International Standard Organization
ISPAR	Interact Serve Propose Agree Realize
KCI	Key Concerns Indicators
KCI_{QUAL}	Qualitative Key Concerns Indicators
KCI_{QUAN}	Quantitative Key Concerns Indicators
KPI	Key Performance Indicators
LH	Leanstone Hornbook
NEWALK	Third Mobilizer Project to the Portuguese Footwear Sector
JETSTONE	First Mobilizer Project to the Portuguese OS Sector
OC1	CBP-Providing in CAD-Procurement Operations Context
OC2	CBP-Providing in BIM-Procurement Operations Context
OC3	I4.0-Providing in BIM-Procurement Operations Context
OS	Ornamental Stones
PCA	Portland Cement Association
PNSAC	Parque Natural da Serra de Aires e Candeeiros
PPI	Provider Performance Index
PWC	Price Waterhouse and Coopers
QR	Quick Response Code
ROI	Return of Investment

RP	Research Problem
RQ	Research Question
S-Bprint	Service Blueprinting
S-D Logic	Service Dominant Logic
SII	Sustainable Innovation Index
SME	Small and Medium Enterprises
SO	Step Outcomes
SOA	Service Oriented Architecture
S-S	Service Science
SSME	Service Science, Management and Engineering
S-System	Service System
SWOT	Strength, Weaknesses, Opportunities and Threats
TPM	Total Productive Management
TPS	Toyota Production System
UK	United Kingdom
UN	United Nations

CONTENTS

LIST OF TABLES

LIST OF CHARTS

LIST OF FIGURES

CHAPTER 1

Life is a journey,
when we stop, things don't go right.

Pope Francis

1. INTRODUCTION

1.1 CONTEXTUALIZATION

The first references to CAD (Computer Aided Design) technology date back to 1957, by the pen of Dr. Patrick Hanratty, which provided Ivan Sutherland, during the 1960s, with the base to develop a graphic editor which, for the first time, introduced the basic principles of how to draw by computer, just replacing the traditional stretcher (Leite, Akcamete, Ackinci, Atasoy, & Kizitas, 2011).

First referenced by Van Nederveen and Tolman (1992), the acronym BIM (Building Information Modelling) has been used to characterize the information covering the entire life cycle of architectural and engineering projects (Venâncio, 2015). Since that time, the term BIM has been generalized (Howard & Björk, 2008), first as the new CAD generation systems used in Architecture, Engineering and Construction (AEC) (Hjelseth, 2010), relegating the acronym CAD to history, and in recent years, as a symbol of the AEC Digital Age (Barazzetti et al., 2015; European Commission, 2014). Although referring to "buildings", the tools provided by this technology are extendable to roads, bridges, tunnels or dams among other infrastructures. In a simple way, BIM may be defined as a database, managed from a graphic interface application based on parametric three-dimensional models and the consequent optimization and reduction of potential errors (Barazzetti et al., 2015), commercialized as collaborative platforms, able to incorporate digital construction elements made available by providers through web libraries (Race, 2013).

In this context, the explicit support of Official Entities (HM Government, 2011) for the gradual implementation of BIM is referred to as a new step in the transparency and efficiency of the entire Architecture Engineering and Construction Supply Chain

(AECSC) (HM Government, 2015). However, according to some authors (Elmualim & Gilder, 2014), it represents new challenges for the AECSC stakeholders, incorporating threats and opportunities.

Referred to as inefficient by some Governments (HM Government, 2011), practitioners (Dankers, van Geel, & Segers, 2014) and academics (Babič, Podbreznik, & Rebolj, 2010), (Blanco & Chen, 2014), the current procurement model in the AECSC generates avoidable wastes, which are reflected in construction and maintenance costs, construction time and ecological footprint, from the beginning of the building project up to the end of its life cycle.

Through the widespread use of BIM, according to some authors (Costa & Madrazo, 2015; Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013; Elmualim & Gilder, 2014; Grilo & Jardim-Goncalves, 2010, 2011; Gu & London, 2010; Hjelseth, 2010; Ibem & Laryea, 2014; Karan & Irizarry, 2015; Liu, Osmani, Demian, & Baldwin, 2015; Matthews et al., 2015; Motawa & Almarshad, 2013; P. Smith, 2014a; Venâncio, 2015; Volk, Stengel, & Schultmann, 2014) there will be a paradigm shift in the way of designing, constructing, maintaining and demolishing the built environment.

In the BIM context, the traditional procurement model shifts to "BIM procurement" (HM Government, 2011), which will occur during the building design phase (Elmualim & Gilder, 2014). In a Standard[1] digital format (Malleson & Watson, 2016) and publicly tendered on the Internet (Terkaj & Šojić, 2015), the construction products and materials are pre-designed (standardized) and made available to BIM workstation operators by their providers (Grilo & Jardim-Goncalves, 2011), which in practical terms, means that the procurement task will be anticipated to the building design phase (project phase) (Venâncio, 2015).

For the entities that support the generalization of BIM in the Industry of Construction (IC), the incorporation of these standardized products increases IC efficiency (HM Government, 2015) as the result of scale production (standardized products), transparency (web purchase) and fewer errors and mistakes because of digital solid objects (Pedraza Martinez, Stapleton, & Van Wassenhove, 2011). However, without neglecting the advantages of BIM (Gu & London, 2010; Marinho, 2014; Rowlinson, Collins, Tuuli, & Jia, 2010; P. Smith, 2014a), several authors have been pointing out that this new

[1]ISO 16739: 2013

procurement concept may present new threats for some sectors in the AECSC, especially those whose competitiveness lies in product customization, as is the case of the Ornamental Stones sector (OS) in Portugal (Silva, 2014). Consisting mainly of SMEs[2] (I. Frazao, 2016), the OS sector is relevant to the Portuguese economy, representing more than 16,000 direct jobs and being one of the main private employers in inland regions (I. Frazao, 2016; J. Frazao, 2016; Silva, 2013, 2014).

Integrated in the AECSC, despite the decline in global demand for construction materials since the sub-prime crisis in 2008 (Ferreira, Dias, Afonso, & Brito, 2012; Silva, 2013), the Portuguese OS sector has recorded an average annual growth of 4.6% in exports between 2006 and 2015 (J. Frazao, 2016) and has shown in a group of companies continuous improvement both in good practices and technologies, where sales, exports, skills admission, environmental care and other indicators have been substantially higher than the sector averages since 2005 (Silva, 2014). The good performance of this group of companies (Peres, Goulão, & Martins, 2016) represents good examples that other must follow, and therefore, they are members of the Cluster Portugal Mineral Resources (CPMR). Referred to as companies following Current Best Practices (CBP) in the OS sector (Silva, 2013) and operating in the international market, these companies are most exposed to global competition, and may consequently be the first to feel the threats resulting from BIM procurement.

Limiting architects' creativity and shifting demand towards standardized, less costly, more quickly delivered and more sustainable products (HM Government, 2011), it is from BIM that the relevance of this research arises. However, considering the constraints imposed on architects' creativity by the standardization of construction elements, if Portuguese OS companies are able to offer customizable stone elements also in BIM procurement and additionally reduce lead time, production cost and the ecological footprint (Heidari et al., 2014), the threats of BIM procurement may be overcome - compared to additive[3] production, the threats of BIM may be reversed in favour of Portuguese OS companies if architects can use stone factories in the same way they may use a 3D printer connected to their BIM workstations.

Paradoxically, contrary to the official objectives that support the generalization of BIM in IC (HM Government, 2011; P. Smith, 2014b) from our own experience as consumers,

[2]Small and Medium Enterprises definition
[3]3D Printers definition

it can be observed, in many sectors, the trend in demand towards customized goods. This trend, combined with increasing market volatility has forced industry to search for new forms of production, based on digital technologies (MacDougall, 2014). This tendency to incorporate digital technologies as a way to respond to increasingly customized demand has led governments (Smit, Kreutzer, Moeller, & Carlberg, 2016), practitioners (B&R, 2015) and academics (Schlechtendahl, Keinert, Kretschmer, Lechler, & Verl, 2015) to consider that a new Industrial Age is starting now, the fourth one, characterized by Digital Production combined with the Internet (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014) and popularized by the term "Industry 4.0" (I4.0), (Binner, 2014; Stock & Seliger, 2016). To produce in I4.0 mode, production must be supported by Cyber-Physical Systems (CPS), in which products, machines and customers, connected to the Internet, interact before, during and after the production process. In this context, it may be considered the possibility that the I4.0 operation mode may eventualy allow OS companies, particularly the members of CPRM, to respond positively to threats arising from BIM procurement in the AECSC.

1.2 RESEARCH PROBLEM (RP)

In the BIM context, for customers (BIM operators) to be able to incorporate customized elements, these must be commercially available in the BIM-web-libraries and also be "mouldable" to the area to be clad including the holding system and surface texture, according to the architect's creativity. This double co-existence of the stone elements in the building design phase becomes even more complex since each stone slab is unique and its natural surface variability means the line separating a defect from a nuance often depends on the observer.

The *Smart Factories Connected to the Internet*[4] concept has become a subject of analysis and study in recent years by scholars, practitioners and governments (Albert, 2015; J. Frazao, 2016; Heidari et al., 2014; Ivanov, Dolgui, Sokolov, Werner, & Ivanova, 2016; Lasi et al., 2014; Lee, Kao, & Yang, 2014; Schlechtendahl et al., 2015; Stock & Seliger, 2016) where dynamic "virtual elements" designated Smart Objects (Motamedi, Setayeshgar, Soltani, & Hammad, 2016), co-created with the customer may be made available in a customized IFC[5] way, is the focus of this research. However, for I4.0 to

[4]http://www.iotevolutionworld.com/m2m/articles/401292-how-industry-40-the-internet-things-connected.htm

[5]Industrial Foundation Class data format

involve customers in products' co-creation, it must consider the customer as an indispensable actor (S. Vargo & Lusch, 2016), a situation still not very common. In fact, in most cases, the customer is still seen as a strange element, independent and far away from the production sites (Robert F Lusch & Nambisan, 2015).

From the need to study the value-creation interactions among stakeholders, a new discipline has emerged – Service Science, Management and Engineering (SSME), or simply Service Science (S-S), as an interdisciplinary scientific field, anchored in the Service Dominant Logic (S-D Logic) Axioms (S. Vargo & Lusch, 2016), from which it has adopted the vocabulary, perspective and the necessary premises to construct its Body of Knowledge (Breidbach & Maglio, 2016; Hsu, 2016; Kwan, Spohrer, & Sawatani, 2016; Maglio & Spohrer, 2008, 2013; Maglio, Vargo, Caswell, & Spohrer, 2009; Spohrer, 2007; Spohrer, Anderson, Pass, Ager, & Gruhl, 2008; Spohrer, Anderson, Pass, & Ager, 2008; Spohrer, Maglio, Bailey, & Grughl, 2007; S. Vargo & Lusch, 2016).

The element of analysis in S-S is the service system (S-System) (Maglio & Spohrer, 2008), an abstract entity constructed by dynamic resource reconfigurations (Maglio et al., 2009) which must be evaluated and innovated combining the human knowledge in organizations with knowledge in management and technology. The S-S aims to categorize and explain S-Systems, including their value-creation interactions (Spohrer & Kwan, 2009).

This was the context that has led the author of this thesis to address BIM and I4.0 from the S-S perspective, whose Theory will support this research and allow evaluation of the response of Portuguese OS companies when in the BIM context they shift the production mode from CBP to I4.0.

1.3 RESEARCH PURPOSE AND OBJECTIVES

The purpose of this thesis is to conceptualize an empirical framework supported by S-S Theory, to evaluate the impact of the I4.0 production model on Portuguese Ornamental Stone companies' response to the Threats resulting from BIM procurement in the AECSC.

Since the OS companies belonging to CPMR (CPMR-OS) are considered those that use the current best practices in the sector (CBP) (I. Frazao, 2016; J. Frazao, 2016) and dissemination of these good practices to all mineral resource activities is part of the official objectives of the Cluster Portugal Mineral Resources Association[6] (ACPMR) (Peres et al., 2016), this group of companies will be the population to study in this research, through application of a conceptual framework to be developed.

In order to conceptualize the empirical framework, it will be necessary to overcome several challenges, such as: how to make cut-to-size stone products available to BIM operators, who as mentioned, look for standardized elements; how to provide BIM operators with natural stone (not homogeneous) products respecting the ISO 16739: 2013 Standard (Malleson & Watson, 2016); how to configure the resources of CPSs adapted to SMEs in a traditional sector; or how to map service interactions including resource activities, in order to innovate during the co-creation relation between the CPSs and the BIM operator.

Keeping in mind these difficulties, using the appropriate paradigm guidelines, selecting the right methodology supported by S-S and adjusted to the Research Problem (RP) (Creswell, 2014) and searching in the literature for methodological tools that clearly represent the service process (Kwan et al., 2016), we strongly believe that the following specific objectives can be successfully achieved.

As the first specific objective, is intended to describe and configure the different actors' resources, for providers in the current best Practices (CBP) operations mode and customers in the current procurement model. The second specific objective arises from BIM procurement, aiming to describe and configure actors’ resources, for providers in the CBP operations and customers in BIM Procurement. As a third specific objective, is intended to describe and configure actors’ resources, for providers producing in Industry 4.0 operations mode and customers in BIM Procurement. As the fourth specific objective, it is intended to determine the actors’ concerns, in these three contexts of operation. Finally, as the fifth specific objective, is intended to determine the evolution of concerns when the operations mode shifts in these Operation Contexts.

Focusing on these five specific objectives, is intended to assess the impact of I4.0 on CPMR-OS companies’ response to the threats arising from BIM generalization in the AECSC. By using the mixed methodology of parallel convergence and adapting some methodological tools to this RP (Kwan et al., 2016), the concept of Key Concern Indicators (KCI) supported by S-S and indexed to the different actors’ concerns will be

[6] Association Cluster Portugal Mineral Resources

proposed. To do so, data must be collected in a sample of OS companies, representative of the population CPMR-OS companies, in order to reach a general proposition of the empirical reality as a whole.

From these specific objectives will result a conceptual framework in which is intended to map the access rights and resource activities of the main actors operating in the three different contexts (OC) and to measure the evolution of KCI when the mode of operation changes. From the evolution of these KCI and after checking the amount of investment[7] required, it will be up to the manager of each CPMR-OS company to decide how production will change in the BIM context. Since I4.0 is an emerging paradigm (Mosterman & Zander, 2015), investing in this must be considered (Drath & Horch, 2014) as a possible option.

1.4 ORGANIZATION OF THE THESIS

The conclusions of this thesis should contribute to the development of the AECSC in general and to the Portuguese Ornamental Stone Sector, in terms of people's well-being and environmental sustainability, as well as proposing advances to developing the Theoretical Body of Knowledge on Service Science.

To achieve these aims, this thesis is organized in seven chapters. Chapter 1 introduces the subject, starting with the predictable paradigm shifts in the AEC, namely the threats to some AECSC stakeholders that may arise from BIM, which is a new concept of design, procurement and management of the Construction Industry. This first chapter also introduces the emerging paradigms in production activity, resulting from the digital economy and from the support that S-S as a new and interdisciplinary approach gives to efficiency, especially when production is supported by a CPS. The relevance of the OS sector in the Portuguese economy, which will face new challenges, but also new opportunities resulting from the digital economy, will also be described in Chapter 1.

Chapter 2 will introduce the Research Context, from which the RP will be raised through a SWOT matrix applied to the Portuguese OS sector, addressing the predictions in the IC demand and the positioning of the Portuguese OS sector in the AECSC, contextualizing their strengths and weaknesses, threats and opportunities in the context of BIM

[7]Analysis of the investment required to operate in I4.0 mode will not be part of this research, and thus, in the Conclusions, Chapter (7), this issue is proposed for future research.

procurement. As the result of the Portuguese OS sector's mobilization since 2004 in terms of new technological developments to make companies more competitive, this chapter will also describe some of the reasons that led the Portuguese Government to officially recognize the Cluster Portugal Mineral Resources (CPMR), as a model of good practices in the sector, with its companies now being considered the front runners in terms of competitiveness. Still concerning the RP, Chapter 2 will describe some S-S perspectives of possible I4.0 architecture, which once adopted by OS companies, may eventually respond positively to the concerns resulting from the threats of BIM procurement.

In Chapter 3, will be presented the result of the literature review carried out, giving support to the research. This will start with a historical approach to the concept of goods and services whose dichotomy emerged from Lusch and Vargo (2004). They defined the S-D Logic Axioms (S. L. Vargo & Lusch, 2004a), which were adopted a few years later by the S-S pioneers Spohrer and Maglio (2008) as the philosophical basis and vocabulary of S-S Theory (Maglio & Spohrer, 2008). Because it is an interdisciplinary scientific area whose Theoretical Body only began to be built about a decade ago, this chapter will introduce the gaps, diverging concepts and different understandings found in the literature in the S-S and S-D Logic communities. Chapter 3 will also discuss some of the methodological S-S tools, to find the best ones for the objectives of this research.

Chapter 4 will present the research methodology, by addressing some of the research paradigms (Creswell, 2014), to find the philosophical conception that provides the best guidelines to define the exploratory scheme of the RP and the research methodology. Once the Objectives and the Research Problem are established, the specific Research Questions (RQ's) to which this thesis aims to respond will be introduced. The methodology used will be adapted to the interdisciplinary nature of S-S and the particularities of this RP, involving on one hand, complex emerging paradigms such as BIM and I4.0 and on the other hand, a traditional industrial sector, consisting mainly of family-owned SMEs. Among several methodological tools available and recommended by S-S, this chapter will briefly describe the *service blueprinting* (S-Bprint) and *Interact Serve Propose Agree Realize* (ISPAR) tools. Using these, through the mixed methodology of parallel convergence, is intended to converge the qualitative and quantitative KCI, and thereby obtain conclusions about the concern relief or aggravation in the three contexts of operation described above. Chapter 4 will also present the criteria for constitution of the sample, the questionnaire guidelines for the qualitative data and the list of quantitative data to be collected throughout the service process indexed to the main stakeholders[8] KCI and related to each of the Threats arising from BIM procurement.

Chapter 5 will conceptualize the *Inovstone4.0* empirical framework, starting with I4.0 addressed from the S-S Theory perspective. Since for S-S, the customer must be considered a main and active stakeholder throughout the service process, for this condition to be guaranteed in I4.0 production mode and mapped by the S-Bprint tool, this chapter will propose a reengineered approach to I4.0, introducing the FingerprintI4.0 (FP-I4.0) and Cockpit I4.0 (Cockpit) concepts as part of Inovstone4.0 and supported by S-S Theory. This chapter will also develop the specific format of both the S-Bprint and ISPAR methodological tools for the application of Inovstone4.0, namely in terms of lines and lanes where resources, symbologies and notations will be placed, as well as the points of interaction between the provider and customer stakeholders, and the steps in which data will be collected throughout the service process.

In Chapter 6, the Inovstone4.0 framework will be applied to a sample of CPMR-OS companies, to seek possible answers to the RQs raised. This chapter starts with the sample constitution, from which is intended to reach conclusions about the response to the threats of BIM procurement. By using the S-Bprint maps in the format described in the previous chapter, this chapter will present the service process divided in 36 steps, during which the OS-Provider resources must interact with the OS-Customer resources and allow the researcher to collect qualitative and quantitative data throughout the service process, in three contexts of operations: (i) CBP-Providing[9] in CAD-Procurement (OC1); (ii) CBP-Providing in BIM-Procurement (OC2) and finally, (iii) I4.0-Providing[10] in BIM-Procurement (OC3). From the data collected in these three OC, the KCI indexed to the stakeholder concerns will be determined, and from their evolution the Innovation Outcomes (IO) will be determined, leading to the conclusions about the relief or aggravation of the concerns, thus answering the RQs. As one of the most important phases of this thesis, it is in this chapter that, through the evolution of the KCI in these three different operation contexts, the Innovation Outcomes (IO) will be determined by the evolution of the concerns for each of the main stakeholders, when operations shift from CBP to I4.0. To confirm the KCI trends, this chapter will finish with the *Wilconxon-*

[8]Service Science considers as main stakeholders: Customers, Providers, Competitors and Authorities
[9]Current Best Practices production mode
[10] Industry 4.0 production mode

Mann-Whitney[11] and *t-Student*[12] KCI significance tests, in order to sustain the researcher's interpretations.

Finally, Chapter 7 will present the conclusions. A brief synthesis of the research carried out, including the five specific RQs as well as the RP from which they originated, will be followed by the conclusion about S-S and the suitability of the methodology in pursuing the specific objectives that led to conceptualization and application of the Inovstone4.0 empirical framework. From the IO obtained in the three operation contexts (OC1, OC2 and OC3), this chapter will first present confirmation of the threats of BIM to CPMR-OS companies' business. Then following the methodology, the conclusions will be presented as the result of the evolution of the qualitative KCI, indexed to the main stakeholder concerns, when the operation context changes from OC1 to OC3 and additionally, according the mixed methodology, the quantitative IO must confirm and quantify the relief or aggravation of concerns obtained from the qualitative IO and thus, answering the specific RQs as well as to the Research Problem.

Before concluding Chapter 7, the difficulties and constraints that the researcher had to overcome will be described, together with identification of the limitations of the research. In addition to empirical analysis that could enhance the results achieved in this thesis, the contributions that may result from this research as proposals for the Theoretical Body of S-S and for Practice in the sense of society's well-being will be highlighted. As the RP is centred on the digital economy supported by S-S Theory, this thesis will be concluded with some proposals for future developments in this area.

[11]Non-parametric test applied to two independent samples.
[12]The Student is a hypothesis test that uses statistical concepts to reject or not a null hypothesis when the test statistic follows a "t" Student distribution.

CHAPTER 2

The pessimist sees difficulty in every opportunity
The optimist sees the opportunity in every difficulty

Winston Churchill

2. RESEARCH CONTEXT

2.1 ORNAMENTAL STONE BUSINESS

The Natural Stone sector is formed of two sub-sectors. The extraction and subsequent transformation of the stone for ornamental purposes, usually referred to as the Ornamental Stone sector, and the extraction and transformation for industrial purposes, usually referred to as the Industrial Stone sector (Galetakis & Soultana, 2016). Even so, supply chain management increasingly tends to join them, and throughout this research it will be only address the Ornamental Stone (OS) sector, since it is where there has been a greater margin of growth and added value in recent years (Silva, 2014). OS refers to types of natural stone which, after transformation, retain their essential composition (Fernández et al, 2012), texture and physical-chemical characteristics, allowing their use in construction and ornamentation (Silva, 2013).

Generally speaking, the essential physical-mechanical characteristics of the most common OS types in the Architecture Engineering and Construction Supply Chain (AECSC) can be categorized as follows (Behera, Mohanty, & Prakash, 2015): (i) granites - reveal excellent physical-mechanical characteristics, meaning they are used in all types of applications, both indoors and outdoors; (ii) marbles - in general, present values corresponding to stones of considerable quality, being used in a wide range of indoor and outdoor applications; (iii) limestone - most have physical-mechanical characteristics compatible with indoor and outdoor use, although in this case there are restrictions on the use of some typologies when faced with situations of strong freeze-thaw exposure (Re & Academy, 2015).

Once extracted, the different stone typologies will originate a differentiated set of products (López, Martínez, Matías, Taboada, & Vilán, 2010), according to the different transformation processes. These will be channelled to different markets as building elements, within the AECSC, so in the context of a digital economy, they must face the eventual difficulties arising from new forms of procurement, as well as taking advantage of the new concepts and technologies of digital operation.

2.1.1 Predictions of the Ornamental Stone Evolution Demand

The United Nations' (UN) forecast of demographic trends points to an increase in the world's population from the current 7.2 billion to 9 billion over the next 40 years (HM Government, 2013), an increase which, according to Global Construction Perspectives and Oxford Economics (2015) will essentially take place in urban areas, where valuation of built assets in the 30 largest economies in the world will increase by more than 35% by 2022 (HM Government, 2015).

China has overtaken the USA to become the largest construction market in the world since 2010 and is expected to increase its current construction quota from 18% to 26% by 2025. Even with some decrease in its growth, it is the world's second largest economy. India is expected to overtake Japan in the next few years, to become the third largest country in terms of the construction market, with an annual growth rate that exceeds China and close to 7.4% (Global Construction Perspectives and Oxford Economics, 2015).

In the coming decades, it is estimated that the global construction market will grow more than the world's GDP, mainly due to the increase in the industrialization of Asian economies and the post-crisis recovery of the United States (Global Construction Perspectives and Oxford Economics, 2015). China, the USA and India together will account for almost 60% of this growth, but in emerging Asian countries such as Indonesia, Vietnam and the Philippines there will also be growth in the Construction Industry (IC). In Europe, on the other hand, the volume of investment in construction in 2025 will still be 5% below the values registered in 2007, according to the same source.

These forecasts are in line with the data released in the UK Ministerial document (HM Government, 2015), according to which an increase in global demand of around 70% is estimated in the construction sector by 2025. Forecasts for the consumption of Portland cement for the next years seem to confirm the predictions of IC growth (Jalaei & Jrade, 2015), for the European Cement Association (CEMBUREAU), and also for the Portland

Cement Association (PCA) the increase in annual cement consumption is expected to be around 4% by 2018 (Portland Cement Association, 2013).

As the IC is one of the largest consumers of raw materials and energy[13] (Global Construction Perspectives and Oxford Economics, 2015), it is imperative to find new solutions and innovative products that can contribute to the construction of sustainable cities, since along with sectors such as transport, the planet's sustainability (Gao, Liu, Wang, Gu, & Yong, 2015) will depend on the IC. Relieving the pressure on natural resources by using building materials that result in lower CO_2 emissions, resorting to the Circular Economy[14], the Digital Economy, and new ways of designing the built environment (building design) appear to be the pillars for a more environmentally friendly IC (Gu & London, 2010).

Bearing this in mind, some Governments (HM Government, 2015) have already started to adopt regulatory policies for new public buildings, integrated in the Circular Economy concept, where in some cases the level of emissions has to be close to zero by 2021 (Corry, Pauwels, Hu, Keane, & O'Donnell, 2015; Luo & Wu, 2015), with regulations regarding recycling of the waste generated during construction, renovation and demolition (Cheng & Ma, 2013). As an example of using the digital economy to mitigate multiple concerns related to the IC from a sustainability point of view, Building Information Modeling (BIM), a building management system described below, has attracted the attention of Government Offices (T. W. Kang & Hong, 2015) not only in developed countries, but in nearly all regions of the globe (C. Wang, Cho, & Kim, 2015).

2.1.2 Predictions for the Procurement Model Evolution

Traditional procurement activity in the AECSC is not simply buying something, since it involves a search and negotiation strategy, which can be structured or unstructured according to whether it is a market or a customized product (Grilo & Jardim-Goncalves, 2010).

---

[13] North-Western University, almost half of the world's energy would be consumed by the built environment if it may be considered the whole of its life cycle, i.e. from the time of construction of the building or infrastructure until its demolition: on the North-Western University Helix Magazine blog https://helix.northwestern.edu/blog/2011/03/construction-has-costly-carbon-footprint

[14] A review on circular economy. Journal of Cleaner Production - https://ec.europa.eu/jrc/sites/jrcsh/files/jrc-brochure-circular-economy.pdf

In the IC, the most common procurement model in Europe is that of design-bid-build (Ribeiro, 2012): the project manager hires a team of designers (architect and engineers) to develop the project, which is then budgeted by the contractors and later selected by the project manager who will build it (Marinho, 2014). The main characteristic of this procurement model is the clear separation between the stages of design, work contracts and construction work (Ribeiro, 2012). The fact there is no sharing of information or risk between the different stakeholders in the supply chain usually leads to enormous waste (HM Government, 2011). For some authors, it is not difficult to find specific cases where, despite the overall failure of a project (Marinho, 2014), some of the elements of the supply chain still obtain enormous financial gains. In this model, the client often ends up accepting the most economic proposal, without taking into consideration the quality of the materials and the services provided (Marinho, 2014). Design and construction errors always fall on the project owner, who sometimes faces tiresome situations and gives precedence to avoiding litigation between the participants, so that the work can be completed (Ribeiro, 2012).

The design-build model, an alternative to the design-bid-build model, is a procurement model that is also widely used in IC. The project owner awards the contractor both the project and its execution, leaving the design team to take on the role of consultant (Marinho, 2014). This method, when compared to the previous one, means more collaboration between stakeholders, which increases the feasibility and precision of the project. However, holding the contractor responsible for any difficulties and unforeseen events might result in the loss of quality of the materials and services provided, especially those that are not immediately visible, since the contractor is also the main auditor of the material (Ribeiro, 2012). When confronted with a possible financial loss the contractor will try to lower costs in every way possible.

Therefore, in many cases, the project owner prefers an alternative model and hires a construction manager, whose job is to analyze the construction projects and their respective specialties, to define the exception program and supervise the costs associated with each operation, setting deadlines and stages. In this third procurement method, often referred to as Cm-at-Risk (Marinho, 2014), the project owner minimizes the risks involved in carrying out the construction, and it is consequently the most advisable method, especially in complex or large projects.

In all these models, practice generally confirms significant waste, budget deficit, delays and a lack of rigor in determining the ecological footprint during building construction and usage (Ribeiro, 2012). It is in this context that since 2016, countries such as the UK, among others (HM Government, 2015), have made it mandatory in public construction work that submitted projects are no longer designed in the traditional CAD systems and instead should be designed using Building Information Modelling[15]. This requirement led to the emergence of multiple WEB libraries, where manufacturers and distributors of elements and materials for the IC make their products available in digital format. These points of sale for IC products, such as the *National BIM Library*[16] or the Library Smart BIM[17], among many others, provide not only products but also manuals containing the recommendations and information necessary to create virtual objects under ISO standard 16739: 2013 (Malleson & Watson, 2016).

Once BIM objects are made available in IFC format by vendors, they must contain a map of specific definitions covering the entire product life cycle, which some authors call the BIM Dimensions (P. Smith, 2014a). The first three dimensions of BIM objects (3D-BIM) obviously refer to their spatial geometry (Marinho, 2014), where the parametric correlation allows users of this digital technology to obtain accurate and real-time information on potential collisions and spatial interfaces between objects.

In AEC, the BIM is seen as an evolution of the CAD in which buildings were designed (drawn) from lines and curves, whereas in BIM the modeler (designer) imports solid objects made available by third parties, which immediately makes design tasks easier and also reduce the likelihood of human error. These solid objects must be available in IFC format ISO 16739: 2013 with *Eight Dimensions* of the corresponding real objects, unlike traditional CAD systems where designers based the dimensions of the elements they designed on architectural and engineering design manuals, but without any direct relation to the elements available in the market.

In addition to their geometry, information related to the temporal logic programming of BIM objects represents the fourth dimension (4D-BIM). Especially during the construction phase, planning of the time spent on each of the specialties is fundamental to avoid conflict or unnecessary changes. The information available in the fourth BIM Dimension, allows BIM operators to plan the time-scale of building-related activities

[15] The use of BIM is only mandatory at maturity level III (Succar & Kassem, 2015)
[16] http://www.nationalbimlibrary.com
[17] http://library.smartbim.com

(Han & Golparvar-Fard, 2015), resulting in greater efficiency in detecting temporal conflicts among the various actions. This information is also useful in terms of the maintenance of the elements throughout the life cycle of the building (Heidari et al., 2014).

By providing the tools for processing real-time information collected at the construction site, BIM allows the real-time visualization of temporal conflicts, generating sequences of alternative steps for all stakeholders involved in the construction including the issuing of warnings about security risks (Heidari et al., 2014). Additionally, the IFC information made available (exported) by BIM from the fourth dimension of the objects is standard and can therefore be integrated with specific project management applications, providing users with benefits in terms of optimizing the design plan (Matthews et al., 2015) and allowing builders and suppliers of elements to take advantage of the BIM outputs in order to manage their production and construction activities in a coordinated and collaborative way with the different teams and specialists involved in the construction work.

The mapping and monitoring of payments to suppliers, from design to delivery is also a major activity in construction project management (Lu, Won, & Cheng, 2015), and so cost-related information represents the fifth dimension of the object (5D-BIM) (P. Smith, 2014a). By integrating the information regarding the costs of the elements (5D-BIM) with the quantities of these same elements, obtained from the 3D-BIM solid geometry and the 4D temporal logic programming, BIM provides a reasonably accurate estimate of the structure of costs and cash-flow maps, thus replacing the traditional Excel spreadsheets (P. Smith, 2014a).

Furthermore, from the information associated with 5D, BIM enables the calculation of variations in the cost of the work as a whole resulting from changes in the type of materials, equipment or workmanship (Lu et al., 2015), providing the modeler with management methods and cost analysis for different scenarios, and the respective impacts of each possible change (Lu et al., 2015).

Sustainability is another area where the Government has great expectations regarding the benefits generalized BIM use might bring to the AEC (HM Government, 2015), because BIM objects have as a sixth dimension (6D-BIM) information related to the ecological footprint (Corry et al., 2015). Based on information such as energy and others, associated with the production, transport, application and use of the elements involved in the building throughout its life cycle, the use of 6D-BIM information during its design phase (building design) enables the building's ecological footprint to be determined, with reasonable accuracy, throughout its entire life cycle (Cheng & Ma, 2013). It is from the sixth dimension of BIM objects that carbon-related information will be incorporated into the AEC, establishing a bridge to global *Green Building* programs (Ghosh, Negahban, Kwak, & Skibniewski, 2011), referred to by some authors as *Green BIM Construction* (Wong & Zhou, 2015). Developers, engineers and architects will be able to reconcile their projects with global carbon emission targets (Smith, 2014) established at the Paris Conference in December 2015 (United Nations, 2015).

The seventh dimension of BIM objects (7D-BIM) covers information related to the individual and integrated maintenance of each element used in the building, including how it will be demolished and recycled at the end of its life (Barazzetti et al., 2015). The information provided by the seventh dimension of BIM objects enables monitoring, from the digital version of the building, of management of the built environment in real time. BIM is thus regarded as a tool of asset management, specification of maintenance models, creation of preventive and curative maintenance procedures and negotiation of warranty conditions among other operations, in relation to each element (object) incorporated in the project, from the construction to the demolition of the building (Cemesova, Hopfe, & Mcleod, 2015).

Some authors also consider that security-related information, from the design and construction stage, all the way through to demolition of the building, should be considered as the eighth dimension (8D-BIM) of BIM objects (P. Smith, 2014a). Once incorporated in the BIM project, 8D information lets modelers develop document preparation, planning and the simulation of aspects of building security throughout its entire life cycle (Malsane, Matthews, Lockley, Love, & Greenwood, 2014).

Some research has been carried out on possible techniques and technologies that might make it possible to keep an updated digital version of the building on the BIM platform throughout its entire life (Johansson, Roupé, & Bosch-Sijtsema, 2015). In other words, to ensure that the digital version remains faithful to the physical version, in practice this means using BIM as an e-procurement tool in the maintenance of the building until its demolition (Matthews et al., 2015). Extensive dissemination and the operational models of the IFC open digital information format (ISO 16739: 2013) promoted by the global building Smart[18]Initiative (Jardim-Gonçalves & Grilo, 2010), have presented the advantages of information sharing between different software applications used in the AECSC. From BIM, the different stakeholders will have to work in a collaborative, transparent way to obtain efficiency and effectiveness.

Considered one of the important areas of research, as Virtual Reality technology (Gu & London, 2010), BIM will most likely enable new dimensions to be added to IFC objects in the future, to clarify the semantics of the particular specifications of each of these dimensions (Binner, 2014), and above all, to develop user-friendly, practical, technical solutions for on-site updating of deviations from design and monitoring the building throughout its life cycle (Matthews et al., 2015).

The shift in paradigm resulting from the adoption of BIM, besides the aforementioned technical implications, will lead stakeholders in the AECSC to a new procurement concept, where BIM will not only be a design and search tool, but also the tool for final validation of the elements forming the building (Grilo & Jardim-Goncalves, 2010). The availability of products in a digital version on platforms accessible to architects and engineers using BIM presents a challenge for suppliers (Kim, Jeong, Clayton, Haberl, & Yan, 2015), i.e., tacit acceptance of positioning themselves in the supply chain with a high level of transparency. By making products available on open web platforms and respecting the standard rules, providers are agreeing to share with the market, which includes their own competitors, information sometimes considered confidential, such as product prices. On the other hand, by opting not to agree to work with this level of transparency, they run the risk of their products not being used in BIM projects, and as such, will be unable to sell them.

As the change in the procurement model is oriented towards standardization (Grilo & Jardim-Goncalves, 2011) in the IC, one of the pillars of the construction change (HM Government, 2011), it is foreseeable that the supply chain in this area will be affected in the coming years (Babič et al., 2010).

We can thus consider that in the BIM context, procurement activity will move upwards (the building design stage). Use of the web sites where BIM objects are publicly put up for sale in the IFC format (Grilo & Jardim-Goncalves, 2011) will put added pressure on prices, deadlines, and ecological footprint and higher quality requirements.

[18] http://buildingsmart.org/

2.2 THE PRODUCTION IN THE DIGITAL AGE

Since the beginning of industrialization, several technological leaps have led to paradigm shifts in production and in society itself. Those leaps have been called *Industrial Revolutions* or *Ages* (Figure 2.1) (Lasi et al., 2014).

England was the first country to record industrial activity in the late 18th century by using the steam engine. This invention gave rise to the concept of Industrialization and was hence considered the First Industrial Revolution, with the accumulation of capital leading the bourgeoisie to power and transformation of the agrarian structure into the maritime-commercial expansion of England and the creation of the Bank of England in 1694.

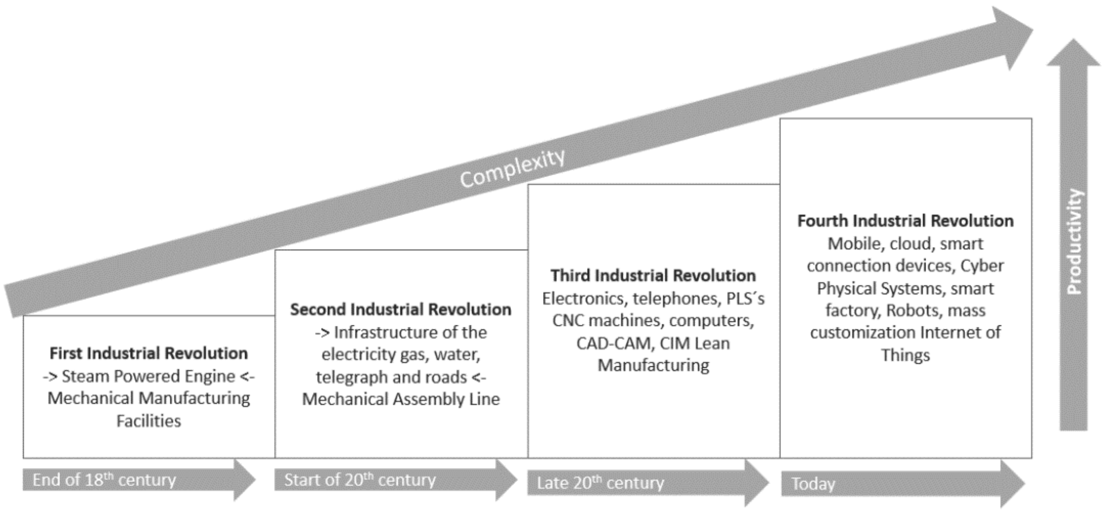


Figure 2.1: From the First to the Fourth Industrial Age (Lasi et al., 2014).

In the early twentieth century, industry expanded beyond Europe. The intensive use of electrical systems enabled the concept of scale production not only in Europe, but also in the USA and Japan, making this period known as the Second Industrial Era. By the end of the twentieth century, the use of computerized systems allowed the automation of production processes with robotized systems beginning to perform repetitive or dangerous tasks, a paradigm that was called the Third Industrial Revolution (Albert, 2015).

As we draw closer to the present day, the XXI century, it is seen the ability of industry to produce customized goods with a shorter and shorter lifespan. This intense increase in the variability of industry’s capacity and consequent increased market volatility has led many observers to believe Industry is on the cusp of its Fourth Technological Paradigm (European Parliament, 2015), driven by the digitization of production processes combined with widespread use of the Internet (Lasi et al., 2014).

2.2.1 Internet of Things and Cyber-Physical Systems

Bryce Barnes, department director of Cisco's Robotic Machines, described the concept of the *Internet of Things* (IoT) as an (...) "intelligent connectivity of smart devices by which objects can sense one another and communicate, thus changing how, where and by whom decisions about our physical world are made[19]" (CPMR, 2017). Associated with the IoT concept is the concept of CPS, meaning the integration of software and hardware to control flexible physical processes (factories), where products and machines interconnect and communicate with each other and with the network they are part of, which also includes consumers (J. Karimi & Walter, 2015). In line with this interpretation, for researchers such as Lee, Baheri and Kao (2015), CPSs are technologies for the interconnections between the digital world and physical assets, made possible by the great evolution in recent years of sensory technologies for acquiring and exchanging information (Lee, Bagheri, & Kao, 2015).

It is thus verified that the concepts of IoT, CPS (O'Brien, 2016) and CPSs (L. Wang, Törngren, & Onori, 2015), while different are still related. The IoT links the consumer to the digital economy, and in addition, production when supported by CPSs also links manufacturing to the digital economy (Mosterman & Zander, 2015).

Digital technologies in the form of Intelligent Connectivity of Smart Devices (ICSD) (Albert, 2015) are the basis that supports both concepts, representing the main common point between IOT and CPS, which once applied to the relationship between consumers (most common situation) is simple to understand, but when applied to factories, levels of complexity take on another dimension, and this may have been the reason why some authors, researchers and Authorities use the term Industrial Internet of Things (IIoT) (European Parliament, 2015). In any case, the industrial dynamics driven by digital technologies, such as ICSD or IIOT (Hoske, 2015), seem to be reconfiguring the 21st century production model to the point that many authors, researchers and practitioners consider we are facing a fourth paradigm shift in History or a Fourth Industrial Era (European Parliament, 2015) .

As with production, this paradigm shift will trend to encompass the maintenance

[19] http://www.mmsonline.com/articles/7-things-to-know-about-the-internet-of-things-and-industry-40

(conservation) of productive means, including the maintenance of CPS themselves, where the systems' operating conditions derive from the interaction between physical objects and the digital parameters of the processes (S. Wang, Wan, Zhang, Li, & Zhang, 2015), also extensible to the service sector, so some authors consider that digital technologies are leading to the *liquidation* of the economy (S. L. Vargo & Akaka, 2009; S. Vargo & Lusch, 2016).

Nowadays, parallel to the growth of the IIoT where additive production[20] is perhaps one of the most emblematic results (O'Brien, 2016), there has been a change in production, which has long since been boosted by the appearance of new sensorial media on the market (Sehgal, Patrick, & Rajpoot, 2014), which gathers information in real time in the most different forms.

The exponential growth in the use of these new sensor networks will certainly result in an increase in the amount of information, generalizing the term "big data" (Lee et al., 2015), as dynamic generators of massive information (Lee et al., 2015). Big data will challenge the ability of CPSs themselves to screen all the information generated in real time. The paradigm resulting from big data in IIoT is seen as a reality for which we must be prepared, and is designated by some authors as "4V's[21] Paradigm"(Breidbach & Maglio, 2016), being interpreted as a sign contrary to the economic advantages of digitalization (Constantinescu, Francalanza, Matarazzo, & Balkan, 2014), since it requires systems to respond in an "immediate way", in order to generate "intelligence" (Caggiano, Caiazzo, & Teti, 2015; Eadie et al., 2013)

2.2.2 Industry 4.0

The term *Industry 4.0* (I4.0) became popular among academics, practitioners and authorities as the combination and integration of digital technologies such as advanced robotics, artificial intelligence, sensors, cloud computing, IoT, analysis and sorting of big data, augmented reality, additive production and mobile devices, among other digital technologies, into an interoperable and shareable global value chain, regardless of geographical location (Lee et al., 2015; MacDougall, 2014).

While it is true that most of these technologies have been available since the late 20th

[20] Equipment also designated 3D Printers
[21] Velocity, voracity, volume, veracity

century, manufacturers created them without any regard to their integration by users, so what is new in I4.0 is the collaborative way all these technologies interact with one another and with the products resulting from their operations. Referring back to Kropotkin's (1903) experiments, for whom evolution depends on the level of collaboration (Kropotkin, 1902), once digitally linked, these technologies create a bridge between the *physical world* and the *virtual world* (European Parliament, 2015), therefore altering organizations' production and management at a global level (Mosterman & Zander, 2015).

In I4.0 mode, a Cyber-Physical System merge the *physical* environment with the *digital* one (Sehgal et al., 2014). Products begin by being just a kind of co-created "digital DNA" (Diniz, Vaz, & Duarte, 2015) which, as a metamorphosis, will start as smart objects (S. Wang et al., 2015) and later become physical during the production process, until the time they are dispatched to the consumer (Lasi et al., 2014). In this operations mode, product design and development tend to occur from virtual laboratories using customers as co-creators, and move forward to digital manufacturing, where the products themselves acquire their form, by interacting with the production methods themselves (Ivanov et al., 2016). The network of machines that make up the I4.0 factory floor will thus tend to become "conscious" and flexible systems, responding quickly, not only to human commands, but also to their own perceptions transmitted through the interaction with the objects being manufactured (Faller & Feldmüller, 2015). Analyzing some practical cases[22](Drath & Horch, 2014), most companies deciding to orient their operations to I4.0 have apparently done so to achieve flexibility in production, which would allow them to mass-produce customization (Kagermann, Wahlster, & Helbig, 2013). More than the search for a specific solution, if indeed it is true that we are transitioning to the Fourth Industrial Era, is expecatable that as more companies gain competitiveness and sustainability in their businesses through I4.0, a mobilizing effect will be seen not only in industry but also in services (Smit et al., 2016).

Likewise, the positive experience gained by adopting I4.0 may also lead to new ways of tackling new problems such as sustainability, the pressure of urbanization or even new ways of solving social issues like the aging population. In a global study on Industry 4.0 adoption, conducted by PwC (2015), involving more than 2,000 companies from 26

[22] https://www.mymuesli.com; http://www.kefholdings.com; https://www.lego.com

countries, in industrial production sectors such as aerospace, automobile, chemical, electronics, engineering and construction, transport and logistics, among others, it was found that a third of respondents considered their companies had already reached advanced levels of integration and digitalization, and 72% of them expected to be fully operating in Industry 4.0 mode in 2020 (http://www.pwc.com/gx/en/industries/industry-4.0.html). This large-scale commitment to digital production increases the concerns about managing the problems of the 4Vs of big data, which CPS must overcome in the short or medium term (Bunse et al., 2014). According to the conclusions of Corry, Pauwels, Hu, Keane, and O'Donnell (2015), about 90% of the data volume circulating on the Internet today did not exist before 2013 (Corry et al., 2015), and most of it has no structure.

Irrespective of the coming problems resulting from the volume of digital information carried by a limited structure that is the very architecture of the current Internet[23], scholars and practitioners predict that reorientation for digital production supported by CPSs will be unstoppable, resulting in a substantial impact in the short to medium term, on the engineering of productive processes (Mosterman & Zander, 2015) and also on professional profiles. The implementation of this new work dimension, specialized on the one hand and collaborative on the other, may identify new types of employment, such as online assemblers, who, in liaison with suppliers, are selected on their merit to develop online support in real-time for assembly lines (Smit et al., 2016), on which production will depend entirely.

Another relevant concern deriving from I4.0 is that investments in industry were made on the assumption that amortization of the productive means, namely machinery and equipment would be in 15 - 20 years (Payne, Storbacka, & Frow, 2008). Due to the existence of an inestimable amount of production equipment, whose payback is still far from being reached, there may be a need to integrate that equipment in CPS, in the short term, which will pose a new challenge for the technology industry. Researchers such as Schlechtendahl, Keinert, Kretschmer, Lechler and Verl have pointed out options, although they themselves consider them difficult to adapt to specific cases, which represent almost the full total of needs (Schlechtendahl et al., 2015).

Development of the gateway[24] concept, of which the Siemens *mindsphere* system is an

[23] It has been found some discussions about the reliability and capacity of the current Internet model for big data, without jeopardizing the security of cities and the planet itself.
[24] https://www.siemens.com

example, a hub placed on traditional machines, coordinating information between itself and its products in manufacturing and at the same time ensuring real-time management of CPS (Sehgal et al., 2014) shows it is not necessary to completely replace all the machinery. The use of artificial intelligence algorithms supported on the cloud concept seems a path to be explored, since the sustainable transformation of industry is only possible if it has time to adapt to the new reality (Schlechtendahl et al., 2015), even when facing the complex problem (Schuh, Potente, Varandani, & Schmitz, 2014) of optimizing production by combining systems from different generations (Schlechtendahl et al., 2015). The dynamics of the cost-benefit ratio, the interpretation of border conditions and the difficulty in hiring expert skills (D. J. Teece, 2014) will be just a few of the new concerns associated with the transition from the Third Industrial Era to Industry4.0 (Constantinescu et al., 2014), which has at its basis the concept of "customer integrated engineering" (Kagermann et al., 2013).

A new generation of factories where CPS are the production support (Schlechtendahl et al., 2015) will thus arise, resulting in so-called “Smart Factories to the Internet of Things” (Ivanov et al., 2016) also designated “digital factories" (Constantinescu et al., 2014) whose objective is to maximize flexibility combined with efficiency (Caggiano et al., 2015). For this new concept, called smart production, (Kagermann et al., 2013) to be effective, some authors believe there must be performance simulation tools in upstream production, thus safeguarding the risk associated with physical experimentation in real time (Caggiano et al., 2015). The reorganization of production processes resulting from this production concept will have unique consequences in each company, since each one will be required to interpret and adapt its specific profile and resources to the concepts associated with I4.0, which include IoT, CPSs and Big Data, among others (Ford, 2015).

A potential problem resulting from *CPS Supported Smart Factories* may be dynamic supply chains (D. Kim, Cavusgil, & Cavusgil, 2013), which must sometimes be short-term, in response to specific needs raised by the new processes, different speeds and collaborative modes (Beske, 2012), integrating, for instance, groups of machines producing in different geographical locations (Ivanov et al., 2016). This process of innovation by a paradigm shift in the supply chain itself (J. Karimi & Walter, 2015) seems to require each stakeholder to adapt their resources (Maglio et al., 2009), processes and values in the collaborative way that digital production demands (Cho, 2013).

From the implementation point of view, since CPS are the basis of I4.0 support technology (Lee et al., 2015), it may be necessary to standardize the CPS model and its implementation in factories by creating a bottom line (Hoske, 2015), in order to conceive what some authors designated "machine fleets" (Lee et al., 2014) and subsequently evolve into a CPS concept. Boosted by the digitalization of production processes and technologies combined with widespread use of, and access to the Internet, the new production modes will tend to be geared towards a batch size of one (Stock & Seliger, 2016), keeping the economic benefits of traditional mass production (Pakdil & Leonard, 2013). Some authors (Lasi et al., 2014) predict that I4.0 may have a 25% impact on the efficiency of European industry and a reduction in lead time of 30%.

With the widespread use of sensory media, the expansion of wireless Internet networks and the development of increasingly smart robotic systems, along with the growing capacity of computers at a lower cost, the problems arising from big data (Ford, 2015) are expected to be overcome, thus transforming the way goods are produced in Europe and in the rest of the world (Corry et al., 2015; European Parliament, 2015) From a holistic perspective, the Industry 4.0 concept will incorporate many other concepts, which are sometimes difficult to describe individually, such as the concept of a smart object (Heidari et al., 2014) or the sensory network associated with products and means of production, integrated in CPS, and sending, receiving and processing information, making autonomous decisions based on digitalization and previous simulations of the product models (Stock & Seliger, 2016).

The term "Industry 4.0[25]" has been popularized since 2011 (Drath & Horch, 2014) when the German Government created a National Initiative with this designation (Fair, Russwurm, & Sector, 2012) to ensure that the German industrial sector would maintain its leading position in the coming decades (Albert, 2015). From the early stages, this official German Initiative involved Chancellor Merkel and thereby all Ministries, universities, research centers, large companies, unions and countless other strategic partners in the country, in the belief that Germany's industrial leadership can only be maintained if the country takes the lead as a user and global implementer of the technologies of the "Internet Smart Factories" generation (Kagermann et al., 2013). Bernd Heuchemer, Vice-President of the Motion Control Department at Siemens stated that for his organization the Industry 4.0 Government Initiative (…) "is to actively drive the reshaping of industry, as it combines aspects of the physical, virtual, IT and cyber-system

[25] *Industrie* 4.0 (German language)

worlds to help create a new working environment of integrated productivity between worker and machine" (Siemens, 2015) [26] and then went on to recommend that companies should implement this new model in stages (Constantinescu et al., 2014), where the first Step should be to study their involvement and the model's implications for their business (Albert, 2015).

As part of the European Program supporting research, development, dissemination and financing of practices and digital technologies assisted by CPSs, and built on the European Parliament document (European Parliament, 2015; Fair et al., 2012), the European Union considers that I4.0 may reverse the industrial decline seen in Europe in recent years. Being aware of what is happening around them, many industrialists and managers have already realized that I4.0 may bring new opportunities regarding the sustainability of their companies (Stock & Seliger, 2016). To connect a factory to the Internet and support production through CPS involves risks, from the investment required to the very maturity of the available digital production technologies (Thramboulidis & Christoulakis, 2016). However, representing more than 20% of jobs, equivalent to more than 34 million people and generating over 6,400 billion euros annually (Smit et al., 2016), European industry cannot risk losing the lead and becoming outdated in this transition stage to the Fourth Industrial Age.

2.3 THE PORTUGUESE ORNAMENTAL STONE SECTOR

The most evident symbols of Portuguese Ornamental Stones are the numerous monuments in stone, built from the fifteenth century onward, using engineering, Portuguese stone and people whose know-how was transmitted from generation to generation. Perhaps because it is part of the country's culture, in the 21st century Portugal is considered a world-class producer of stone products, with incorporation in the IC depending mainly on architects' will, knowledge and interest. Despite its small size, Portugal has a diverse and significant reserve of stones suitable for ornamental use, and so, more than ever, the ability to co-create value with architectural technicians and investors, while still in the design phase, should be one of the core tasks of a stone products supplier.

According to data provided by the Portuguese Marble, Granite Industry Federation, in the

[26] https://www.siemens.com/press/pool/de/events/2015/corporate/2015-11-innovation/innovationbrochure-e.pdf

year 2013, the Portuguese OS sector (i) exported to 116 countries; (ii) was in 9th position in the World International Stone Trade; (iii) was the 2nd country in International trade per capita; (iv) exports covered imports by 823%; (v) 45% of exports were to countries outside Europe and (vi) it was in 2nd position in the gross value added national ranking (after telecommunications) *(Silva, 2014)*. Consisting mainly of small and medium-sized enterprises (SMEs) (I. Frazao, 2016), the OS Sector is considered relevant in the Portuguese economy, representing more than 16,000 jobs, and being one of the main generators of private employment in inland regions. It has a record of sustained growth in exports (Chart 2.1), placing Portugal as the eighth country in the International Trade of OS and the second country in the world in International Trade per capita[27] (J. Frazao, 2016).

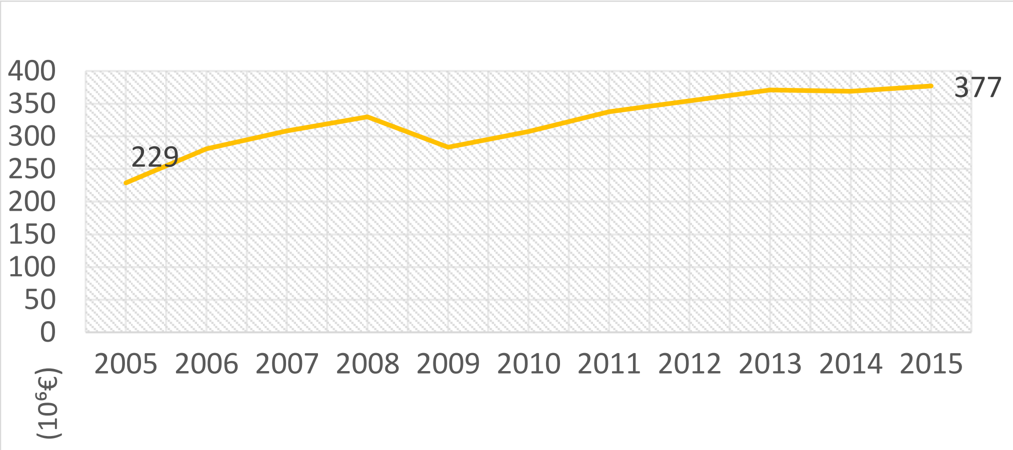


Chart 2.1: Evolution of Portuguese of Ornamental Stone Exports. Source: European Commission (2016), Trade Export Helpdesk[28], [Online accessed 20 November 2016]

2.3.1 Cluster Portugal Mineral Resources

Recent studies (I. Frazao, 2016; J. Frazao, 2016; Silva, 2014) indicate that the positive results observed in the sector since 2005 may be related to the progressive adoption of innovative practices and technologies designated *leanstone hornbook*[29](LH) as well as a professional and global marketing stance.

Starting in 2004, the movement to mobilize the Portuguese OS sector to reduce waste and improve flexibility (Peres & Costa, 2006) has had as its main milestones Technological Innovation Projects in consortium, which have resulted in a new generation of

[27]Gross Domestic Product per number of inhabitants
[28]http://exporthelp.europa.eu/thdapp/index.htm
[29] Set of practices and technologies to reduce waste and provide flexibility in production

technologies, concepts and innovative practices adapted initially to the needs of Portuguese OS companies. The leanstone movement (Silva, 2013) emerged from a process of cross-fertilization and technology transfer between the footwear sector and the OS sector (J. G. Cardeal, 2010), through the Facap[30], Fatec[31], Newalk[32], Jetstone[33] and Inovstone[34] projects. These will have been decisive in making many companies from both sectors believe that evolving technologically would help their search for competitiveness (Silva, 2014).

The Jetstone Mobilizer Project was one of the first major thrusts of leanstone (I. Frazao, 2016; Silva, 2013), bringing to the OS sector flexibility, agility in responding to customized projects, reduction of raw material waste and improved energy efficiency, which in turn led to increased productivity, improved working conditions, the ability to create new products and services, and ultimately contributed to evolution of the value chain (I. Frazao, 2016; J. Frazao, 2016). Completed in 2013, the Inovstone[35] Project acted transversally in all stages of the valorisation of natural stone (Silva, 2014), including extraction, transformation and finally restoration of the Historical Heritage in stone (Silva, 2013).

This phase ends with the Portuguese Government's recognition of the Cluster Valor Pedra in 2009 (Valorpedra, 2016), which can be seen as official recognition of the good practices adopted from the consortium of the Jetstone and Inovstone research projects. With the main goal of promoting competitiveness factors in the Portuguese OS sector, through the development and use of technologies, the Jetstone and Inovstone consortium aimed to develop technologies that would optimize raw materials and allow a quick response to small orders (Silva, 2013).

In her research work entitled *The Evolution of the Stone Cluster*, Inês Frazão (2016) concluded that the Portuguese OS companies which joined the Cluster Valor Pedra and freely adopted the *LH* (...) "can show a higher evolution in different domains, when compared to the sector's average in the same period." (I. Frazao, 2016). In this research, the author sought to explore the evolution of companies making up the Cluster of

[30] First Mobilizer Project to develop innovative technologies to produce Footwear
[31]Second Mobilizer Project to develop innovative technologies to produce Footwear
[32]Third Mobilizer Project to develop innovative technologies to produce Footwear
[33] First Mobilizer Project to develop innovative technologies for Ornamental Stones
[34]Second Mobilizer Project to develop innovative technologies for Ornamental Stones
[35] Inovstone Mobilizer Project is a consortium of 15 entities from the national business and scientific environment (http://www.valorpedra.com/inovstone)

Portuguese Ornamental Stones, characterized by the dominant profile of adoption of leanstone, export and innovation practices. From a comparative analysis of OS companies' performance, the author also concluded that between 2010 and 2015, exports from the sector registered a growth of 12%, during which time the restricted group of OS companies making up the cluster registered a 25% growth in exports (Chart 2.2).

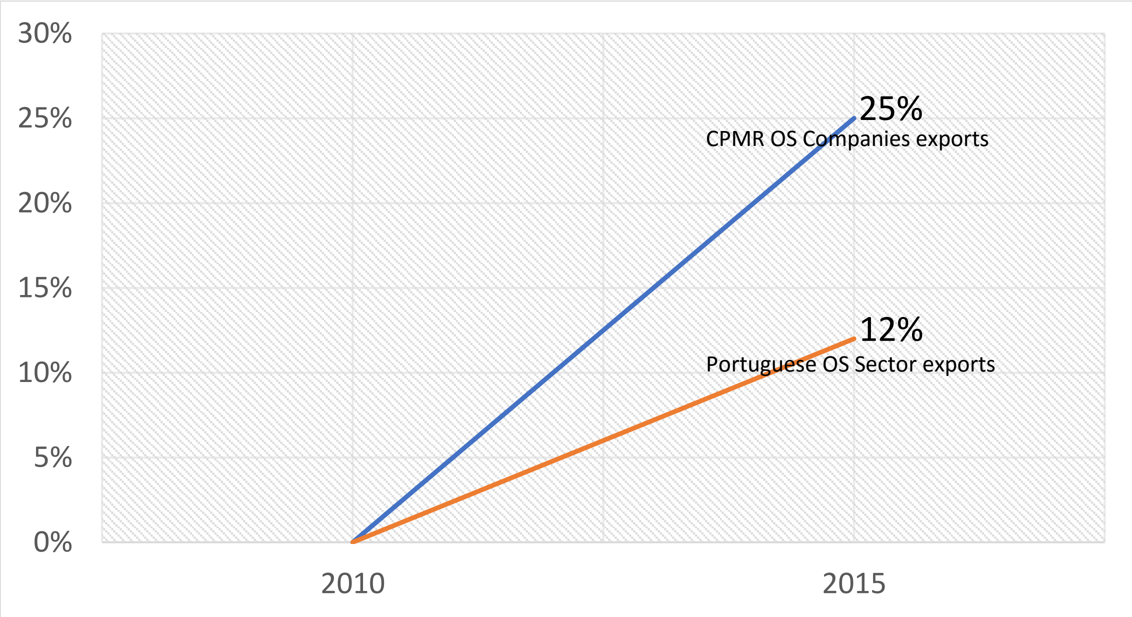


Chart 2.2: Exports Evolution of Ornamental Stone Companies' (2010-2015). Source: (I. Frazao, 2016)

In the same line of thought, in the research carried out by Joana Frazão (2016) entitled *Evolution of the Collaborator in the Stone Sector*, the author states that there is (…) "a significant increase in the export of stone in value and in quantity, and also an increase in the average level of human resources' qualifications in CPMR companies" (J. Frazao, 2016). The results of these two investigations conducted in 2016 are in line with the qualitative research work (Silva, 2013) and confirmed by the quantitative study conducted by the same author the following year (Silva, 2014). Based on accounting and other data, the author concluded that from 2008 onward, the companies that had begun to veer their management model towards the *LH* registered a strong growth in sales, exports, GAV and job creation (Silva, 2014). In the same investigation, the author confirmed the results of the research carried out the previous year (Silva, 2013), which had found that the same group of companies (the Cluster) had compensated better for the impact of reduced demand in the internal market (Ferreira et al., 2012) than their competitors that were not following the *leanstone*. The study also pointed to evidence in this group of companies in terms of (...) "better exterior and interior factory premises, caution with the areas for raw materials, concerns about people’s safety, storage, workers' uniforms and catalogue design, among other good practices" (Silva, 2014).

It will have been due to the positive results of the Cluster Valor Pedra companies, until then confined only to Ornamental Stones, that in February 2017 the Portuguese Government officially recognized the extension of this cluster to all activities related to mineral resources, from that date onward to be designated CPMR. This official recognition of the "new" (2017) Portugal Mineral Resources Association (ACPMR) may be seen as the willingness of Government entities to extend the good practices of the OS companies forming the CPMR, not only to other OS companies, but also to companies related to other mineral resources, both metallic and non-metallic.

It would not be true to say that the OS companies CPMR[36] members are representative of the OS sector in Portugal, just as they cannot be claimed to represent the state-of-the-art. However, they can indeed be considered as containing the "front-runners" in terms of best practices, and thus companies that operate according to Current Best Practices (CBP).

2.3.2 Portuguese Ornamental Stone Sector SWOT Analysis

2.3.2.1 Weaknesses and Strengths

According to data from World Business Partners (2013), of the 472 Portuguese SME working specifically in the extraction of ornamental stones, 56% have their activity in the extraction of granites, 25% in the extraction of marbles and the rest in the extraction of limestones and slates (Silva, 2014). Typically small and family-owned companies, the need to acquire critical mass and financial capacity could be some of the obstacles to be overcome to allow the necessary changes in companies in the Portuguese OS sector in the context of digital procurement, as a consequence of generalized BIM (Silva, 2013).

Supported by several studies carried out in recent years and mentioned above (I. Frazao, 2016; J. Frazao, 2016; Silva, 2013, 2014), it is possible to identify some of the reasons behind the positive output of Portuguese stone exports from 2005 onwards, the conclusions being in line with the results provided by Assimagra[37].

Following the implementation of innovations resulting from the Jetstone Project (Silva,

[36]www.clustermineralresources.pt
[37] http://www.assimagra.pt/

2013), there was an increase in OS companies' exports in 2005, which began by "importing" the model that the Portuguese Footwear Industry had been following since the last decade (Diniz et al., 2015). After a slight decline in 2008 (Chart 2.1), OS exports resumed growth the following year. According to data published by Assimagra on its website, this trend continued until 2015, with only a slight correction, perhaps resulting from the exceptional years of 2013 and 2014.

Also revealing the dynamics and sustainability of the Portuguese OS sector is the *Sustainable Exploitation of Resources in the Estremenho Limestone Massif* Project in co-promotion between Assimagra, Icnf, Dgeg, Cevalor, Lneg, Visa Consultores, Biodesign, Municipalities of Alcobaça, Porto De Mós, Rio Maior, Santarém, IPL and about 100 companies from the Pnsac[38] exploration quarries, which was awarded the 1st National Prize in 2015 in its category - *Supporting The Development of Ecological Markets and Resource Efficiency*. According to Mira Amaral[39] (...) "the internationalization of a Portuguese company is always a difficult process." (Amaral, 2014)[40]. Added to this, the fact that the increase in OS exports is in counter-cycle with most construction materials (J. G. Cardeal, 2010) suggests that the sector has achieved a healthy gain in "relative competitiveness" in the AECSC at an international level. A collaborative culture that aims for collective sustainability (Kropotkin, 1902), the positive "pull" effect of getting more companies to reach for a higher level of competitiveness, is seen by competing companies as an advantage and a way of adding value and prestige to Portuguese stone (Silva, 2014).

Nevertheless, to reduce the strengths of the Portuguese OS sector to just accounting numbers would be clearly unfair, as José Manuel Fernandes[41](2014) points out (...) "any business whose results are only accounting records is a poor business." (Fernandes, 2014). With an average salary that is substantially higher than the national average, the Portuguese OS sector has a ballast of almost two decades of incorporating new techniques and production technologies, which has allowed it to attract and incorporate critical mass through the admission of thousands of university graduates, according to Assimagra, and thus acquire an attitude oriented towards innovation (J. G. Cardeal, 2010). This predisposition towards continuous innovation, seen in recent years, has led to the

[38] Parque Natural das Serras de Aires e Candeeiros
[39] Member of the X, XI and XII Constitutional Governments, he held the positions of Minister of Labour and Social Security (1985-1987) and Minister of Industry and Energy (1987-1995).
[40]http://forumcompetitividade.org/wp-content/uploads/2014/04/O-projecto-Porter-e-o-Impasse-Portugu%C3%AAs-ISEG-2-Abril-2014.pdf
[41] Frezite Group, President

development of products, means of production and a management approach, all aimed at creating value for the customer (Antony, Setijono, & Dahlgaard, 2014), which may be a good indicator of the possible future response of OS companies in the context of the approaching BIM procurement and surely one of its strengths to be taken into account (Ibem & Laryea, 2014). The fact that the *LH* has come to encompass, from the Inovstone project onward (Image 2.1), not only OS transformation but also the upstream phase of raw material production (extraction of blocks) has allowed companies to acquire a more realistic perception of the full supply chain (Gupta & Andersen, 2012).

In view of these results, it is therefore reasonable to accept that the companies that have been consolidating an internal critical base, from their adherence to the *LH*, are likely to respond well to the digital procurement paradigm in the context of mandatory projects using BIM at the AEC (Gu & London, 2010). However, for this to be possible, it seems necessary to create a production model, from which to develop new techniques and sustainable technologies compatible with the new BIM procurement scenario. It is also necessary to set the guidelines that can turn this new threat into a new opportunity.

2.3.2.2 Opportunities and Threats

In the *Report on the Competitiveness of Portuguese Industr*y[42] by Michael Porter (Amaral, 2014), traditional sectors such as OS and footwear, among others, were the clusters (Björkdahl, 2009) on which Portugal must concentrate to make the national economy robust (J. G. Cardeal, 2010). At the time, Michael Porter (1994) predicted that with the growing impact of globalization, Portuguese companies would no longer be able to compete for low prices, where the adherence of new countries - China, India, among others - to globalization would mean that any country with lower wages would be able to produce and sell cheaper products than the Portuguese. With the aggravating factor that Portugal had come from a closed economy and was now competing in an open and competitive economic model (Bento, 2011). Contrary to these signs, but in full agreement with Porter's prediction, Miguel Goulão[43], referring to the OS sector, in an interview with the *Jornal de Negócios*[44] (2014), considered that (…) "the year 2013 was the best year ever in terms of sector exports" (Jornal de Negócios, March 17th, 2014). An even more

[42]http://forumcompetitividade.org/wp-content/uploads/2014/04/O-projecto-Porter-e-o-Impasse-Portugu%C3%AAs-ISEG-2-Abril-2014.pdf
[43] Vice-President Executive of Assimagra
[44] Portuguese daily business newspaper

intriguing performance, considering that from the end of 2007 onwards, there was a sharp reduction in the demand for construction materials, especially in Europe and the USA (Ferreira, Dias, Afonso & Brito, 2012).

As mentioned above, the research carried out in the sector in recent years leads to the conclusion that the positive response of Portuguese OS companies appears to be related to the incorporation of modern practices and technologies in their production, which allowed them to offer the market custom-made products (I. Frazao, 2016; J. Frazao, 2016) Regardless of the importance of technology in the good response given by companies, it is possible that a sector that so far has managed to turn various threats into opportunities might be facing a new threat with the new form of procurement resulting from BIM.

Integrated in the AECSC, the procurement model for stone products is the general model used in the IC itself (Behera et al., 2015), with only some slight nuances in the different typologies of products and markets in which OS companies specialize (Silva, 2013). Of great relevance in CPMR-OS companies' activity, the process of acquiring facades and custom paving (Veludo, 2015), for example, is operated from market consultation in the form of CAD parts lists, from which potential providers prepare and send their proposals to customers (Silva, 2014; Vieira, Silva, Sousa, Brito, & Gaspar, 2015). In the kitchen top, toilet or furniture market, however, the procurement model operates essentially through previous measurement of the work to be carried out by the potential suppliers, then moulds, or more commonly nowadays, files with the design of the pieces are created, which are budgeted by the potential suppliers in the form of a proposal that includes installation (Vieira et al., 2015). In BIM mode, the model for purchasing stone products will change substantially. As mentioned before, during the building design phase, solid

elements in IFC format, including specificities (dimensions) such as price, footprint and maintenance, among others, are "added" to the virtual building one by one from the IFC libraries online (Jung & Joo, 2011), as mentioned above (Jung & Joo, 2011). Once the design is completed, which means that all the elements of building have been added to the virtual building (Sehgal et al., 2014), the resulting BIM files are submitted to the process of approval by the competent authorities, based on the output generated by specific algorithms. This is followed by the payment of taxes, after which the process moves on to purchasing the elements that constitute the project, according to the planning extracted from the project in BIM (Malleson & Watson, 2016).

Consequently, in the BIM context, after approval of the project, the buyer, despite being free to choose the provider, must ensure that the specifications (eight BIM Dimensions) of each element of BIM are respected under the terms of the project approved by the official authorities (Eadie et al., 2013). As a result, the choice made during the project's design phase may sometimes permanently determine choice of the product and the supplier, unless the project is submitted to further approval by the authorities. It can be therefore considered that in the BIM context, product selection and very probably provider selection is moved upstream, which means it is done during the project phase (Malsane et al., 2014), thus leading to a change in the model of procurement. That is actually no surprise since it makes the acquisition process transparent (Grilo & Jardim-Goncalves, 2011), explicitly one of the political reasons for governments, such as the United Kingdom's, supporting the requirement to present projects in BIM.

For procurement in the BIM context, the availability of products on web-platforms, as they are necessarily accessible to BIM users, means first of all agreeing to share commercial information with the market, including competitors. Prices, deadlines, innovations and other information that in the current context is usually considered confidential (Volk, Stengel, & Schultmann, 2013). On the other hand, by opting not to work with this level of transparency, firms risk their products not being used in the design stage of the project (the BIM project phase) and as such may be permanently unable to sell them (Succar & Kassem, 2015).

The first consequence of this new procurement model (Ibem & Laryea, 2014), where OS-Providers have to publicly and globally present all the information about their products (Melton, 2005), is that the production model has to be very efficient, in order to become competitive (Sigalas & Economou, 2013). When dealing with public prices, the most competitive product will be the one produced in the most efficient environment, with waste playing an important role in competitiveness (Yang, Hong, & Modi, 2011; Fullerton, Kennedy, & Widener, 2013). Defending the generalization of BIM, the UK Government set clear objectives by stating "The construction industry and Government jointly aspire to achieve by 2025: a 33% reduction in both the initial cost of construction and the whole life cost of assets; a 50% reduction in the overall time from inception to completion for new build and refurbished assets and a 50% reduction in greenhouse gas emissions in the built environment." (HM Government, 2013) .

In view of these official assumptions, stakeholders in the AECSC, including OS companies, may find themselves confronted with a new procurement situation for their products, which can be described as five trends or threats:

i. Threat 1 (standardization trend) - in the BIM context, procurement in the AECSC will tend to be orientated towards standard products;

ii. Threat 2 (faster delivery trend) - in the BIM context, buildings' construction time will tend to be lower than at present;

iii. Threat 3 (lower costs trend) - in the BIM context, buildings' costs will tend to be lower than at present;

iv. Threat 4 (lower emissions trend) - in the BIM context, buildings will tend to be more environmental friendly than at present;

v. Threat 5 (lower non-quality trend) - in the BIM context, tolerance of non-quality products will tend to be lower than at present;

There are strong reasons to believe that the BIM generalization will become the norm. The first reason comes from the fact that the new CAD software releases for building design are already BIM, ensuring compatibility with the format established by the ISO Norm 16739, 2013. Even more significantly, the second reason comes from the political and financial support given by Government Initiatives such as EUBIM[45], among others, in which BIM technology is seen as the main driving force behind the change in the current procurement model in the AECSC (Grilo & Jardim-Goncalves, 2011). According to the UK Government, for example, the current procurement model is ineffective, so (…) "construction in 2025 is no longer characterized, as it once was, by late delivery, cost overruns, commercial friction, late payment, accidents, unfavourable workplaces, a workforce unrepresentative of society or as an industry slow to embrace change. In short, by 2025 construction has been radically transformed."(HM Government, 2013) and so compulsory use of BIM would be introduced gradually from 2016 onwards" (UK Government, 2011). Similar official initiatives in the EU, USA, Australia, China and many other world economies point in the same direction, and it is expected that in many countries, starting from 2025 with BIM in full maturity mode (with all its dimensions), it will become the mandatory technology in building projects which require licensing and approval (HM Government, 2015).

[45] http://www.eubim.com/

As mentioned previously, it is estimated that the global construction market will grow more than global GDP in the coming years (Global Construction Perspectives and Oxford Economics, 2015), according to the Competitiveness Factors contributed by I4.0. These are opportunities that Portuguese OS companies should not miss.

2.3.2.3 SWOT Analysis Summary

Analysing the SWOT matrix (Figure 2.2), the OS sector in Portugal is seen to have proven capabilities, while presenting the typical weaknesses of a sector mainly composed of SMEs, most of them family-businesses. On the other hand, it is a sector with several centuries of accumulated knowledge which has been tried and tested all over the world, where it has erected whole cities when necessary, as happened in Lisbon after the earthquake in 1775.

Strengths
- Proven know-how
- Proven competitive ability
- Proven environmental attitude
- Proven Collaborative Sectorial Culture
- Proven tendency for technological incorporation
- Proven critical mass attraction capacity
- Proven innovation-oriented mindset
- Proven tailor-made customization

Weaknesses
- Small size of companies
- Family businesses
- Low financial capacity
- Lower branding compared to Italian companies
- Low critical mass
- Small promotion capacity

Opportunities
- Global Construction Industry Growth Forecast
- Industry4.0 operations mode

Threats
- BIM-oriented Procurement for Standardized Products
- BIM-oriented Procurement to Lower Prices
- BIM-oriented Procurement to Lower delivery Times
- BIM-oriented Procurement to Lower Footprint
- BIM-oriented Procurement to Lower non-quality

Figure 2.2: SWOT Analyses of the Portuguese Ornamental Stone Sector in Digital Context

Given these indicators of resilience built on the wisdom accumulated over many generations, Portuguese OS Companies will surely find a solution to the threats resulting from BIM procurement. This solution may come from the digital operations of Industry4.0, combined with its historically global nature, taking advantage of the global growth of the IC foreseen for the coming years.

2.4 CHAPTER SYNTHESIS

In recent years, widespread use of the Internet has created the concept of *electronic* *procurement*[46], often by simply connecting to inter-organizational virtual platforms, also known as e-marketplaces (Grilo & Jardim-Goncalves, 2011), where buyers and sellers share information about prices and the type of products offered, while also carrying out payment and product transactions. However, this procurement model, although effective when structured (when the buyer knows exactly what he intends to buy), has a very low volume of transactions in e-marketplaces whenever it is a question of complex levels of customized product specification, as general happens in the IC (Marinho, 2014).

With as yet unpredictable impacts on the supply chain, BIM procurement will imply a reinvention of the business model itself in some sectors within the AECSC (Ibem & Laryea, 2014) especially in those that base their competitiveness on product customization, as in the case of OS in countries like Portugal. Since customization is one of the main competitive advantages of Portuguese OS companies, when competing with ceramic materials for example, this possible shift in the AECSC towards standardization will create, from the outset, a real problem for its sustainability. However, the threat can be transformed into an opportunity, if in the face of the creative constraints imposed on architects by the standardization of building elements in BIM, Portuguese OS suppliers allow architects to create their projects from customizable virtual elements in BIM, especially if combined with a productive response to designers' creativity (Heidari et al., 2014). The concept of *Smart BIM Objects* (Chen, Lu, Peng, Rowlinson, & Huang, 2015) has become a subject of study for many researchers in recent years. Virtual, standard and dynamic objects are easy to understand, but it is not yet possible to predict the implications for the processes that allow their production. (Heidari et al., 2014). During the design phase, the assignment of specifications (Dimensions) to the virtual BIM /IFC elements added to the digital building can be seen as the creation of their *fingerprint* (Sehgal et al., 2014), which some authors call the object's "DNA" (Matthews et al., 2015), the guidelines for the subsequent purchase and manufacture of the products. One of the characteristics of using BIM is that all the elements and stages of the work are correlated, meaning, a priori, that each element's *fingerprint* contains its eight dimensions. That correlation will facilitate its monitoring through BIM during the entire product lifecycle (Marinho, 2014).

It is in the context of searching for a solution to the threat resulting from BIM procurement

[25] Electronic procurement, also known as e-procurement, is business-to-business (B2B) requisitioning, ordering and purchasing of goods and services over the internet (Cheung, Rihan, Tah, Duce, & Kurul, 2012).

that this research thesis is focused. Concerning the possible impact of the I4.0 operations model on OS companies' response to the new BIM procurement, and if this is positive, I4.0 may even turn the new threat into a new opportunity, as happened about a decade ago with the *LH*.

In recent years, due to their good practices, the OS CPMR companies had export results substantially above the sector average, which means that they are more efficient than the sector average but also means that by operating in a global context they will be more exposed to competition, and thus to the threat arising from BIM procurement. As these companies use CBP in the Portuguese OS sector, this research will consider the impact of the response to I4.0 on this population. Having discussed the issue and identified the population to study, a literature review seeking a Theoretical Body that supports the research will be presented in the next Chapter.

CHAPTER 3

I think we're going to the Moon because it's in the nature of the human being to face challenges. We're required to do these things just as salmon swim upstream

Neil Armstrong

3. LITERATURE REVIEW

Contemporary with improvement of the steam engine, in the first volume of *Nature and Causes of the Wealth of Nations*, Adam Smith (1776) begins by presenting the context that leads to the creation of wealth, which according to him, would be generated from the inseparable articulation of specialization at work, exchanges and private property (as cited in Baraúna, 1996).

By using the expression *useful labour productivity* as the specific meaning of surplus production of goods, Smith (1776) saw wealth as the result of this excess production and its consequent export. Surplus production would be a direct consequence of the division of labour, executed by individuals specialized in the best of their abilities, enabling the individual to exchange the fruit of his talent to access the result of the others.

It was only during the Second Industrial Age that Adam Smith's proposals were applied in practice, through the specialization of work in mass production, in the form of assembly lines and rolling systems through which the parts making up the products circulated, such as the Ford car assembly plants (Melton, 2005).

The Third Industrial Age would come with the automation of processes through robotics and culminate in the last decade of the 20th century with widespread use of the personal computer, which led to popularization of the Internet and globalization of the modern economy (D. J. Teece, 2014).

For some authors, it was during this period (Ariu, 2016) that activities not involving *physical products* were designated by *services*, a word with a double meaning, (i) used to define activities that add direct value to the products, such as a pleasant salesperson or after-sales service, but also (ii) to designate outputs, where production cannot be separated from the consumer or the consumer does not obtain exclusive ownership of the acquired *thing* (except in the case of an exclusivity agreement) (S. L. Vargo & Lusch, 2010).

According to the International Labour Organization[47] (2007), services became the first global economic activity in 2006, overtaking agriculture and industry in terms of the labour force (Spohrer & Maglio, 2008). In Japan in the 1970s, for example, industry accounted for more than 40% of national GDP, compared with data for 2015, when the output of goods, including construction, contributed to less than 25% of Japanese GDP (Kwan et al., 2016), in line with the USA, where services accounted for approximately 80% of GDP in the first decade of the 21st century (Bitner, Ostrom, & Morgan, 2008b).

It is understandable that by the end of the twentieth century, the perspective, logic or way of looking at economics was based on the distinction of products between tangibles or intangibles, which some researchers call *Goods Dominant Logic* (G-D Logic) (S. L. Vargo & Lusch, 2010). This logic is based on the idea that the objective of economic activity is to produce and distribute goods (units of output) (Robert F Lusch & Nambisan, 2015), usually tangible, which can be stored and transported to the customer who only chooses and buys, and thus, it is only through the production process that goods incorporate value (Matthies & D'Amato, 2016).

For Lusch and Vargo (2006), because it is entirely up to the producer to create and attribute value to goods (Vargo &Lusch, 2004a), something seemed to be wrong, since the consumer, when seen as an external actor and independent of product production, would become an element alien to the product, without any participation in its value (R. Lusch & Vargo, 2006).

3.1 SERVICE DOMINANT LOGIC

In the second half of the twentieth century, several researchers and economists addressed the issue of product value. Wroe Alderson (1958), for example, in his reflections on markets, considered that (...) "what is needed is not an interpretation of the utility created by marketing, but a marketing interpretation of the whole process of creating utility." (cited in R. F. Lusch & Vargo, 2008). With the same understanding, Philip Kotler (1977) stated in his essays (...) "the importance of physical products, is not so much in owning them as obtaining the services they render." (cited in Vargo & Lusch, 2004b). Or in the

[47] http://www.ilo.org/global/lang--en/index.htm

marketing perspective, Evert Gummesson (1995) (...) “customers do not buy goods or services. They offer services that render services, which create value...activities render services, things render service" (as cited in Vargo & Lusch, 2004a). In the same line of thought, Christian Gronroos (2000) states that (...) “the focus is not on products, but on the consumers' value-creating processes, where value emerges for consumers, and is perceived by them." (as cited in Payne et al., 2008) and for Fredric Bastiat (1848) (...) “the great economic law is this: services are exchanged for services." (as cited in Robert F Lusch & Nambisan, 2015).

Looking at our own experience as consumers, it may be found that the main reason driving us to buy a product or service is not the value that the producer or seller has assigned to it, but rather depends on what can be done with the product or service. It is thus bought not for its tangibility, but for its intangibility. We buy brands, meanings, self-portraits, experiences, knowledge, specialization and value for life but the goods themselves are not the reason for buying (S. L. Vargo & Lusch, 2004b) and the acquisition of specialization can be used to manufacture and co-create innovative goods (S. L. Vargo & Lusch, 2010).

Possibly inspired and motivated by all these renowned economists in the History of Economics, first by its founder Adam Smith (1776), the researchers Robert Lusch and Stephen Vargo (2004) in their article entitled *Evolving to a New Logic for Marketing* (S. L. Vargo & Lusch, 2004a), proposed a new understanding for trade and value creation, which they named Service-Dominant Logic (S-D Logic). In this article, the authors considered that in the S-D Logic mindset, the concept of *service* (in the singular) should presuppose a process of doing something for someone, thus distinguishing itself from the word *services* used in the traditional mindset (G-D Logic). For the S-D logic, the concept of *service* would become the common denominator in the trade, leaving no distinction between services (intangible goods) and products (tangible goods) (R. Lusch & Vargo, 2006).

It is interesting to note that the concept of *exchange* proposed by Adam Smith (Baraúna, 1996) does not differ from the concept of *service* that Lusch and Vargo (2004) have adopted as Fundamental Premises or Axioms for the S-D Logic mindset (S. L. Vargo & Lusch, 2004a). Also Frédéric Bastiat (1848), when saying that the law should protect the individual, freedom and property, private in its perspective, where *services are exchanged* *for services* must have greatly influenced the creators of S-D Logic (Robert F Lusch & Nambisan, 2015).

This new way of observing commercial transactions, where *service* would become the basis of exchange, when applied to marketing, implied a continuous analysis of social and economic processes, focused on the operant resources (Bharti, Agrawal, & Sharma, 2015), with which companies must adopt a new attitude, based on continuous process improvement (Jaca, Santos, Errasti, & Viles, 2012). The adoption of continuous improvement strategies is thus, from the S-D Logic perspective, essential to reach sustainability through effectiveness, identifying competencies that become potential competitive advantages (Brasco, Found, & Moura, 2014) and identifying other entities that can benefit from these same competencies (Gupta & Andersen, 2012).

Vargo and Lusch (2008) articulated in a grounded manner the new entity used in the exchange, the *service*, which in their view is the basis of exchange for all types of organizations, regardless of whether they provide services or products, the S-D Logic matrix being defined through eleven Fundamental Premises (R. F. Lusch & Vargo, 2008). A few years later (2016), in their article entitled *Institutions and Axioms: An Extension and Update of Service-Dominant Logic*, the same authors presented a review of all S-D Logic Fundamental Premises, selecting five to become the S-D Logic Axioms (Table 3.1) (Robert F. Lusch, Vargo, & Gustafsson, 2016), since apparently some of the original concepts overlapped or derived from overlapped concepts (Robert F. Lusch et al., 2016).

Axiom 1	"The Service" is the fundamental basis of exchange in the form of skills that we use for the benefit of others
Axiom 2	Value is co-created by multiple actors, always including the beneficiary
Axiom 3	All social and economic actors are resource integrators
Axiom 4	Value is always unique and strictly determined by the beneficiary
Axiom 5	Value co-creation is coordinated by institutions and generated by actors, in institutional arrangements

Table.3.1: Service Dominant Logic Axioms. Source: (Robert F. Lusch et al., 2016)

By definitively abandoning the focus on physical resources, such as natural resources, buildings or others, the meaning of *service* from the S-D Logic perspective can no longer be confused with the concept of *services*, which in the traditional view means intangible goods (S. L. Vargo & Lusch, 2004a), while *service* is understood as the availability of skills, trust and knowledge usable for the benefit of others (S. L. Vargo & Lusch, 2008). The concept of *utility* (Naor, Bernardes, & Coman, 2013), for S-D Logic is associated with the fact that physical things, although absolutely essential, are seen as mechanisms to support service (R. Lusch & Vargo, 2006). In the same way, the concept of end-user, as a destructive element of the value created by the producer (R. Lusch & Vargo, 2006), also ceases to exist. Value is co-credited among actors, since goods have no value before being used (Kuo, Lin, & Wu, 2011).

In this sense, for Vargo and Lusch (2004), the increase in services is more apparent than real and depends more on the way we look at and think about the economy, than about the economy itself (S. L. Vargo & Akaka, 2009). Behind this apparent increase in services, for Vargo and Lusch (2004), there is an widespread adherence to the dominant paradigm of economic relations where the central element of well-being is *the tangible good.* Moreover, it is also due to outsourcing resulting from the continuous improvement of resources in specialization and market access. These factors lead to the idea of service growth, where advances in information and communication technologies (ICT) have led to a phenomenon known as dematerialization (Gronroos, 2011) or economic liquefaction (Robert F Lusch & Nambisan, 2015).

In this context, it is nonetheless contradictory that two years after Fundamental S-D Logic Premises was published (S. L. Vargo & Lusch, 2004a), Chesbrough and Spohrer (2006) in their article *Research Manifesto for Services Science* said (...) “it is necessary to give increasing attention to services due to a growing services economy that can be considered a Service Revolution." (Chesbrough & Spohrer, 2006). For these authors, the service-oriented economic paradigm shift, require profiles related to this activity, despite of several teaching entities are currently offering to their students new disciplines and service-oriented courses (Spohrer & Maglio, 2008), albeit in a disjointed fashion (Chesbrough & Spohrer, 2006).

This Manifesto echoed in the S-D Logic community, with its advocates Vargo and Lusch (2010) arguing that the way the authors of this Manifesto refer to services as intangible goods was still in line with the traditional view of observing the economy since Adam Smith, that is, G-D Logic (S. L. Vargo & Lusch, 2010). For S-D Logic authors, the Manifesto keeps considering economic activity based on the production of output units (of tangible or intangible goods), which are delivered to customers (S. L. Vargo & Lusch, 2004b) who consume them. Segregationist logic remains (Bardhan, Demirkan, Kannan, Kauffman, & Sougstad, 2010), where producers continue to be the only active actors creating value for tangible or intangible products, for which consumers are mere passive actors that destroy the value created (S. L. Vargo & Lusch, 2010).

3.2 SERVICE SCIENCE A SCIENTIFIC DISCIPLINE

When analysing the economic activity of a group of service companies, Chesbrough and Spohrer (2006) concluded there were elements common to all of them, which provided elements solid enough to be considered consensual in a new discipline applied to the study of the services[48] which they proposed should be designated *Services Science*. The list of common elements to all service companies, as elaborated by the authors of the Manifesto (Chesbrough & Spohrer, 2006), consisted of (i) the direct interaction between supplier and consumer; (ii) the simultaneity of production and consumption; (ii) the exchanged element, based on the combination and nature of knowledge; (iv) exchanges and experiences being an integral part of the business process (v) Information and Communication Technologies (ICT) being always present, promoting efficiency and transparency.

The creation of a scientific body of knowledge to support services activity (Services Science) for Chesbrough and Spohrer (2006) arose through the need to systematize and promote scientific research in order to find ways and solutions to real problems, such as: (i) creating more value by combining and accelerating information, generated by the continuous advancement of information, communication and sensing technologies; (ii) finding answers to integrate all information in order to create new services and new solutions for customer problems; (iii) managing the tacit knowledge of the entities involved in order to create more value from this exchange; (iv) leading people and organizations to create tangible and intangible assets that produce value for both.

In short, the Manifesto advocated the need to create a value-creation theory (Bharti, Agrawal, & Sharma, 2015) for service activities, to systematize innovation and accelerate value creation (Spohrer & Maglio, 2008). It is in this context that Jim Spoher and Paul Maglio (2006), both researchers at the IBM Almaden Research Center, in their article

---

[48]Services activity was the concern of Chesbrough and Spohrer (2006), when they published the document entitled *A Research Manifesto for Services Science*

entitled *The Emergence of Service Science: Toward Systematic Service Innovations to Accelerate Co-Creation of Value* reaffirm the need for this new field, now (2006) proposing that its designation must be *Service Science* and for which IBM would publicly disclose its own experience[49](Spohrer & Maglio, 2008).

Focused now (in 2008) on the logic of service, and four years later, after Lusch and Vargo introduced the Fundamentals of S-D Logic (Vargo &Lusch, 2004a) at the time already cited by thousands of researchers, it is still strange that Spoher and Maglio before June 2008[50] had not made any reference to the concept of S-D Logic proposed by Lusch and Vargo (2004). This could be the reason leading the pioneers of S-D Logic, Lusch and Vargo, in 2006, to publish an article that indicates some discomfort with the overlap of concepts between the new discipline of *Services Science*[51] and the S-D Logic mindset. Entitled *Service-dominant logic: reactions, reflections and refinements,* in this article Lusch and Vargo (2006) invited the research community to participate in a critical way in the S-D Logic mindset, firstly because the S-D Logic as introduced in 2004 is an open-source and collaborative model (R. Lusch & Vargo, 2006).

It is in this context that Spohrer, Maglio, Bailey and Gruhl (2007) systematize the foundations of the new scientific area, renamed *Service Science, Management, and Engineering* (SSME), with the first purpose of providing theory and practice for *service innovation* problematics (Spohrer et al., 2007). In July 2007, the pioneers of S-D Logic, Vargo and Lusch, published an article called *Service-Dominant Logic: Continuing The Evolution* (R. F. Lusch & Vargo, 2008), claiming authorship of the concepts associated with S-D Logic and proposing an update of its Fundamental Premises as introduced in 2004 (S. L. Vargo & Lusch, 2004a).

The first major contribution to consolidating S-S Theory came in June 2007,when Jim Spoher and Paul Maglio, in their article entitled *Fundamentals of Service Science, w*ho until then had ignored the work of Vargo and Lusch, proposed that the construction of the

[49]The business activity of IBM until 1982 was based essentially on products. Through its internal reconfiguration, transactions in 2008 were essentially services, taking advantage of the growth of the service sector in the ten major world economies

[50]This may be partly since they were both IBM researchers, who would have an interest, for commercial reasons, first and foremost to ensure that the epicentre of this new scientific area was associated with the IBM Almaden Research Center, and as a result, the results of the research, they would more easily move to their "Business Consulting Services" division.

[51]In 2006 the new discipline proposed was still designated Services Science

Body of Knowledge for *Service Science* must be elaborated based on the perspective, propositions and vocabulary of S-D Logic (Maglio & Spohrer, 2008).

Considering S-D Logic's Axioms as the basic premises of SS, Spoher and Maglio (2008) propose that S-D Logic must be the basis of this new scientific area, where the abstract entity designated *service system* would be the *element of study*. This proposal (2008) from S-S pioneers was in line with the earlier proposal from the S-D Logic pioneers (2007), for whom S-D Logic must provide the basis for a review of *Company Theory* (Rice, Liao, Martin, & Galvin, 2012) based on study of service systems (R. Lusch, Vargo, & O'Brien, 2007).

Laura Anderson, Norm Pass, Spohrer and Tryg Ager, all researchers at IBM Almaden Research Center, publish another key article to consolidate this new scientific area entitled *Service science and Service-Dominant Logic*, in which, in an articulated way, they substantiate the importance of S-D Logic Axioms as the Fundaments of the of S-S Body of Knowledge (Spohrer, Anderson, Pass, & Ager, 2008). It is found from the literature review that since this article was published, S-S and S-D Logic have evolved towards the convergence of their principles, each community keeping distinct purposes, and their contributions and criticisms have made these two "movements" increasingly collaborative, solid and complementary (Spohrer, Anderson, Pass, & Ager, 2008).

As the Body of Knowledge has been consolidated, the designation *Service Scien*ce has been used as a diminutive or as a substitute for the *Service Science, Management, and Engineering* designation, which according to its main precursors, from 2008 would become the new scientific area, available to develop the skills needed for economic activity based on *service*. By abandoning the *traditional* perspective, where products and services are understood separately, S-S adopted the concept of service exchange (Spohrer & Maglio, 2008) and thus, *service* and *service systems* have become the objects of study for this new scientific area, in the sense of its development and improvement in order to create value and innovation for an Ecologically Sustainable and better World (Spohrer et al., 2007). By adopting the vocabulary and philosophy of S-D Logic, the field of application of S-S went far beyond the activities of services, applying its scientific methodologies to all types of economic activities related to the production of tangible and intangible goods (Kwan et al., 2016).

3.3 SERVICE SCIENCE: THE BODY OF KNOWLEDGE

According Ganz, Satzger, and Schultz, a scientific discipline is a set of methods and standards, accepted and used by a community, to develop a Body of Knowledge that explains and typifies observable phenomena in the world (Kindström, Kowalkowski, & Erik, 2013). Thus, it was necessary to attribute to S-S the conceptual structures, theories, models and laws that could not only be empirically tested but also applied to the benefit of society (Fraunhofer, 2012), and in this context, the main advocates of S-S, Spohrer, Anderson, Pass, Ager and Gruhl (2008) considered that S-S must be viewed as a scientific field under construction, for which the Body of Knowledge would emerge slowly but with a challenge to become truly interdisciplinary (Spohrer, L.C. Anderson, et al., 2008).

This led to construction of S-S Theory, which could support it as a scientific field, taking into account its interdisciplinarity and considering the Sustainability of the Planet as a transversal concern, in exchanging service and assuming S-D Logic as its philosophical anchor. One of the first difficulties for S-S Theory consolidation is its own interdisciplinarity, to the point that some authors have considered it as a scientific area emerging from a melting pot (Spohrer & Kwan, 2009).

3.3.1 Service Science: The Fundamental Concepts

As mentioned in previous sections, the authors of the Manifesto (2006) noted that there were several common aspects in all of the observed service firms, which, being consistent enough in the authors' opinion, should incorporate the foundations of *Services Science* (Chesbrough & Spohrer, 2006) and later (2009) proposed to incorporate *Knowledge Body of the Service Science* Theory (Spohrer & Kwan, 2009).

(i) As a first common point, the authors verified that all service companies used knowledge from the same ten scientific disciplines[52] and people, information, technologies and organizations were always involved. From this common aspect, the authors of the Manifesto considered that the new scientific field must consider these four typologies of resources as a basis, and thus use these ten disciplines to study how these resources should be applied and configured to create value.

[52]The disciplines that are part of the Service Science: History, Law, Marketing, Operations Management, Political Science, Sustainability, Anthropology, Engineering, Computer Science, Procurement and Management (Spohrer & Kwan, 2009).

(ii) As a second common point, they verified that the four common types of resources identified could be classified into resource classes with rights (people and organizations), classes with ownership (technology and shared information), classes with physical entities (people and technology) and classes with socially constructed entities (organizations and shared information).

(iii) As a third common point, they verified that the use of the ten scientific disciplines in the services companies studied integrated and coordinated the resources, in an occasional or systematic way, to respond to specific permanent company requirements.

(iv) As the fourth and last common point observed in all companies, the authors found that all these scientific disciplines use qualitative or quantitative metrics to measure the results of their activity.

From these findings, the Manifesto authors found that in order to increase efficiency it would be necessary, useful and urgent to use a common vocabulary in all disciplines, later resulting (2008) in S-D Logic becoming the source of the vocabulary and assumptions of the Theory to study S-Systems, their configurations and interaction modes (Maglio & Spohrer, 2008).

During the present literature review, it was found that the process of creating the Theoretical Body of S-S has evolved from 2008 till today. Firstly, by incorporating the S-D Logic concepts such as *value co-creation* and *resource integration* (Vargo & Akaka, 2009) and *service* , which is the basis of all exchanges in the S-D Logic mindset, so that for S-S, all economies have become service economies as well as all companies nowadays being service companies belonging to service ecosystems (Robert F. Lusch et al., 2016). This extends the scope of S-Systems far beyond specific types of industries or services, concepts that no longer exist in S-D Logic. S-S is concentrated on the value-creation process underlying all exchanges (Edvardsson & Tronvoll, 2013), finally abandoning the focus on physical resources such as natural resources, buildings or others.

As in S-D Logic, also for S-S the meaning of *service* cannot be confused with *servic*es, which in the traditional perspective means intangible goods (S. L. Vargo & Lusch, 2004a). Also for S-S, the concept of *service* will become the provision of capabilities, trust and knowledge, usable for the benefit of others (Akaka et al., 2014) and physical things, being essential, come to be seen as mere mechanisms of service provision (R. Lusch & Vargo, 2006).

This is how Service Science became the discipline that intends to categorize and explain the various types of S-Systems, their interactions and their implications for value creation (Maglio &Spohrer, 2008). Since not all interactions co-create value, it tries to understand the reasons for these normative[53] deviations (Maglio, Vargo, Caswell & Spohrer, 2009).

For activities related to the production of tangible goods (industry), increasingly supported by digital technologies common to intangible assets, S-S may become an interesting discipline at several levels. Firstly, the need for new professional profiles (Demirkan & Spohrer, 2015), which can contribute to making the digital service innovation process more systematic and therefore a better choice of investment and business management (Stoshikj, Kryvinska, & Strauss, 2016). In this context in 2009 (Spohrer, Anderson, Pass, & Ager, 2008) the ten fundamental concepts of Service Science were published, the Foundations of the Theoretical Body of Service Science, defined below:

(i) RESOURCES DEFINITION - for S-S anything that has a name and can be useful must be considered as a resource (Spohrer et al., 2007). Physical and non-physical *things* are potentially useful (Spohrer & Maglio, 2008) and framed in four primary types: people, technology, organizations and shared information (Merschbrock & Munkvold, 2015). This is not fully coincident with the S-D Logic mindset, for which any economic entity consists of two types of resources (Robert F. Lusch, Vargo, & Tanniru, 2010) - *operant resources*, such as people and organizations and *operand resources* such as technologies and knowledge (Robert F. Lusch et al., 2016), the *service* being the application of these resources for the benefit of the other (R. Lusch & Vargo, 2006). The resources, whether circumstantial or generic, will have a useful life (beginning, middle and end), relative abundance, cost of creation, cost of maintenance and cost of end of access and use (Spohrer, Anderson, Pass, & Ager, 2008). Formalizing resources that make up a service system in a consistent and valid way, for the different disciplines that comprise Service Science, is one of the purposes of this new scientific area (Maglio & Spohrer, 2008). For S-S, *People* are physical resources with legal rights; *Organizations* are non-physical resources with legal rights; *Shared Information* is non-physical resources treated as property, and *Technology* is physical resources, treated as property (Spohrer et al., 2007). For SS, *Innovation* ceases to be a strategic option to become a mental pre-

[53] It is considered a normative interaction when it results in value creation (Maglio, Vargo, Caswell, & Spohrer, 2009).

requisite for survival (Stoshikj et al., 2016), and for this change to be successful, a new professional profile will be needed (Demirkan & Spohrer, 2015), supported by a new profile of organizations (Spohrer & Kwan, 2009). In other words, companies and universities need to readjust their talent-building resources to empower the next generation of *service innovators* (Spohrer, Anderson, Pass, Ager, et al., 2008). From this need, Demirkan and Spohrer (2015) anticipate for the twenty-first century an effective workforce with adaptive and innovative professional skills, whose background and leadership abilities allow them to create consensus, both in terms of isolated academic expertise and multifunctional organizations where they work (Demirkan & Spohrer, 2015).

(ii) SERVICE SYSTEM ENTITIES DEFINITION - For S-S, some complex resource configurations are able to initiate actions, and thus can be considered as S-Systems (Maglio & Spohrer, 2008). Each S-System will have an identity and will be connoted with a class or type, such as people, companies and government agencies, among others (Maglio et al., 2009). Thus, for S-S, S-System entities are the elemental unit of analysis (Spohrer et al., 2007). Maglio et al., 2009). Abstract entities (Storbacka, Brodie, Böhmann, Maglio, & Nenonen, 2016) arising from the configuration of people, technologies and other resources that interact with other entities to create mutual value (Maglio et al., 2009). This means that all S-System entities are resources, defined in SS as dynamic configurations of other resources (Q. Wu, He, & Duan, 2013), including people, organizations, shared information and technology, and can interact informally or formally (Spohrer, Anderson, Pass, & Ager, 2008). This means that not all resources can be considered S-Systems according to the S-S perspective. Within S-Systems, different resources share their competencies across at least four different dimensions: information sharing, job sharing, risk sharing, and asset sharing, so the S-Systems can be classified according to their dominant exchange (Spohrer, Anderson, Pass, & Ager, 2008). From practice, (i) Information-Sharing tends to be dominant in business consulting (Ciancimino, Cannella, Bruccoleri, & Framinan, 2012); (ii) Work-Sharing tends to be dominant in subcontracting; (iii) Risk-Sharing in insurance and (iv) Asset-Sharing is more frequent in rental businesses, although all four dimensions are present in almost all S-Systems (S. L. Vargo & Akaka, 2009).

(iii) ACCESS RIGHTS DEFINITION – service system entities are dynamic configurations of a set of resources, where there must be at least one resource with rights and responsibilities (Edvardsson & Tronvoll, 2013). In addition, within an S-System, the resources must be accessible to each other, and to allow interaction between two S-Systems, both will have to provide, directly or indirectly, access to the resources of the other (Anya, Moore, Kieliszewski, Maglio, & Anderson, 2015). In this sense, in S-Systems, resources can be made available through four different types of access (Spohrer, Anderson, Pass, & Ager, 2008): (i) because they are own resources, (ii) by renting, (iii) they are held in common with other entities or because (iv) they are privileged access resources (Maglio & Spohrer, 2013). Access rights end up being linked to social norms and legal regulations, associated with the access and use of resources and therefore restrict the interactions and results of the interactions between S-Systems, throughout the service process (Bharti et al., 2015). In the modern economy, increasingly supported by digital technologies, where the Internet is a resource available and accessible to all, the notion of cyberspace arises (Robert F Lusch & Nambisan, 2015). Here, consumers and producers coexist and a cyber-client has become a new type of actor (Hoske, 2015). Thus, for a cyber-client to be considered an S-System, it will have to include resources with rights and responsibilities and propose value-creation actions through the co-existence of its capacities, constraints, rights and responsibilities (Kwan et al., 2016), That is, it must contain at least one person, duly identified.

(iv) VALUE-COCREATION INTERACTIONS DEFINITION – Among academics and practitioners, from the literature review (Spohrer & Kwan, 2009) it was found that in recent years, the definitions of *value-cocreation* have become confused, when applied in different scientific areas. In an attempt to clarify the meaning, Bharti, Agrawal and Vinay (2015)[54], based on a structured thematic content analysis applied to the published literature until 2015, identified 27 definitions of *value creation*, which the authors classified according to five different types of disciplinary areas or environments: (i) process environment, (ii) resources, (iii) co-production, (iv) perceived benefits and (v) management structure (Bharti et al., 2015). For S-D Logic (Vargo &Lusch, 2004a), value co-creation occurs through

[54]Researchers from the Indian Institute of Technology

the integration of existing resources with others available in a vast array of S-Systems, resulting in a contribution to the well-being of those S-Systems or ecosystems where they are inserted (Robert F. Lusch et al., 2016). However, for S-S, value co-creation is defined as the result of communication, planning and other intentional interactions among multiple entities (Maglio & Spohrer, 2008). Thus, there is a gap between these two perspectives, which seems to be related to the interpretation of the outcomes: whereas for S-D Logic, co-creation always results in a positive benefit (Robert F. Lusch et al., 2016), for S-S, co-creation does not always result in positive value (Breidbach & Maglio, 2016). The mechanisms of value interactions are based on value propositions, intuitively the promises and contracts to which two or more entities agree, because they believe that value will result for all entities (Demirkan & Spohrer, 2016). A repeated value proposition that creates profits for a company is thus considered a *business model* (Kwan et al., 2016). In a service process, the *provider* S-System resources are integrated with the resources of the "client" S-System among others, and the value results from this interactive context (Robert F Lusch & Nambisan, 2015). This process continues over time, as new knowledge is generated and exchanges occur within and among the surrounding S-Systems (S. L. Vargo & Akaka, 2009). Since not all activities result in benefit, for the S-S it means that not all interactions between S-Systems co-create positive value, i.e., not all outcomes are normative (S. L. Vargo & Lusch, 2010). In this sense, it is also the challenge of the study of S-S to understand the reasons for deviations from normative behaviour, (Cox & Chicksand, 2005) applying scientific methods and understanding to promote the ability to design, develop and size S-Systems for commercial and social outcomes that result in efficiency, effectiveness and sustainability (Stoshikj et al., 2016).

(v) GOVERNANCE INTERACTIONS DEFINITION - the interactions of Governance depend on the degree of compliance of the entities involved, as well as the degree of coercion the entity authorizes through norms and laws (Spohrer, Anderson, Pass, & Ager, 2008). Throughout the co-creative process between S-System entities, the expected value of a previously accepted (mutually) value proposition may not occur. In these situations it may result in a dispute between the entities involved, resulting in the need to trigger governance mechanisms (Stoshikj et al., 2016). It may be therefore considered that the availability of resources from Governance entities reduces uncertainty (and therefore the risk of involvement) in these situations, prescribing in advance a mutually agreed process to resolve any disputes that may arise (Anya et al., 2015). The S-D Logic provides the vocabulary and philosophical foundations for S-S, which must use this vocabulary and philosophical bases in the disciplines, practices and management of business and everyday social affairs (Breidbach & Maglio, 2016), guiding the way the world is seen (S. L. Vargo & Akaka, 2009) and thus reducing possible disputes over vocabulary mismatch (Robert F Lusch & Nambisan, 2015). Governance mechanisms are also known as mechanisms of conflict resolution (Camarinha-Matos & Afsarmanesh, 2007). Therefore, formalization of the notion of governance interactions and the development of more dispute resolution mechanisms is also a challenge for Service Science Theory (Spohrer, Anderson, Pass, & Ager, 2008).

(vi) OUTCOMES DEFINITION- from the S-Systems' interactions, the outcomes are the result, whose normative or desired value is of course the co-creation of positive value for all the actors (Robert F. Lusch et al., 2016). When two or more S-Systems interact, the outcome is judged by each stakeholder from their perspective. Each one evaluates the value created or destroyed, according to their frameworks or references (Spohrer, Anderson, Pass, Ager, et al., 2008). In a simplistic approach, in a value interaction between S-Systems, as in the *prisoner's dilemma* (DeCanio & Fremstad, 2013), four results are logically possible: the co-creation of value (win-win), co-destruction of value (lose-lose) and then the two possibilities where if one player wins the other has to lose (Spohrer, Anderson, Pass, Ager, et al., 2008). To go a little further, the S-S proposes its own normative model, with the objective of evaluating the result of the value interactions among S-Systems, based on ten possible outcomes, proposing for this the methodological tool of ISPAR[55] (Stoshikj et al., 2016). In a customer-provider interaction, the final evaluation of the value will depend heavily on the S-System that makes the evaluation, which in turn depends on many factors, such as the historical experiences and expectations established. In tangible goods, for example, quality can sometimes be measured absolutely from the properties of the physical object (Antony et al., 2014), where the quality and satisfaction indices (Rice et al., 2012) depend on customer

[55] Interact Serve Propose Agree Realize

expectations. However, the evaluation of quality fluctuations (irregularity), although also dependent on customer evaluation, depends more on supplier performance (Marodin & Saurin, 2013), Therefore, in many organizations, one of the objectives is to obtain quality approaches (Chavez et al., 2015), by using lean thinking methodologies (Lyons, Vidamour, Jain, & Sutherland, 2013).

(vii) STAKEHOLDER CONCERNS DEFINITION - From the S-D Logic perspective, the place where the value creation takes place goes far beyond the geographical or other limits of the individual or customer-provider actors. Value co-creation is seen as a dynamic and continuous process, involving groups or systems of S-Systems, designated as service ecosystems (Robert F Lusch & Nambisan, 2015), within which, for S-S four types of main stakeholders co-exist - customer, provider, competitor and authority (Spohrer, Anderson, Pass, & Ager, 2008). At each Step of the service process, the service system making the proposal must put himself in the position of the other stakeholders, including himself, reasoning in terms of concerns about expectations and access to resources (Bardhan et al., 2010). Thus, for S-S this approach is fundamental in proposing that the researcher should use metrics to measure these concerns to assess the outcome of each interaction (Zheng, Zhang, Wu, & Du, 2011), designing innovative value-creation interactions, mechanisms and new configurations of S-System resources always needed throughout the service process (Spohrer, Anderson, Pass, & Ager, 2008).

(viii) MEASURE DEFINITION - for S-S, the four main types of measures are quality, productivity, compliance, and sustainable innovation, each corresponding to the concerns of the four key stakeholders (Spohrer & Kwan, 2009). However, perhaps because productivity is strongly associated with physical outputs, this literature review revealed that not only in the S-D Logic community (Robert F. Lusch et al., 2016; Matthies & D'Amato, 2016), but also in publications related to AECSC (Motamedi et al., 2016), Operations Management (Karan & Irizarry, 2015), Industry4.0 and the Internet of (Faller & Feldmüller, 2015; Pan et al., 2015; Thramboulidis & Christoulakis, 2016), as well as in several S-S publications (Bardhan et al., 2010; Storbacka et al., 2016; Stoshikj et al., 2016), the designation *performance* has often been used instead of *productivity*. In this sense, customers' concerns are about quality, providers' concerns about performance, authorities' concerns about compliance and the concerns of competitors related to sustainable innovation (Spohrer, Anderson, Pass, & Ager, 2008), without which there is no longer an incentive to innovate (Bolton, Grewal, & Levy, 2007). The adoption of Lean thinking has been recognized as a competitive advantage for organizations (Fullerton, Kennedy, & Widener, 2013) where the application of metrics to Performance Indicators (KPI) has resulted in help for managers, engineers and those leading continuous improvement processes (Yang, Hong, & Modi, 2011) to increase efficiency. In order to assess the evolution of stakeholder concerns, in S-S, associating the metrics of the evolution of these concerns with performance indicators (KPI) would lead to results that are contrary to those intended, for example, the efficiency evolution value is the inverse of the concern about the efficiency evolution value. Thus, in S-S to measure the concerns (R. F. Lusch & Vargo, 2008; Spohrer et al., 2007), for presentation of the results to be more coincident with this scientific discipline, the Key Indicators might no longer be referred to as *Performance* (KPI)[56] to be referred to instead as *Concerns* (KCI)[57], continuing to be quantitative or qualitative and adopting clear names, measured throughout the service process as well as in traditional KPI, with the aim of measuring their evolution in terms of Innovation Outcomes (IO) (Kwan et al., 2016).

(ix) SERVICE NETWORKS DEFINITION- For the S-D Logic mindset, a service ecosystem is a community of interactive entities, composed of organizations or individuals (Robert F. Lusch et al., 2016) who apply their capacities and play their interdependent roles aiming for its effectiveness and survival (Robert F Lusch & Nambisan, 2015). This approach leads us to the end of the 19th century and the research carried out by Peter Kropotkin[58](1882) who, accepting the Theories of Evolution previously presented by Darwin, considered that mutual aid is also a Factor of Evolution (Kropotkin, 1902). For SS, S-System networks (Kahkonen & Lintukangas, 2012) are communities in which S-Systems interact with each other through value co-creation propositions (Akaka et al., 2014). Over time, that is, throughout the co-operative process or service process, routine interactions can be

[56] Key Performance Indicator (KPI)
[57] Key Concerns Indicator (KCI)
[58] Mutual Aid, published in 1903

transformed into long-term mutually beneficial relationships, resulting in authentic S-System networks (Stoshikj et al., 2016). In these S-System networks, or simply networks, there are also positive aspects from the S-S perspective, thus allowing the share of resources and increasing the capacity of, for example, the investment available to improve these resources (Matthies & D'Amato, 2016). However, catastrophic failures can rain down on many entities when networks are stopped, and this is one of the negative aspects that cannot be overlooked (O'Brien, 2016).

(x) ECOLOGY DEFINITION – for S-S, the Sustainability of the Planet as well as people's well-being is a concern that must be present in every S-System interaction and therefore must be considered as a concern for all stakeholders when making and assessing a value proposal (Hsu, 2016; Spohrer, Anderson, Pass, Ager, et al., 2008; Spohrer & Kwan, 2009; Stoshikj et al., 2016). In this sense, for S-S ecosystems' ecology is part of concerns about the Planet's Sustainability (Anya et al., 2015) acting at a macro level, in the interactions between populations or ecosystems (Robert F Lusch & Nambisan, 2015) regardless of the type of entities involved (Matthies & D'Amato, 2016).

3.3.2 Service Science: The First Principle

The First Service Science Principle has been defined as s*ervice system entities dynamically configure four types of resources: people, technologies, organizations, and information* (S. L. Vargo & Akaka, 2009), since the purpose of economic relations for the S-D Logic mindset is the exchange of service among entities aiming for reciprocal benefit (S. L. Vargo & Lusch, 2004a), that is, for S-D Logic *exchange service for service* (Robert F. Lusch et al., 2016). This view of economics contrasts with the perspective of Adam Smith (1776), also referred to as G-D Logic (S. L. Vargo & Lusch, 2010), since for the S-D Logic mindset products are not the fundamental basis of trade but rather the service, in the form of skills applied to benefit others (S. L. Vargo & Lusch, 2004a), with each economic entity consisting of a set of operant and operand resources (R. Lusch & Vargo, 2006). For S-D Logic, value emerges from the result of the interactions between these entities and here S-S appears as the discipline to analyse, evaluate and optimize these interactions (Spohrer & Maglio, 2008), with its First Principle incorporating the following concepts:

(i) RESOURCE TYPES - for S-S, anything useful and named may be considered as a resource, from which it can be deduced that physical or non-physical resources are potentially useful things (Spohrer, Anderson, Pass, & Ager, 2008), with a beginning, middle and end to their useful life, limited abundance and a cost of creating, maintaining and withdrawing it from use (Maglio et al., 2009). These resources or groups of resources forming economic entities or others interact by granting access rights to each other's sub-resources, and when interacting, they form networks which may be totally or partially contained in larger entities such as Cities, States and Nations (Maglio et al., 2009). A slightly different view is the S-D Logic perspective, where it is from the resources that the service arises by applying these same resources to the benefit of others (R. Lusch & Vargo, 2006), all the resources being linked in entities that link to other entities inside ecosystems and in the form of value-creation proposals (Maglio & Spohrer, 2008). To overcome this gap, in this research it will be assumed with some level of approximation that the four types of S-System resources as proposed by S-S (Spohrer et al., 2007) - *people, technologies, organizations and shared information* - can be considered particular cases of the general typologies of operant and operand resources of the S-D Logic mindset (S. L. Vargo & Lusch, 2004a).

(ii) RESOURCES’ DYNAMIC CONFIGURATION - Taking advantage of the results from previous research (Tien & Berg, 2003), Spohrer and Maglio (2007) designated as S-Systems the entities formed by configurations of people and technologies when they make value propositions linking organizations’ resources through the sharing of information (Maglio & Spohrer, 2008). Thus, for SS, the smallest S-System is a human individual when interacting with others and the largest S-System the global economy, and cities, companies, nations and government agencies are just a few examples of medium-sized s- systems (Kwan et al., 2016). For S-S, any analysis must consider the evolution of S-Systems at the level of value-co-creation interactions, their capacities, limitations, rights and responsibilities (Maglio & Spohrer, 2008), and so once they form a S-System, the entities share their competencies in terms of at least four dimensions: information sharing, job sharing, risk sharing and asset sharing, so S-Systems can be classified according to their dominant service exchange (Maglio & Spohrer, 2008). The modern economy has demonstrated that effective subcontracting agreements require a clear and frank information exchange and substantial risk-sharing between the customer and the provider, which means the service is increasingly applying skills to the benefit of others (Taylor, Jylhä, & Junnila, 2014), in line with the conclusions of Kropotkin (1903) one hundred years ago. This aspect becomes even more relevant in this research, since the Service Science analysis model starts out from the description of S-Systems, interactions and results, to understand the mechanisms explaining the evolution of value-creation interactions (exchanging) (Spohrer, Anderson, Pass, & Ager, 2008).

(iii) RESOURCE FORMALIZATION AND SERVICE SYSTEMS DEFINITION - formalizing S-System resources in a consistent and valid way for the different disciplines forming the S-S is not only a challenge but also one of the purposes of Service Science (Maglio & Spohrer, 2008). Each S-System has its own identity, connoted with its dominant activity (Maglio et al., 2009), where people are physical resources with legal rights (Beske, 2012), organizations are non-physical resources with legal rights (D. J. Teece & Augier, 2007), shared information is non-physical resources but with property, and technology a physical resource also owned (Spohrer et al., 2007), the reason why all resources can be classified in terms of their nature: physical, non-physical, with rights or without legal rights (Maglio & Spohrer, 2013). The *legal rights nature* clarifies whether the resource is able to sign contracts, agreements or is imputable for its actions (Sandstro & Kyla, 2007), which happens with resources such as people or organizations (Maglio et al., 2009), while the "physical nature" clarifies whether a resource exists in itself (such as people or buildings) or whether, on the other hand, it depends on other resources to exist (such as symbols or organizations) (Spohrer et al., 2007). For S-S, an entity can only be considered an S-System if it includes at least one resource with rights and at least one physical resource (Spohrer et al., 2007). In the digital economy, where the notion of the Internet of Things is increasingly important, this aspect is very important, because for Service Science a robot or an artificial intelligence algorithm cannot be considered S-Systems, since they have no rights. When a dynamic configuration of resources interacts with another resource configuration, from the S-S perspective, we are in the presence of S-Systems (Maglio & Spohrer, 2013), where all the entities that make up these S-Systems are resources, but not all of these features are S-Systems (Spohrer, 2007), the history of an S-System being the sequence of episodes of interaction with other S-Systems (Maglio et al., 2009). Informal interactions between S-Systems occur through explicit or implicit commitments (Bardhan et al., 2010) or promises governed by social norms, once again confirming conclusions that collaborative interactions are one of the essential forces for species' survival. (Kropotkin, 1902). On the other hand, formal interactions occur through explicit or implicit contracts that are legally binding within a legal system, with rights guaranteed by a third S-System, Authorities (Spohrer, Anderson, Pass, & Ager, 2008). From our own experience, it is observed that not all interactions between entities co-create value (positive), so it is the object of S-S study to search for the reasons for these deviations from normative behaviour, applying scientific methods and understanding to promote efficiency, effectiveness and sustainability of processes and activities (Stoshikj et al., 2016).

3.3.3 Service Science: The Second Principle

The Second Service Science Principle has been defined as *service system entities compute value given the concerns of multiple stakeholders* (S. L. Vargo & Akaka, 2009), since the relationships between S-Systems are based on value propositions, which from the S-S perspective can be understood as an S-System's request for another S-System to execute an action. Thus, a value proposition seems to be the basic relationship among S-Systems, in the form of service exchange or service interactions (S. L. Vargo & Akaka, 2009). For the exchange of service to occur, it is necessary to involve at least two distinct entities, designated in S-S as "stakeholders" (Maglio & Spohrer, 2013) and in S-D Logic as "actors" (Edvardsson & Tronvoll, 2013). It is thus expected that when the first stakeholder makes the value proposition, for example, the client conducting a market inquiry or the supplier making an offer, each of the other actors make a different evaluation of the proposal's value (Spohrer, Anderson, Pass, & Ager, 2008), since each has different objectives (Chavez et al., 2015). In this context, it is essential that the S-System that makes the value proposition, before making it effective, identifies the concerns that different stakeholders will have when they receive that value proposition (J. Smith & Colgate, 2007), related to perspectives, expectations, access to resources and many others held by each stakeholder.

As determined by the First Principle, the four primary stakeholders in S-S are the customer, provider, authorities and competition (Maglio & Spohrer, 2013). If the provider is the author of the value proposition, they must therefore consider the customer's perspective, their own perspective, the perspective of the authorities and that of the competition, before sending the proposal, as reasoning in this way will raise different concerns about what should be proposed. The customer, provider and authority stakeholders are traditionally considered in any business, since each one clearly participates in the benefits of the value co-created between the customer and the provider (Taylor, Romero, & Molina, 2010). It is a non-consensual situation, however, when it comes to the "competition" stakeholder (Sigalas, Economou, & Georgopoulos, 2013). For Spohrer and Maglio (2013), as competitors are part of the business ecosystem context (S. Vargo & Lusch, 2016), in which there are common shared agreements, rules and benefits, they must be considered as stakeholders, their perspectives contributing to generating additional value to the ecosystem through sustainable innovation (Maglio & Spohrer, 2013). In addition to the perspectives of these four stakeholders directly concerned, SS accepts that the study of value interactions can consider other secondary stakeholders, such as employees, partners, entrepreneurs, citizens and others (Spohrer & Kwan, 2009).

Among several methodological tools available in S-S, the service blueprinting has been widely used as a way to represent shared access to resources throughout the service process (Kwan et al., 2016), allowing visualization of the evolution of value propositions, contact points and actions that coordinate and motivate access to the resources of the S-Systems involved (Boughnim & Yannou, 2005). For S-S, the customer being the product's co-creator (Breznik & Lahovnik, 2014), mapping the service process using a tool such as the service blueprint becomes necessary, to generate new dynamics that brings positive and measurable innovation outcomes to the different stakeholders' concerns (Beske, 2012). As one of S-S's main objectives is to innovate in value propositions, it means that to improve IOs, it is necessary to know at the outset what resources are involved in these propositions (Wong, Ignatius, & Soh, 2014). Improving a value proposition does not mean benefit for customer or provider, but rather adding value to all directly interested stakeholders, competition being the main driver of innovation (Hüttinger, Schiele, & Veldman, 2012). As S-Systems (stakeholders) gain experience from lessons learned over time, systematic refinements will improve proposals, based on historical statistical and anticipated future standards, a lean thinking concept designated *continuous improvement process* (Melton, 2005; Taylor et al., 2014).

In this sense, any analysis model must promote and facilitate the usage of mechanisms for the continuous improvement process of value propositions which, in times of market turbulence, must consider the lessons learned as a challenge to improve the process continuously in a structured way (Chavez et al., 2015). Changes in government regulations, disruptive technological innovations, natural catastrophes, or aggressive movements by the competition may require adjustment of value propositions throughout the service process (Hsu, 2016).

This review has shown that much of the literature published involving Service Science has been related to the activities traditionally[59] referred to as *services* in the sense of intangible goods, while publication related to industry is restricted. This asymmetry in the scientific publication may be interpreted, on the one hand, by the fact that S-S is a relatively recent scientific field and, on the other hand, because industry is making the transition to a new Industrial Age based on the digitalization of productive processes, designated Industry 4.0 as referred to in Chapter 2 (Stock & Seliger, 2016). However, in adopting the basic assumptions of S-D Logic, S-S no longer distinguishes between products and services, resulting in the concept of "resource density" (Robert F Lusch & Nambisan, 2015).

In the digital Era, for customer stakeholders, quality concerns are the key indicators of their satisfaction, the evaluation of which must be based on an index of concerns whose reduction leads to satisfaction (Spohrer & Kwan, 2009). For the provider stakeholder of the Digital Era, performance concerns are the key indicators of their productivity, and evaluation must be based on an index of concerns whose reduction leads to productivity (Spohrer & Kwan, 2009).

For the Authority stakeholder in the digital Era, compliance concerns remain the key indicators of conformity, and evaluation must be based on an index of concerns whose reduction leads to conformity (Spohrer & Kwan, 2009). Contrary to what it might seem, with regulatory compliance being a factor in transaction costs associated with business in different regions of the world (Cox & Chicksand, 2005), fiscal transparency is increasingly desired by all, as this facilitates carrying out that business. In his paper "A General Theory of Competition", Hunt (2000) describes the theory of resource advantage and warns that reducing competition in economic systems results in diminishing

[59]Old logic (G-D Logic) (S. L. Vargo & Lusch, 2008)

innovation capacity over time (Hunt, 2000). In this sense, the existence of competition is a fundamental factor for the existence of sustainable innovation, which is a relative measure of value created in the short and medium term (Spohrer & Kwan, 2009).

3.3.4 Service Science: The Third Principle

The Third Service Science Principle has been defined as *the access rights associated with customer and provider resources are reconfigured by mutually agreed to value propositions* (S. L. Vargo & Akaka, 2009), since in the traditional view (G-D Logic) (Robert F Lusch & Nambisan, 2015), the producer is the main actor who produces goods and services and consumers are secondary actors or passive recipients (S. Vargo & Lusch, 2016). According to G-D logic, the producer is the source of knowledge and creativity, and therefore also the only source of product innovation (Matthies & D'Amato, 2016).

In contrast to the traditional perspective dating back to Adam Smith (1776), in the S-D Logic mindset all actors are considered resource integrators, networked with other actors and therefore all are potential innovators or value creators (S. L. Vargo & Lusch, 2004a). In this way of viewing the economy, by centring value from the existence of a network of resources which coexist and are available in the imaginary form of "resource density" to benefit others and oneself (S. Vargo & Lusch, 2016), when liquefied, the resources according to the S-D Logic perspective can be quickly mobilized in time, space or even the actor making the proposal (Robert F Lusch & Nambisan, 2015).

One of the fundaments of S-S is to consider access to S-Systems' resources as the necessary link for value creation (Maglio & Spohrer, 2013), whenever the resources of both stakeholders are reconfigured in order to propose something to each other (Q. Wu et al., 2013). If it is imagined as the fundamental mechanism of interaction between S-System resources or between different S-Systems, the reconfiguration of resources then arises, related to the notion of non-ownership or leasing (Stoshikj et al., 2016).

Applying the Third S-S Principle to the emergent paradigms of the Fourth Industrial Era, cyber-stakeholders (customers and providers), through digital technologies, become part of the I4.0 ecosystem and when they are internally reconfigured in order to acquire capabilities, rights, limitations and responsibilities may be considered in the light of the Third Principle (Demirkan & Spohrer, 2016) as *S-Systems I4.0* whose resources once mapped by the service blueprinting tool (Boughnim and Yannou, 2005) may be subdivided into three complementary groups in permanent dynamic reconfiguration for value co-creation (Bitner et al., 2008b):

(i) FRONT-OFFICE RESOURCE GROUP - consisting of people and interface technologies, which interact directly with other digital S-Systems, providing specialized skills (knowledge and skills) through actions, processes and performance for the benefit of other entities.

(ii) FRONT-OFFICE RESOURCE GROUP - consisting of people and technologies that interact directly with Front-Office resources, also providing specialized expertise through actions, processes and performance for the benefit of other entities.

(iii) FRONT-OFFICE RESOURCE GROUP - consisting of people, means of production, partners, company management, specific know-how, accounting, marketing, public and private entities, among others, that interact directly or indirectly with all available resources, by providing specialized expertise through actions, processes and performance for the benefit of the other entity.

In this way, in digital mode and according to the 3rd SS Principle, it becomes the dynamic configuration of all these physical and non-physical resources, with or without rights, that guarantees the existence of digital service interactions with other digital S-Systems, realizing value co-creation interactions and thus constituting a service process (Meynhardt, Chandler, & Strathoff, 2016), in which the formalization of continuous access rights to resources is one of S-S's purposes (Maglio & Spohrer, 2008).

3.3.5 Service Science: The Fourth Principle

The fourth Service Science Principle has been defined as *service system entities compute and coordinate actions with others through symbolic processes of valuing and symbolic processes of communicating* (S. L. Vargo & Akaka, 2009).

The researchers Newell and Simon (1976) described *symbol systems* as comparable to the universal machine of the British mathematician Turing (1936), a theoretical invention created many years before the existence of modern digital computers, known as the Turing machine[60] (Newell, 1980). For the symbols be studied in the context of value co-

[60]Abstract model of a computer, which is restricted only to the logical aspects of its operation (memory, states and transitions) and not to its physical implementation. It can be used to model digital equipment such as a computer.

creation interactions, some authors (Akaka et al., 2014) consider a more holistic and systematic view of the symbols, articulated in a structure that leads to the creation of symbol systems through empirical adoption of good practices (Newell, 1980), and thus, the Forth Principle incorporates the following concepts:

(i) HOLISTIC VISION OF SYMBOLS AND PRACTICES IN VALUE CO-CREATION - a symbol represents *a sign* which refers to the object it denotes by virtue of a law, generally an association of general ideas, which operates to cause the symbol to be interpreted as referring to that object (Peirce, 1932). In an attempt to conceptualize the market as a system of signals, some authors (R. F. Lusch & Vargo, 2006) draw attention to the linguistic conventions of signals (the rules of interpretation), such as shared images, to constitute the meaning (interpretation) of material objects and realities (signs) in the description of the process of communication and exchange of economic value, among actors, in consumption and marketing practices (Domegan & Bringle, 2010). For Domegan and Bringle (2010), a way to explore the role of symbols in value creation could involve exploring the relationship between a sign (for example, the physical form of a symbol), its interpreted meaning (e.g. valuation of the value) and the rules that determine this interpretative relationship (e.g. institutions) (Domegan & Bringle, 2010). In this same line of thinking, Loebler (2012) considers that signals explicitly coordinate interactions within ecosystems, whereas practices coordinate the different interactions from which the value emerges, that is, the practices serve as a way to attribute meaning to signs (Loebler, 2012). Thus, individual practices, such as actions and words that are executed at a micro level, may result in different meanings if they overlap with higher levels of interactions (Akaka et al., 2014). It may be considered that the study of the relationship between signals and practices can lead to a deeper understanding of symbols and their role in value co-creation, although the meaning of a sign or symbol may vary between the micro, medium and macro levels (S. Vargo & Lusch, 2016). In a non-convergent way, for Shove and Pantzar (2005), practices are interrelated sets of meanings (symbols), skills and competences (e.g. processes and know-how) and tools (e.g., material objects), which are integrated by actors through their routine performances (Shove & Pantzar, 2005). This is completely in line with Loebler's (2012) position for which practices contribute to the creation of symbols within a given ecosystem or even multiple contiguous ecosystems (Loebler, 2012). By combining all these different understandings, it may be accept that the interpretation of signs and symbols leads actors to performances based on practices (Akaka et al., 2014), which combined with other signs or symbologies, lead to the creation of Symbol Systems, with identification of three types of practices that contribute to the performance or continuous reproduction of markets: normative practices, representational practices and exchange practices (Kjellberg & Helgesson, 2006). The classification of these three types of practices provides insights into how symbols, signals and interrelated practices (Loebler & Lusch, 2013) guide actors' actions and interactions in ecosystems, all of which (Kjellberg & Helgesson, 2006) contribute to value co-creation within ecosystems (Robert F. Lusch et al., 2016). In the particular case of normative practices, they influence the development of social norms (how to act and interact in specific contexts) and coordinate interactions among different actors (Loebler & Lusch, 2013). On the other hand, representational practices allow the communication of information and interpretation of signs, such as language (Akaka et al., 2014). From the nature and role of symbols in value co-creation, a holistic perspective emerges of how actors co-create value and how these practices affect the rules and relations of sign interpretation that constitute the role of symbols within service ecosystems and vice-versa, with relevance for Service Science (Maglio & Spohrer, 2013).

(ii) SERVICE ECOSYSTEMS AND SYMBOL SYSTEMS - an ecosystem is a community of interactive entities, organizations and individuals (including clients) that co-engage their capacities and roles and depend on each other for their global effectiveness and survival (Iansiti & Levien, 2004). The service-centric, value-oriented vision extends the scope of market interactions to networks (e.g. multiple providers, firms and clients) and underscores the dynamics of social systems driven by the service exchange (R. Lusch et al., 2007), but also a system of relatively self-defined and self-adjusting borders, made up of social and economic actors (resource members) linked by shared institutional logics of mutual value creation (Meynhardt et al., 2016), which for S-D Logic are classified as Service Ecosystems (Robert F Lusch & Nambisan, 2015). This definition of ecosystem allows exploration of how the rules and relations of signal interpretation influence the way in which actors practise value co-creation within service ecosystems, a theoretical view in which symbols are signs linked to practices (Loebler & Lusch, 2013) and incorporated into broader social institutions (Storbacka et al., 2016). In recent years, Vargo and Akaka (2015) have been using the "market practices" model (Kjellberg & Helgesson, 2006) to identify a number of practices they consider central to value creation, particularly from a perspective of service ecosystem (Akaka et al., 2014). According to this model, during the co-creative process, the systems involved raise the concerns of the other S-Systems, at the same time as the co-creation of value is a joint activity that depends on communication and how entities question the value attributed by others, so it is fundamental to have an effective symbolic process accepted by everybody (Akaka et al., 2014). Since co-value results, a priori, from the implementation of practices among multiple resources and stakeholders, this fact means each value proposition is evaluated from different perspectives of the actual value co-created. Thus, for the interaction or exchange to succeed, there will inevitably be a sharing of points of view or even overlapping of the meaning of value by the resources and stakeholders involved (Robert F Lusch & Nambisan, 2015). From the S-S perspective, stakeholders evaluate and coordinate actions with other stakeholders through symbolic processes of value and communication, so some authors propose use in S-S of the concept of Symbol Systems (Maglio & Spohrer, 2013), as abstract entities (Akaka et al., 2014) which by standardizing the meaning of value and communication signals, from the first language, facilitate better understanding and success during the process of value co-creation interactions. During the service process, the value attributed to the proposals made by the other entities will be the big unknown in all the steps. Therefore, since value creation is a collaborative process, the success of the value propositions depends on the clarity of the communication among the entities' resources (Maglio et al., 2009), in which symbol systems can play a very relevant role. In this sense, questioning the value attributed by others and the way of communication must be considered a symbolic process in S-S (Maglio & Spohrer, 2013), since value co-ordination depends on the coordination of activities among individuals, organizations and often personal relationships involving resource sharing, risks and benefits (Spohrer & Kwan, 2009).

(iii) THE IMPORTANCE OF SYMBOL SYSTEMS IN SERVICE SCIENCE – the information and communication technologies (ICT) are an essential resource in the digital economy context. Incorporating fundamental symbologies of valorisation and communication at work, both at the level of communication among S-Systems' internal resources and among S-Systems along the entire service process (Maglio & Spohrer, 2013), it may be considered that ICT incorporates true physical symbol systems in the more classical sense of the term (Newell, 1980). Even so, since symbols guide internal behaviour and immediate interactions (Maglio & Spohrer, 2013), co-creations of value often depend on a symbolic reasoning on the real value of proposals, and so we may believe that the symbology, organized in formal symbol systems, will tend to become a central component of markets and marketing in the digital context, incorporating the practices and meanings specific to each type of market (S. L. Vargo & Akaka, 2009). Also for S-D logic, symbols and practices can influence resource integration, service exchange and value creation (R. Lusch et al., 2007). In Service Innovation processes, symbols cannot be separated from phenomenological practices, institutions and values, since symbols and practices guide how actors evaluate themselves, evaluate others, or evaluate the value of propositions (Spohrer, 2007). One possible way to consolidate knowledge about the nature and role of symbols in S-S value co-creation may be by using a holistic perspective of how actors practise value co-creation and how these practices affect the rules and relations of signal interpretation, which constitute the role of symbols within service ecosystems and vice versa (Robert F. Lusch et al., 2016). From the literature review, symbol-systems appear to play an important role in the co-creation of value in S-S. However, the way symbols influence and are influenced by the adoption of practices in the digital economy, specifically in the I4.0 context, will require a more in-depth analysis starting from discussion of the reasoned value-creation of S-D Logic (Gronroos, 2011) and in the view of S-S eco-systems (Kwan et al., 2016), it will be necessary to integrate symbol sets into dynamic ecosystems of service exchanges. In the digital economy where IoT and I4.0 play an increasingly important role, it will become increasingly interesting to study and integrate the symbols used by cyber-actors, thus facilitating their understanding, skills and competences, and develop tools that facilitate interpretation of cyber-practices, along the various co-creative steps in which they participate.

3.4 SERVICE SCIENCE AND S-D LOGIC: DIVERGENCIES AND GAPS

The S-D Logic mindset was incorporated as the philosophical basis for S-S Theory (Maglio & Spohrer, 2008). However, in the literature there was found several gaps between these two communities, and the definitions and ways of observing transactions are not (yet) totally coincident.

3.4.1 Service Science and S-D Logic: Service *versus* Services

Service Science, Management, Engineering and Design (SSMED), or simply Service Science (Spohrer, Anderson, Pass, & Ager, 2008), was introduced as an emerging discipline aimed at understanding "the service" in the context of innovation among S-Systems (Spohrer & Kwan, 2009). As the original name (Service Science Manufacturing and Engineering) suggests, it is a discipline that joins together several research areas (Spohrer & Kwan, 2009), and from this interdisciplinarity it intends to combine human organization and understanding with business and technological understanding to categorize and explain S-Systems (Maglio & Spohrer, 2008), from the way they interact and evolve to co-create value, to the scientific approach application that enhances the design and innovation of S-Systems themselves. Focusing on the study of how value is generated and measured within and among S-Systems, to have interactions in S-S, it is assumed there is access to the resources' capacities, which depends on understanding the symbols and language used by all of them (Breidbach & Maglio, 2016).

In contrast to S-D Logic, by placing the study of the interaction among S-Systems at a scientific level, S-S may contribute to accelerating the design of new value propositions (Lee, Kao & Yang, 2014), systematizing the search for adaptive and collaborative competitive advantages between its different disciplines and transforming current proposals (state-of-the-art) into innovative proposals that lead to reconfigurations of S-System resources and even the ecosystems themselves (Keith, Demirkan, & Goul, 2013). Although this purpose is clear in the Fundamental Principles of S-S, the literature shows that researchers such as Wu (2013) and Wang (2010), continue to publish Service Science papers under the traditional assumptions of G-D logic, and so it is still frequent to find the expression *services* (in plural) *science*, suggesting a clear division between tangible and intangible goods, which is no longer accepted by S-S Theory (Spohrer & Maglio, 2008).

As mentioned before, the first express action to create *Services Science* may have emerged from the Manifesto presented by Chesbrough and Spohrer (2006). In this document (Chesbrough & Spohrer, 2006), the authors speak about the need to have a new scientific field designated *Services Science Manufacturing and Engineering* to study the activity of services, understood as intangible goods. It may thus be inferred from this that some researchers wrongly maintain the separation, between activities related to tangible goods and intangible goods in Service Science.

For S-D Logic, *service* (in the singular) is an abstract concept that can be provided directly or through goods, in the form of a common denominator in social and economic exchange (Robert F. Lusch et al., 2016), as opposed to the term *services* related to intangible assets. In this way, S-D logic excludes the terminology *services* if understood as an intangible result internally created by an entity, be it a person, company or a State (Robert F. Lusch et al., 2016).

3.4.2 Service Science and S-D Logic: Resource Typologies

Another gap found in the literature is in the way S-S and S-D Logic communities define S-Systems' resources. It was found from the literature that for S-D Logic service system resources consist of operant resources such as people or companies and by operand resources such as technologies and knowledge (Robert F. Lusch et al., 2016), mitigating aspects related to their ephemerality and the cost of usufruct, among other things. On the other hand, anything that has a name and is potentially useful can be seen as a resource for S-S (Spohrer & Maglio, 2008) and can be framed in four typologies (people, technologies, organizations and shared information), (Demirkan & Spohrer, 2016), and so ephemerality and the cost of usufruct, among other aspects, become fundamentally important, as circumstantial or generic resources have a useful life (beginning, middle and end), relative abundance, a creation cost, a maintenance cost and an end of access cost (Spohrer, Anderson, Pass, & Ager, 2008).

As a way of overcoming resource-related gaps in this research, the four types of S-System resources in SS (Spohrer et al., 2007), will be considered as particular cases of the general typologies of the S-D logic mindset (S. L. Vargo & Lusch, 2004a).

3.4.3 Service Science and S-D Logic: Value-Propositions Innovation

Another gap found in the literature between the SS perspective and the S-D Logic mindset is related to the sequential process of the search for improvement of the value interactions between entities, this point being especially relevant for this research, since it is related to the methodology to follow for elaboration of the Conceptual Framework, the main objective.

At the time of publication of the S-S Principles (Maglio & Spohrer, 2008), the S-D Logic community, as it still does today, considers that the analysis and improvement of value propositions should start with the descriptions and nature of the exchanges (value co-creation interactions), aiming to understand how the evolutionary nature of exchange leads to prejudices in understanding the true nature of exchange (Robert F. Lusch et al., 2010). On the contrary, for S-S the sequence must start with description of the entities, interactions and outcomes, from which mechanisms must be looked for to support the evolution of value-creation interactions (exchanges) (Stoshikj et al., 2016).

In the light of Structuration Theory (Giddens, 1984), it may be considered that S-S adopts an evolutionary perspective (Spohrer, Anderson, Pass, & Ager, 2008), since it starts with the structuring of S-Systems and the configuration of resources, how to access and use, and innovates in the form of value-creation interactions. In this co-evolutionary process, structuring and innovating are being restricted and mutually adapting to each other (Malsane et al., 2014).

As we are dealing with two different methodological approaches, for this research it will be considered the approach proposed by S-S to be more appropriate, which with some adaptations will become the basis of the objectives for this research. It will be started by describing and configuring the stakeholder resources in the operations contexts to be established in the methodology Chapter, followed by definition of the stakeholders' concerns and their indexing to Key Concern Indicators (KCI) using appropriate qualitative or quantitative metrics. Then resource access rights will be described with process mapping using symbologies appropriate to the methodological tools to facilitate value co-creation throughout the service process and finally the KCI evolution will be determined and Innovation Outcomes interpreted.

3.4.4 Service Science and S-D Logic: The Service

The literature revealed that the definition of *service* is different among the disciplines forming S-S (Bardhan et al., 2010), and S-S defines *service* differently from the S-D Logic community. Since it is a central concept in the co-creation process, it is somewhat incomprehensible that almost a decade later, in the S-S community, *service* is defined as synonymous with *value co-creation* (Demirkan & Spohrer, 2016; Spohrer & Kwan, 2009), while for the S-D logic community, *service* is defined as the application of competence for the benefit of another (Robert F. Lusch et al., 2016).

Changing the focus of services as intangible units of production to service as the process of applying one's skills to benefit another moves the emphasis of the exchange to operant resources instead of operand resources (Edvardsson & Tronvoll, 2013). In other words, while in G-D logic, the separation between services and products is concentrated on the quantity of produced outputs (tangible or intangible), for S-D Logic the service is to apply someone's skills to benefit another, which according to S-S may be positive or negative (Spohrer, Anderson, Pass, Ager, et al., 2008; Spohrer & Kwan, 2009).

With the global shift in the digital economy in recent years, the importance of the concept of service used as a synonym of co-created value (J. Karimi & Walter, 2015) seems more appropriate because companies compete through the value understandable by customers which has become the basis of market competitiveness (N. Cardeal & António, 2012). This research, although using the understandings of both communities as they are not contradictory, the definition proposed by S-S apparently represents better the meaning of service, in the digital economy context.

In the scope of Service Science and oriented towards increasing the value co-created (service), different methods and tools to support service innovation have been introduced by academics and practitioners (Breidbach & Maglio, 2016), different methodological tools to support service innovation improvement (Vargo &Lusch, 2004a), so that the service exchanged between the supplier and customer provides the desired value and configuration negotiated by both parties (Suhardi, Doss, & Yustianto, 2015).

It was also found in the literature review that most of the methodological tools proposed by SS were developed for the production of intangible goods (C. Y. Wang, Wu, & Chou, 2010), which has led academics and practitioners (Kwan et al., 2016) in studies related to efficiency in the production of tangible goods to keep using the traditional tools of lean thinking such as value stream mapping[61]and others (Rohac & Januska, 2015), which need to be adapted for use in the scope of S-S.

This issue found in the literature will probably have resulted from the fact that S-S is a recent (Spohrer & Maglio, 2008) scientific discipline which arose from the need to find a discipline for service activities (intangible goods) (Chesbrough & Spohrer, 2006) which only a few years later was extended to tangible goods (Vargo & Lusch, 2016) by adopting the S-D Logic mindset (S. L. Vargo & Akaka, 2009).

According to Spohrer and Kwan (2009), the tools to interpret and innovate in value interactions depend on the customer typology. For example, if it is an individual (B2C), (Gunasekaran & Ngai, 2004), the service intensity matrix methodological tool (Gunasekaran & Ngai, 2004) allows a good approximation in helping to create different mechanisms for value, from highly customized and highly interactive service offerings to standardized, low-interaction service offerings. Similarly, the *Service Blueprint* methodological tool has been particularly successful in testing new concepts and identifying potential failures or innovation opportunities (Bitner et al., 2008b). and when there is a complex (B2B) organization on the customer side (Rid & Pfoertsch, 2013), other tools such as the *Component Business Model* (CBP)[62] have also been found.

3.5 SERVICE SCIENCE METHODOLOGICAL TOOLS

From the literature review it was found that the two methodological tools used most successfully in service innovation processes have been the *Service Blueprinting* tool (S-Bprint) and the *Service Oriented Architecture* (SOA) tool.

SERVICE ORIENTED ARCHITECTURE - is an emerging approach to the study of ICT-related activities (C. Y. Wang et al., 2010), introduced as a bridge between the requirements of the business process and the necessary components for Information and Communication Technologies (Nickul, Reitman, Ward, & Jack, 2007). Characterized as a software architecture based on freely integrated modules into a distributed computing system (Bardhan et al., 2010), in SOA resources are represented through blocks that build the company or organization, which is defined by a pool of available internal and external

[61]Value stream mapping is a lean-management method for analysing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer.
[62]Component Business Model (CBM) is a technique to model and analyse an enterprise. It is a logical representation or map of business components or "building blocks" and can be depicted on a single page.

resources, and by interaction patterns between these resources (Suhardi et al., 2015). Increasingly adopted in non-software areas (T.-W. Kang & Choi, 2015) in the form of variants, there is nevertheless no single view on the adoption of SOA (Grilo & Jardim-Goncalves, 2010), just as there is no consensus regarding its implementation (Nickul et al., 2007). Therefore, numerous forms of implementation are used by practitioners and academics, although the most popular are perhaps IBM's SOMA and Thomas Erl's SOA (Suhardi et al., 2015).

SERVICE BLUEPRINTING (S-Bprint) - considered as (…) “a potent methodology to visualize the entire service process for efficient analysis is service blueprinting. The framework of service blueprinting to understand the service process is also useful as a framework to interpret the process of service innovation." (Kwan et al., 2016), S-Bprint allows the evolution of the service process to be mapped in S-S, and is also used for efficiency analysis and interpretation of the innovation processes among S-Systems, with the aim of optimizing the value co-created. First introduced by Shostack (1982), the S-Bprint tool was initially developed to study processes related to commerce and services in general, which were interpreted as a sequence of actions, where customer and provider were separated by an abstract concept, which Shostack designated the *line of visibility* (Seyring, Dornberger, Suvelza, & Byerns, 2009).

In the late 1980s, Kingman-Brundage (1989) introduced a new S-Bprint model, replacing the line of visibility of the Shostack model with three new imaginary lines, designated the *line of interaction*, which separated the customer from the provider, *line of internal interaction* which separated, inside the provider, the support functions from the customer service functions and the *line of execution* separating management functions from support functions (Seyring et al., 2009). Kingman-Brundage also proposed the concept of *back stage* and *frontstage* lanes where providers move and develop their activities (Bitner et al., 2008b). Although currently seen as a practical tool for mapping shared access to resources from different stakeholder perspectives (Bitner et al., 2008b), S-Bprint has been introduced and developed as a tool for monitoring these processes (Seyring et al., 2009). With the emergence of S-S years later, S-Bprint was adopted as one of the methodological tools of this new discipline (Boughnim & Yannou, 2005), and has proved its usefulness in helping to understand service processes, both in terms of interpreting results and in the search for innovative processes (Bitner et al., 2008b), interpreting the service process as a sequence of service functions.

The first project in the *Service Productivity & Innovation for Growth* (SPRING)[63] initiative started in 2015 and was attributed the *Japan 300 High-Service Award* by the Japanese Government. It aimed to help companies to innovate in their business model and find ways to develop their activity, regardless of sector, region or weaknesses they wish to overcome, and the S-Bprint methodological tool is still being used successfully (Kwan et al., 2016). According to Professor Norihisa Doi[64] (2016), one of those responsible for this transversal project, in the 236 case studies carried out by the Japan 300 High-Service Award Project, as the first conclusion (...) “service innovation occurs in different aspects of the service process, where each case has a unique history in which the service blueprint tool has been used successfully but adapted on a case-by-case basis" (Kwan et al., 2016). Keeping a common matrix in order to compare the different structures of service innovation and describe the different processes in this project, the researchers have developed a flexible S-Bprint format adaptable to the different cases, based on the separation of services into processes that can be individualized, which allows the mapping of time progress, represented horizontally by a sequence of steps where each individual component (resources) is placed in a different lane and ordered vertically (Boughnim & Yannou, 2005).

INTERACT SERVICE PROPOSE AGREE REALIZE TOOL (ISPAR) – was developed for assessing the outcome of the proposals in each of the value creation stages in Service Science (Maglio et al., 2009; Stoshikj et al., 2016).

As established by S-S Principles (Maglio & Spohrer, 2008), the generic value-creation interactions between S-Systems designated as service interactions (Akaka et al., 2014) comprise three activities: formalization of the value proposition agreement and action that leads to value (Spohrer & Kwan, 2009). Once the value proposition has been made, it can be refused, from which no value will result, and acceptance will depend on the combination of different resources such as economic, social, technical, emotional, etc. (Stoshikj et al., 2016), whose understanding depends on the perspective and concerns of the stakeholders involved (Spohrer, Anderson, Pass, & Ager, 2008).

Based on ten possible results (Spohrer & Kwan, 2009), for ISPAR if in a value interaction, (i) the desired result is obtained for both parties in the sense that the value proposition was made with success, the outcome must be (R); (ii) if the desired result is not obtained

[63]http://www.service-js.jp/modules/spring
[64]Keio Yokohama University

because the proposal has not been well communicated or well understood by the other S-System, the resulting outcome must be (-P); (iii) if the desired result is not obtained, although the proposal was well communicated and perceived and the S-Systems did not reach agreement, an outcome (-A) is obtained; (iv) if the desired result was not obtained and no disputes arose between the S-Systems, the outcome obtained is (-D); (v) if disputes have arisen the outcome will be (-K); (vi) if the desired result is not obtained, but the S-Systems understood each other peacefully and closed the question, the outcome will be (K); (vii) if an interaction cannot be considered a service interaction, because it does not result in any value, but still, the other stakeholder does not raise problems, the outcome will be (W); (viii) if at least one of the S-Systems interprets with displeasure although not a criminal act, the outcome will be (C); (ix) however, if at least one of the S-Systems interprets it as an illegal or criminal act, the outcome will be (-C), (x) and finally, if an interaction cannot be considered a service interaction and the authorities confirm it as criminal, the outcome will be (J). In addition to the customer and provider stakeholders, ISPAR assumes that the outcome assessment in each service process Step must consider (Maglio et al., 2009) the perspective of the other two main stakeholders, authority and competition, as recommended by Service Science Theory (Spohrer, Anderson, Pass, & Ager, 2008).

3.6 SERVICE SCIENCE: DISCIPLINES AND PROFESSIONAL SKILL PROFILES

As already mentioned in this thesis, Service Science is an interdisciplinary and multidisciplinary scientific area (Stoshikj et al., 2016), supported by ten pillars or scientific disciplines (Spohrer & Kwan, 2009), understood as necessary for service interpretation and innovation among S-System entities : (i) History of Economics and Law, (ii) Marketing, (iii) Operations Management, (iv) Political Science, (v) Sustainability, (vi) Anthropology, (vii) Engineering, (viii) Computer Science, (ix) Procurement and (x) Management, whose accumulated knowledge helps to improve S-Systems' efficiency (Spohrer & Kwan, 2009). In this interdisciplinarity context, Demirkan and Spohrer (2015) consider that in the professional profile of a *service scientist* (Fraunhofer, 2012) there must be expertise in one of the scientific areas forming S-S (Demirkan & Spohrer, 2015) but also elementary knowledge of the subject matter of all the disciplines involved in S-S, to be able to fully integrate a multidisciplinary S-S team (Spohrer & Kwan, 2009) .

Additionally, as an absolutely fundamental requirement, according to some authors (Demirkan & Spohrer, 2015), in the professional nature of a *service scientist* there must be a willingness to work in a collaborative way with all other service scientists, making their specific knowledge available for all others to use, which in figurative terms can be represented as a *T Shaped* profile (Kwan et al., 2016).

3.7 CHAPTER SYNTHESIS

In this chapter, It has been sought Theories, scientific approaches, empirical models and actual cases which may provide scientific and empirical support for the research to be proposed in this thesis. The research issue being related to the digital economy, where ICT shortens distances and dilutes the line that traditionally split services and industry, it has been started this literature review by finding in the S-D Logic mindset an interesting philosophical basis to support operation models that integrate industry and services together as is the case of I4.0 discussed in Chapter 2.

Having initially been thought to be the *Science of Services*, by adopting the philosophical bases and language of S-D Logic, S-S has become a discipline applicable to both industry and services, with lines separating these two types of activities ceasing to exist. Because it is interdisciplinary and although recent, S-S is focused on the study of service system interactions, from which the *service* results as the co-created value, and for S-S, this must be evaluated through indicators of the concerns of the four main stakeholders.

The Key Concern Indicators have an inverse meaning to the traditional Key Performance Indicators (KPI) concept, leading to ($KCI = \frac{1}{KPI}$) whether concerns are qualitative or quantitative, for which the researcher must find appropriate metrics related to the main stakeholders' concerns, using the typical metrics from the disciplines forming the S-S Body of Knowledge. The KCI evolution according to S-S measures the result of reconfiguration of the S-System resources during the service process, which for better visualization must be mapped by an S-S recommended tool and the results interpretation evaluated through Innovation Outcomes (IO), which mean the evolution of stakeholders' concerns in different Operation Contexts (OC).

Therefore, with S-S being the theory supporting all this investigation in the following Chapters, filling the gaps between this discipline and the S-D Logic mindset, it has been identified the potential methodological tools. Still in this literature review, it was found that the professional profile of a service scientist according to S-S, is once again in line with Peter Kropotkin (1903), who concluded in the nineteenth century that the evolution of species also depends on the level of collaboration among its members (Kropotkin, 1903), which is similar to the character of a service scientist according to Service Science (Demirkan & Spohrer, 2015).

CHAPTER 4

Our brain accepts what the eyes see
and our eyes looks for whatever our brain wants

Daniel Gilbert

4. RESEARCH METHODOLOGY

As part of the research, the researcher must select the right worldview, also designated *paradigm* which according Guba (1990) (…) "is a basic set of beliefs that guide action as a general philosophical orientation about the world and the nature of research that a researcher brings to a study" (as cited in Creswell, 2014). The research paradigm comprises (i) the epistemology (Johnson & Onwuegbuzie, 2004), which seeks to understand the relationship between the researcher and the research reality, (ii) the ontology, which raises essential questions about the nature of reality, and (iii) the methodology with which the researcher focuses and acquires knowledge from reality (Denzin & Yvonna, 1994).

4.1 CONCEPTUAL RESEARCH APPROACH

The choice of paradigm has therefore particular importance, since it helps the researcher to clarify the problematics of the discipline, allowing him to develop an exploratory set of models and theories and to create conditions to try to solve them (Morgan, 2007). Although assuming that their position is not consensual, for Creswell (2014) paradigms may be understood as perspectives or philosophical concepts which may be termed as post-positivism, constructivism, transformative, and pragmatism (Tashakkori & Creswell, 2007) (Table 4.1).

Worldview	Method	Logic	Ontology	Epistemology
Postpositivism	Quantitative	Deductive	Realism	Objective
Constructivism	Qualitative	Inductive	Relativism	Subjective
Transformative	Collaborative	Change Oriented	Power and justice oriented	Mixed
Pragmatism	Mixed	Mixed	Accepts the Reality	Mixed

Table 4.1: Philosophical Paradigms. Source: (Creswell, 2014)

Based on a deterministic worldview, while accepting that the values and prior knowledge of the researcher may affect the results, for post-positivists, it is the causes that determine the results. For proponents of this paradigm, there are laws or theories governing the world, through which, once tested and refined, the reality may be understood (Morgan, 2007). As a scientific method, the post-positivist approach sets out from the theory for the collection of data that support or refute this theory (Biesta & Burbules, 2000). In an opposing position, proponents of the constructivist paradigm develop varying and subjective meanings from their object-oriented experiences or things (Creswell, 2014). The constructivist researcher looks for the complexity of points of view, rather than restricting meanings to categories or ideas (Oliveira, 2010). In this sense, for constructivists the situation that is being observed or studied is confined or entrusted to the view of the participants (Mertens, 2014) who, recognizing that their own experiences shape the interpretation, position themselves during the investigation so that they can recognize their interpretation will depend on their own experiences, whether cultural or historical (Bravo & Eisman, 1998). The constructivist paradigm emerged from populations of individuals who understood that post-positivist assumptions imposed structural laws and theories that did not fit with people not integrated into society and with social justice as imposed on them (Nielsen, 2006). Therefore, for constructivists, theoretical perspectives should be integrated with philosophical presuppositions (Rocco, Linda, Suzanne, & Aixa, 2003), which construct an image of the questions under analysis (Denzin & Yvonna, 1994).

A different view is taken by proponents of the transformative paradigm, for whom research must be linked to political change agendas to face social oppression, regardless of the level at which it occurs (Mertens, 2014), thus sustaining a transforming view of the world (Johnson & Onwuegbuzie, 2004). The pragmatist paradigm originally arose from Pierce's (1932) work, but only after Tashakkori and Teddlie's (1998) work has its theoretical rationale been properly structured (Tashakkori & Creswell, 2007). Accepting that truth is what happens at the moment, pragmatists reject the existence of independently constructed realities from the mind of each individual (Tashakkori & Teddlie, 2010), so that the researcher must focus on the problem, resorting to all kinds of approaches available to understand it (Rossman & Wilson, 1985). They look at what and how to research, based on the intended consequences from which (Creswell, 2014), resorting to mixed methodology, quantitative and qualitative data are used to better understand the RP, assuming as much as possible a posture that reflects social justice and political objectives which take into account issues such as sustainability (Johnson & Onwuegbuzie, 2004).

From the literature review, it was found here the first point of contact between the Pragmatist Paradigm and Service Science Theory, for which an approach that recognizes the nature of reality as dynamic, evolutionary and interactive (Matthies & D'Amato, 2016), appears to be better tuned to the analysis of value co-creation interactions throughout the service process (Meynhardt et al., 2016), which must consider sustainability as transversal to all stakeholder concerns (Spohrer, Anderson, Pass, Ager, et al., 2008). Positioned between post-positivists and constructivists, for pragmatists the process of knowledge acquisition is seen as continuous, rather than two opposing and mutually exclusive poles of objectivity and subjectivity (Rocco et al., 2003). This aspect is also in line with the S-D Logic perspective (Robert F. Lusch et al., 2016) which is, as previously stated, the philosophical basis of Service Science (S. L. Vargo & Akaka, 2009).

As in Structuration Theory (Edvardsson & Tronvoll, 2013), S-S adopts an evolutionary perspective (Spohrer, Anderson, Pass, & Ager, 2008): the process begins with the structuring of the systems, their resources and access to them, after which, in the form of value creation, relationships are developed and engage with each other in a co-evolutionary way throughout the service process (Meynhardt et al., 2016). This philosophical approach seems to be in line with the pragmatist paradigm, for which all researching involve inductive and deductive logic (Hammersley, 2010). Similar conclusions were advanced by Perry (1998), which later became the basis of mixed methodology (Creswell, 2014).

Some authors argue that inductive logic is strictly linked to qualitative methodologies (Morgan, 2007), where the researcher starts from particular data observed, to reach a general proposition of the set of empirical reality (Hammersley, 2010), that is, general conclusions are developed from empirical observations (Ghauri, Kjell, & Ivar, 2010). In the literature review, however, this position was found not to be consensual (Mertens, 2014), since nothing prevents the researcher from using quantitative data with exploratory methods of analysis (for example, exploratory factorial analysis), starting with empirical observations and from there, explain this reality, that is, creating a theory that fits this reality (Johnson & Onwuegbuzie, 2004).

At the opposite extreme, in the deductive logic associated by some authors with quantitative methodology[65], theory is used as a guide (Hammersley, 2010), using theoretical and conceptual structures, in which the researcher starts from the general to the particular (Ghauri et al., 2010), implying the need to conceptualize a model, followed by empirical testing (Perry, 1998).

By way of theory or hypotheses, two or more concepts can be linked to a causal chain consisting of untested assertions about the relations between concepts (Quivy & Campenhoudt, 2013). However, these assertions, based on theory, will not be ready for empirical testing until the abstractions are translated into observables, that is, they need to be conceptualized previously (Yin, 2013). For Perry (1998), conceptualization is the formulation of a theoretical argument, studying the theory and deducing conceptual structures which will be evaluated through the collection of appropriate data (Blaikie, 2000).

Based on the researcher's different approaches to data collection and analysis, there are three formats of mixed research methodologies: convergent parallel, explanatory sequential and exploratory sequential (Creswell, 2014). The explanatory sequential mixed methodological approach involves two phases. The researcher begins by collecting the quantitative data and analyses the results which he uses to construct the qualitative phase. A typical way of using this methodology is to carry out a quantitative survey followed by its analysis, after which qualitative interviews are conducted to help explain the results of the survey (Mertens, 2014).

On the other hand, in exploratory sequential mixed methodology, the researcher starts with the qualitative phase, followed by the quantitative phase, so the strategy is to test forms of measurement from small specific population samples (qualitative phase) and check whether the data obtained can be generalized to a representative sample of the population (quantitative phase) (Tashakkori & Teddlie, 2010).

Contrary to the previous two mixed methodologies, in the convergent parallel method the researcher collects quantitative and qualitative data, sometimes simultaneously, which once analysed are compared. The objective is to complement the information and

[65] This position, although defended by some authors, is not consensual because nothing prevents the researcher from starting from theory to formulate hypotheses and then using qualitative methods to evaluate the applicability of theory itself (i.e., it is about using deductive logic by applying qualitative methods).

consequently, confirm the results or otherwise (Rocco et al., 2003). The key assumption of this approach is that both qualitative and quantitative data provide different types of information - often detailed insights of participants qualitatively and scores on the instruments quantitatively - and together produce results that should be the same (Creswell, 2014).

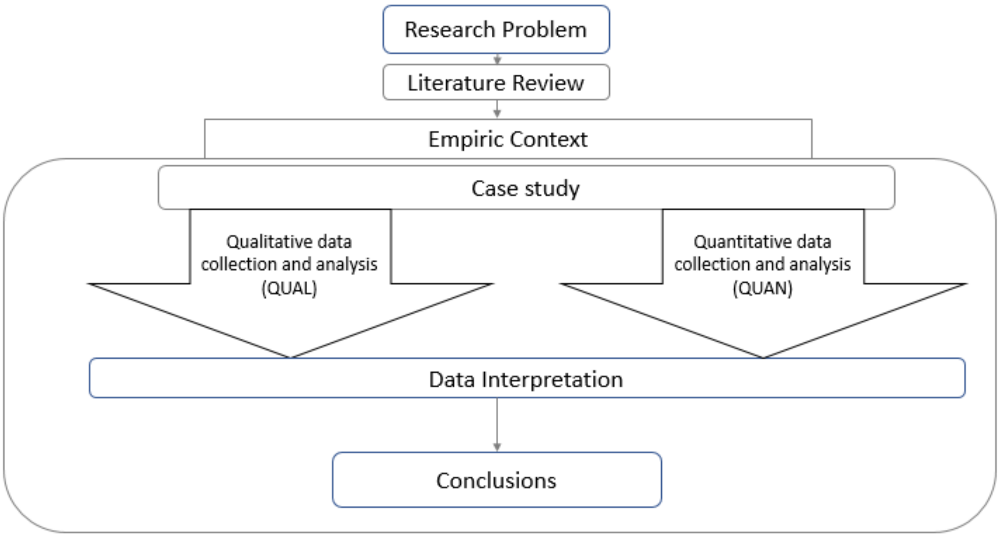


Figure 4.1: Parallel Convergent Mixed Methodology. Source: (Akwei, Peppard, & Hughes, 2010)

As it was found in the literature review, Service Science is based on the study of the value co-creation interactions between service systems (Storbacka et al., 2016), namely the quantification and qualification of stakeholders' concerns during the service process. The investigation proposed in this thesis will follow the pragmatist paradigm, in the methodological format of convergence in parallel (Figure 4.1).

4.2 EMPIRICAL RESEARCH

Guided by the pragmatist paradigm, the fundamental challenge of this research is to describe, provide the foundations for, and apply to an empirical case, a framework conceptualized through the Service Science, making it possible to describe and compare the value creation interactions in a sample of OS companies belonging to CPMR when they evolve their operations from the CBP mode to the future Industry 4.0 (I4.0) mode. Following S-S Theory, conceptualization of the empirical framework must start by characterizing resources, defining variables and parameterizing stakeholder concerns, including the metrics to be used in data collection, according to the objectives (Maglio & Spohrer, 2008).

The literature review revealed that from 2010 the empirical research related to digital processes and ICT was intense, the emergent paradigm of I4.0 being referred to very often from 2011. However, despite all this investigation oriented to the digitization of processes, there has been little study of the impacts of the transition from traditional production processes to digital processes (Drath & Horch, 2014), and there is almost no scientific literature about the impact of this transition on specific threats identified in companies, clusters or ecosystems. Ford (2015), for example, considers the interests behind the "main stream I4.0" to be partial, to the point of considering “The benefits and return on investment (ROI) are not as black and white as you might think, and the engineers would like them to be. Industry 4.0: Who Benefits?" (Ford, 2015).

Although the digitization of processes is a cross-cutting paradigm for all areas of the economy, the literature review shows there is a shortage of authors describing digitization in an interdisciplinary way, and even fewer describing I4.0 from the Service Science perspective.

Service Science is an interdisciplinary scientific area and therefore (Rennung, Luminosu, & Draghici, 2016), the research proposed in this thesis is of academic and practical interest, S-S providing the theory and the decisive contribution to the understanding of value co-creation interactions among actors.

4.2.1 Main Research Objective

Supported by Service Science, the main objective of this research is to conceptualize an empirical framework, designated as *Inovstone4.0* (Inov4.0|F), which, when applied to a representative sample of CPMR-OS companies, allows evaluation of the impact of I4 .0, on these companies’ response to the threats resulting from BIM procurement in the AECSC.

For S-S theory, as observed in the literature review, the impact of innovation on processes should be measured through the *Innovation Outcome*[66] (IO) concept (Spohrer, 2007), which results from the evolution of the main stakeholders’ concerns, designated in this thesis as Key Concern Indicators (KCI), inverse to the traditional concept of KPI ($KCI = \frac{1}{KPI}$).

[66] Innovation Outcomes means the innovation results in Service Science

By applying the Inovstone4.0, the intention is to evaluate the impact of I4.0 on the response of OS companies from the CPMR to the Threats from BIM procurement in the AECSC, resulting in the following objectives:

(i) Describe and configure stakeholder's resources, in the context of providers in current best practices operations mode (CBP-Providers) and customers in current (CAD-Procurement), designated by "OC1".

(ii) Describe and configure stakeholder's resources, in the context of CBP-Providers and customers in BIM-Procurement, designated by "OC2".

(iii) Describe and configure stakeholder's resources, in the context of providers in Industry 4.0 operations mode (I4.0-Providers) and customers in BIM-Procurement (OC3), designated by "OC3".

(iv) Determine the Step Outcomes (SO) and Key Concern Indicators (KCI) in each Step of the service process, in the three operation contexts (OC1, OC2 and OC3).

(v) Determine the Innovation Outcomes (IO) in the three operation contexts (OC1, OC2 and OC3).

Using mixed parallel convergent methodology and the various methodological tools recommended by Service Science, duly formatted and adapted to the research context (Kwan et al., 2016), KCI will be proposed, from the S-S perspective, and to determine these, data will be collected from a representative sample of OS companies belonging to the CPMR in order to reach a general proposition of the empirical situation as a whole.

4.2.2 Methodological Tools

As mentioned in the literature review in Chapter 3, S-Bprint is a methodological tool (Boughnim & Yannou, 2005) that allows the representation of shared access to S-System resources along the service process (Bitner et al., 2008b), as shown in several successful cases found in the literature review in the field of Service Science (Kwan et al., 2016). As in SPRING[67] related projects (Kwan et al., 2016), Inov4.0|F will also require adaptation

[67]Japanese Government Initiative in which Service Science is the discipline used to promote increased productivity in the service sector

of the classic S-Bprint format (Boughnim & Yannou, 2005) to the specificities of OS companies' operations, and to the digital economy context, particularly I4.0, as described in Appendix A. It will thus be necessary to identify the resources involved in each Step of the co-creative process, allowing them to be assigned responsibilities for each action towards continuous improvement (innovation) (Gupta & Andersen, 2012).

In S-Bprint mapping, though the effect of the innovations is apparently on the provider side, in practice, the benefits are equally for the customer, on whom the focus must remain, according to the Service Science perspective. This fact does not contradict S-S Theory, but on the contrary, fits perfectly in its fundamental pillars (Stoshikj et al., 2016). It was also found in the scientific and empirical literature (Kwan et al., 2016) that the S-Bprint tool graphically represents the activities developed by the configuration of the stakeholders' resources, focused on the customer, but also considering the provider's benefits, and in this way does not contradict any of the axioms of S-D Logic (S. Vargo & Lusch, 2016). When representing the time progress map horizontally, through S-Bprint the individual components will be placed in different lanes, and thus each lane will represent a level of proximity to the customer: the higher the lane, the closer the interaction to the customer (Hsu, 2016). Therefore, it can be considered that the S-Bprint is a good methodological tool to improve the efficiency of industry, even in digital mode, as well as an interesting tool for describing the interactive processes, helping to clarify the results and generating clues to innovate in interaction between S-Systems throughout the service process. At each Step of the service process, the success or failure of each proposal must be evaluated using the ISPAR tool (Spohrer, Anderson, Pass, Ager, et al., 2008). In the case of non-normative outcomes (failure), or a need to improve the response, S-Bprint mapping provides clues to visualization of the resources involved in this step, making it a good tool to reorganize these resources (Stoshikj et al., 2016).

As advocated by S-S, the first Step in conceptualizing a framework must be elaboration of the list of Indicators (KCI) to assess the concerns of each of the four primary stakeholders: customer, provider, competitor and authorities (Spohrer, 2007; Stoshikj et al., 2016). Evaluation of these stakeholders' concerns in each Step must be measured by proper units adjusted to the respective KCI (concern), and the variation of the KCI result, when operations change from the current state to the future state, gives rise to the respective IO (Kwan et al., 2016).

4.2.3 Research Questions

From the literature review, but also from our own daily experiences, the digitization of the economy appears to be unavoidable (E.Weisberg David, 2008). However, this change requires investments, sometimes huge, especially when this involves digitizing production processes (Lasi et al., 2014). These concerns are frequently raised by corporate managers in order to put pressure on ensuring that their proposed investments respond to the problems or threats faced by their organizations, and converge on the recommendations described in the Financing Europe's Investment and Economic Growth Report (2014), it is necessary to mitigate the risk associated with investment uncertainties (Llewellyn Consulting, 2014), and from which it can be formulated the Research Problem: **What impact could Industry 4.0 have on the response of CPMR-OS companies to the threats posed by BIM procurement in the AECSC**?

Supported by the Research Problem, which is the core of this research, it is important to define the specific Research Questions (RQs) to be studied, which for some authors is the most important stage in a research study (Yin, 2013), addressing Industry I4.0 from the Service Science perspective, the following RQs were identified:

(i) RQ1 | Will Industry 4.0 operations, in the context of BIM (standardized) procurement, allow CPMR-OS companies to retain their main current competitive advantage of customizing their products?

(ii) RQ2 | Will Industry 4.0 operations, in the context of BIM Procurement, reduce the "delivery time" of CPMR-OS companies' products when compared to the current way of operating?

(iii) RQ3 | Will Industry 4.0 operations, in the context of BIM Procurement, reduce the "cost" of CPMR-OS companies' products when compared to the current way of operating?

(iv) RQ4 | Will industry 4.0 operations, in the context of BIM Procurement, reduce the "ecological footprint" of CPMR-OS companies' products, when compared to the current way of operating?

(v) RQ5 | Will Industry 4.0 operations, in the context of BIM Procurement, reduce the "non-quality" of CPMR-OS companies' products, when compared to the current way of operating?

In addition to the empirical contributions from the answers to these RQs to CPMR-OS companies, a scientific approach to the co-creation of value between the resources of the I4.0 providers (digital providers) and BIM customers (digital engineering customers) may also contribute to consolidating Service Science Theory, and contribute to mitigate the investment risks associated with the very early stages of digital production, in relation to more environmentally friendly consumption and more sustainable industry.

4.2.4 Framework Conceptualization and Application Procedures

Mixed methodology is an approach to the subject guided by the pragmatist paradigm, which involves the collection and analysis of quantitative and qualitative data, aiming at better understanding of the RP (Creswell, 2014).

Emerging in the late 1990s (Tashakkori & Teddlie, 2010), mixed methodology resulted from investigations in different fields, such as assessment, education, management, sociology and health sciences, among others, going through various periods of development, including philosophical debates, procedural stages and, more recently, through reflective positions raised from controversies and debates (Creswell, 2014).

The literature review revealed that mixed methodology is usually seen as a way to minimize the limitations of strictly qualitative and quantitative approaches, allowing a sophisticated and complex approach to the research problem (Sequeira, 2010), and this seems to be a convenient approach to the new scientific discipline of Service Science.

4.2.4.1 Methodology Mixed Parallel Convergent

As previously stated, this thesis will follow the pragmatist paradigm guidelines, benefiting from the inductive and deductive advantage of the mixed methodological approach from the parallel convergence perspective (Creswell, 2014) (Figure 4.2).

Using the guidelines provided by the pragmatist worldview, S-S research requires methods and tools able to provide innovative configuration of stakeholder resources in the deepest possible way, since the outcomes result from their interactions. In this sense, Convergent Parallel Mixed Methodology, by allowing the simultaneous collection of qualitative and quantitative data, seems to match the Service Science methodological sequence effectively (Figure 4.2): (i) Starting with description of the entities and configuration of their resources; (ii) identifying stakeholder concerns and defining variables (KCI) to assess the concerns; (iii) describing access to resources; (iv) identifying and proposing symbol systems that facilitate the co-creative process; (v) mapping the service process for the interpretation of outcomes and (vi) evaluating the IOs from the evolution of the KCI from the current state to the future state.

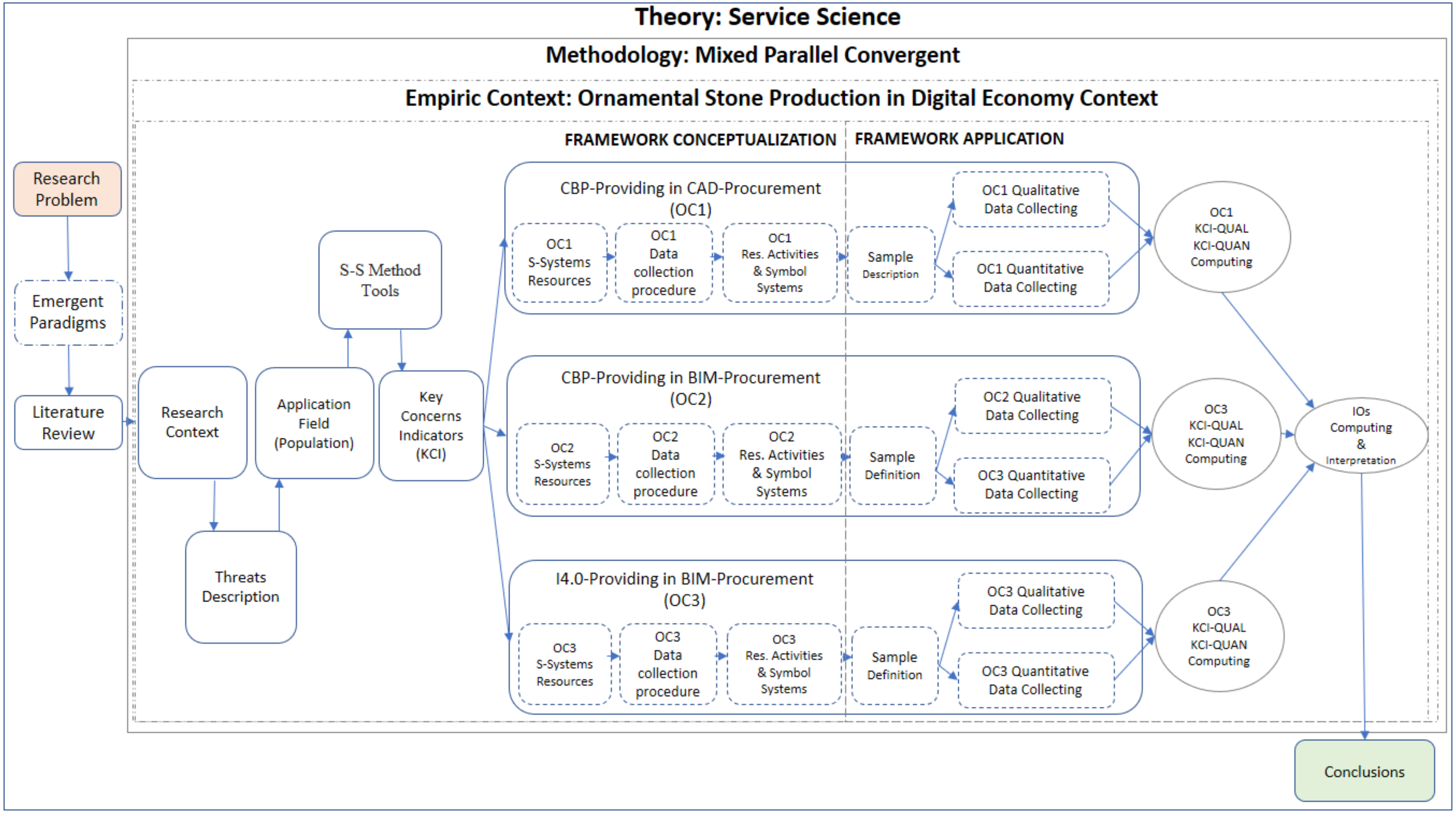


Figure 4.2: Methodological sequence for Conceptualization and Application of the Inov4.0|F from the Service Science perspective.

4.2.4.2 The Population and Sample

Identifying the population to study and its size is one of the fundamental issues when using mixed methodology (Johnson & Onwuegbuzie, 2004). The CPMR, as described above, a group of thirty-two entities[68] of which sixteen are directly operating as Ornamental Stone producers, will be the population to study in this thesis. Considering the specificity of the research, the sample will be selected by convenience, since the orders to be followed up are real, which implies that the interaction results (qualitative and quantitative) must be measured in real-time and inside the companies where the orders are being produced.

Based on criteria related to the typology of orders, CPMR-OS companies' managing directors will be approached directly and informally, and invited to participate in this research. With this procedure, it is expected to obtain a minimum number of companies representing at least 30% of the total population, as recommended by some authors (Creswell, 2014). The written agreement with the CPMR-OS companies must mention clearly the rules and our promise not to identify them, their customers, employees or competitors.

Because it is one of the most common typologies in CPMR-OS companies, the type of orders adopted for follow-up and data collection, in each sample provider, will all be a ventilated cut-to-size facade, using limestone as the raw material. To collect data, it will be followed up the order process closely, during which time qualitative and quantitative data will be collected simultaneously at all stages of the service process, that is - from the customer's intention to buy, to installation of the products on site.

4.2.5 Data Collection Consolidation and Treatment

The key benefit of mixed methodology is the possibility of collecting qualitative and quantitative data (Creswell, 2014) by using parallel constructs, variables and concepts, to obtain complementary information that leads to greater certainty of results (Creswell, 2014; Tashakkori & Teddlie, 2010). Thus, in accordance with these principles, qualitative data can be observed from sources such as interviews, visual observations, documents and records, among others. Likewise, quantitative data can be collected from measuring

[68] Data for April, 2017

instruments, observable checklists or even numerical records, among others (Creswell, 2014).

The procedure of selecting orders to follow up and data collecting will be by convenience as was the selection of companies to belong to the sample group, since they have to be aligned with CPMR-OS companies' core business, where cut-to-size stone covering is one of the main products (I. Frazao, 2016; J. Frazao, 2016; Peres & Costa, 2006; Silva, 2013, 2014).

In the research carried out, no Ornamental Stone company was found to operate in I4.0, to be able to measure and observe this form of operation. To overcome this limitation, five real orders from customers who already use BIM[69] will be selected, and they will be processed by the sample companies, according to the following conditions:

(i) Service Process Phase 1 - through a "prototype Cockpit", developed in partnership with technology companies also belonging to CPMR, from which all communication (co-creation) with the BIM operator will be carried out, from the first sign of interest in buying stone, to acceptance of the value proposition.

(ii) Service Process Phase 2 - through two digital prototype machines, developed in the Flexstone[70] Project and operating in a real production environment, once connected to the prototype Cockpit, a I4.0 environment will be created which could be called an "industry4.0 mini-factory", albeit with a scale for only micro or very small orders.

The data acquisition process will be continuous like in a film, and throughout the service process the observer (researcher) will assess data in real time, respecting the previously described procedures, in order to obtain the qualitative and quantitative data with which the KCI will be calculated.

4.2.5.1 Qualitative Data

In the traditional or digital economy context, Inov4.0|F will be conceptualized according to Service Science and Mixed Methodology rules (Tashakkori & Creswell, 2007), and thus, the Qualitative Key Concern Indicators (KCI_{QUAL}) will represent stakeholders' concerns, determined from non-numerically measurable data, such as feelings and

[69]Maturity level III or higher
[70] Project in co-promotion for high-technology development of stone processing, 2015-2017

opinions, answers to a non-structured questionnaire (Table 4.2, 4.3, 4.4 and 4.5) repeated at each stage of the service process (Creswell, 2014; Tashakkori & Teddlie, 1998). In order to collect qualitative data related to the four main stakeholders (customer, provider, competitor and authorities), the following four information collecting procedures (Creswell, 2014) will be used in parallel and atypically: (i) Qualitative Observations - using shop-floor notes related to the orders' execution, and openly observing respondents' opinions; (ii) Qualitative Interviews - using questions directly asked to stakeholders' human resources, directly or by phone, aiming to obtain respondents' opinions; (iii) Qualitative Documents - using digital or paper documents, public or private, such as minutes of meetings, reports, letters and e-mails, and finally (iv) Qualitative Audio and Visual Material - using audio materials and qualitative visuals such as photographs, physical products, websites, e-mails and text messages, among others.

For each of the main stakeholders, qualitative data maps will be drawn up (Tables 4.2, 4.3, 4.4 and 4.5) throughout the service process. These tables are an instrument for recording the interviewer's (researcher) opinion (feelings) based on the respondent's (stakeholder) concerns together with shop-floor observations, recorded in terms of two possible outcomes: (i) Outcome = U (Up) means that in relation to each stakeholder, the interviewer inferred that the respondent's concerns are in favour of accepting the value proposition; (ii) Outcome = D (Down) means that in relation to the stakeholder, the interviewer inferred that the respondent's concerns discourage acceptance of the value proposition.

SERVICE PROCESS STEPS	4		8		12		16		20		24		28		32		36	
CUSTOMER QUALITATIVE CONCERNS | QUESTIONNAIRE-GUIDELINES	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?																		
What is your concern with respect to Product Sustainability?																		
What is your concern with respect to Product Quality?																		
What is your concern with respect to Contract Compliance?																		
What is your concern with respect to Brand Reputation?																		
What is your concern with respect to Flexibility?																		
What is your concern with respect to Purchasing Price?																		
What is your concern with respect to Total Product Cost?																		
What is your concern with respect to Warranty?																		
What is your concern with respect to After Sales Service?																		
What is your concern with respect to Product Reliability?																		
What is your concern with respect to Product Safety?																		
What is your concern with respect to Product Recycling?																		

Table 4.2: OS-Customer Questionnaire-Guidelines - Qualitative Concerns

SERVICE PROCESS STEPS	4		8		12		16		20		24		28		32		36	
PROVIDER QUALITATIVE CONCERNS | QUESTIONNAIRE-GUIDELINES	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?																		
What is your concern with respect to Time to Receive the Product?																		
What is your concern with respect to Product Sustainability ?																		
What is your concern with respect to Procuct Maintenance Costs ?																		
What is your concern with respect to Contract Compliance?																		
What is your concern with respect to Brand Reputation?																		
What is your concern with respect to Flexibility ?																		
What is your concern with respect to Product Safety?																		
What is your concern with respect to Product Recycling?																		

Table 4.3: OS-Provider Questionnaire-Guidelines - Qualitative Concerns

SERVICE PROCESS STEPS	4		8		12		16		20		24		28		32		36	
COMPETITOR QUALITATIVE CONCERNS | QUESTIONNAIRE-GUIDELINES	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?																		
What is your concern with respect to Innovative Product ?																		
What is your concern with respect to Innovative Manuf. Process ?																		
What is your concern with respect to Total Product Cost?																		
What is your concern with respect to Product Recyclable ?																		
What is your concern with respect to Contract Compliance ?																		
What is your concern with respect to After Sales Response ?																		
What is your concern with respect to Product Reliability ?																		

Table 4.4: OS-Competitor Questionnaire-Guidelines - Qualitative Concerns

SERVICE PROCESS STEPS	4		8		12		16		20		24		28		32		36	
AUTHORITIES QUALITATIVE CONCERNS | QUESTIONNAIRE-GUIDELINES	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?																		
What concern with respect to Product Manufacturing Compliance?																		
What concern with respect to Product Transport Compliance?																		
What is your concern with respect to Product Recyclable Compliance?																		
What concern with respect to Product Moral Hazard Compliance?																		
What concern with respect to Product Legal Compliance?																		
What concern with respect to Taxes & Fines application and execution?																		

Table 4.5: Authorities Questionnaire-Guidelines - Qualitative Concerns

4.2.5.2 Quantitative Data

Like qualitative data, for Inov4.0|F the KCI_{QUAN} represent the concerns of each stakeholder, gathered from numerical data such as time, energy, quantity of parts and costs, among others, along the service process. This quantitative data will be collected from direct measurements in the production machinery, computers, servers and databases, shop-floor measurements and direct measurements made during visits to the sites where the pieces were installed. For each stakeholder, quantitative data maps will be elaborated, filled in as the service process occurs for every order followed up and evaluated. In these quantitative maps, steps with no value mean it was not possible or unnecessary to carry out measurement in this step.

4.2.6 Defining the X variable, the KCI

As mentioned above, according to the S-S perspective, value propositions must consider simultaneously the concerns of the customers, providers, competitions and authorities[71], with ecosystems' sustainability being a transversal concern in all steps of the service process (Maglio & Spohrer, 2008).

Additionally, for S-S Theory, value propositions are the basic relationship between S-Systems interactions (S. L. Vargo & Akaka, 2009). This means it can be expected that when one stakeholder configures his resources to carry out a value proposition, all the others may evaluate the value differently (Spohrer, Anderson, Pass, & Ager, 2008). Also for Inov4.0|F to be developed in this thesis, the different perspectives of value of the proposals must consider the concerns of each of the four main stakeholders, including the one making the offer, and address each concern as a Key Concern Indicator (KCI). In this way, Inov4.0|F will be in line with the Fundamental Principles of S-S Theory (Spohrer, Anderson, Pass, & Ager, 2008) and it becomes possible to measure the relative evolution of the concerns, when the service process evolves in its operations mode (Maglio & Spohrer, 2013; Matthies & D'Amato, 2016).

Therefore, for the framework to be developed along the value co-creation process involving CPMR-OS companies, whenever it is verified that the qualitative outcome obtained in a given Step (i), regarding a Concern (j) from a Stakeholder's perspective (k) favours acceptance of the offer discussed, the resulting Qualitative Key Concern Indicator ($KCI_{QUAL\text{-}j\text{-}k\text{-}i}$), as mentioned above, must be "U" (Up). On the contrary, whenever the qualitative outcome appears to go against acceptance of the proposed offer, the resulting $KCI_{QUAL\text{-}j\text{-}k\text{-}i}$ must be = "D" (Down). If in any Step (i) of the service process, the outcome cannot be assessed or becomes irrelevant according to the interviewer's interpretation, no data must be recorded in the table or in the resulting $KCI_{QUAL\text{-}j\text{-}k\text{-}i}$. This means that one table will be used per followed-up order in each service process operation mode,

[71] For Service Science, the meaning of "stakeholder concerns" is associated with the four different perspectives that the stakeholder who has the initiative to make the value proposition must consider, at the moment immediately before making the value proposition, placing itself in that moment, in the situation of each one of the four stakeholders (three plus himself) (Spohrer, Anderson, Pass, Ager, et al., 2008).

recording the data at every Step of the service process and for all the main stakeholders. However, to reduce the number of tables and facilitate analysis in this research, by using the **average result** of the orders followed up (Tables 4.2, 4.3, 4.4 and 4.5), this great number of tables will be reduced to one table per service process and per stakeholder. If the results producing a step's average outcome are not consensual (not all equal to "D") or (not all equal to "U"), the result ($KCI_{QUAL\text{-}j\text{-}k\text{-}i}$) must be recorded as "U^D" (Up and Down).

To assess each $KCI_{QUAL\text{-}j\text{-}k\text{-}i}$ Inovstone4.0 Framework proposes an appropriate mathematical equation (Appendix B). When the interaction between two S-Systems evolves its operations mode, it generates as outputs the Innovation Outcomes (Stoshikj et al., 2016), (Equations 4.1 and 4.2).

$$\mathrm{IOqual}_{\mathrm{ijk}} = \frac{[\mathrm{KCIqual\_jki(Current\_State)} - \mathrm{KCIqual\_jki(Future\_State)}]}{\mathrm{KCIqual\_jki(Current\_State)}} \tag{4.1}$$

$$\mathrm{IOquan}_{\mathrm{ijk}} = \frac{[\mathrm{KCIquan\_jki(Current\_State)} - \mathrm{KCIquan\_jki(Future\_State)}]}{\mathrm{KCIquan\_jki(Current\_State)}} \tag{4.2}$$

If $IO_{jki} > 0$, (i) it means the innovation impact tends to favour acceptance of the value proposition; (ii) if $IO_{jki} < 0$, it means the innovation impact goes against acceptance of the value proposal and; (iii) if $IO_{jki} = 0$, it means the innovation did not have any impact on acceptance of the value proposition.

4.2.7 Defining de Y-variable, the Innovation Outcomes

From the Service Science perspective, customer concerns are typically related to "Quality" (Meynhardt et al., 2016), a concept with multiple interpretations, depending on the scientific discipline used (Edvardsson & Tronvoll, 2013; M. H. Karimi & Asemani, 2013). This thesis being related to Operations Management, a discipline included in the S-S group of disciplines (Spohrer & Kwan, 2009), "Quality", as understood by this discipline, must be directly related to Customer Satisfaction (Brakus, Schmitt, & Zarantonello, 2009; Gollan, Kalfa, Agarwal, Green, & Randhawa, 2014; Naylor, Naim, & Berry, 1999) and thus, for Inov4.0|F, must be assessed along the service process through a "Customer Satisfaction Index" (CSI) concept (Ivanov et al., 2016) "imported" from TPS[72] and recommended by different academics and experts in *lean thinking* (Pinto, 2013).

CUSTOMER QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	CUSTOMER QUALITATIVE KEY CONCERNS INDICATORS $(KCI_{QUAL\_c})_i$
What is your concern with respect to Time to Receive the Product?	$TRP_{QUAL\_c} = \sum (D \,.\, TRP_{QUAL\_c})_i \div \sum (U \,.\, TRP_{QUAL\_c})_i$
What is your concern with respect to Product Sustainability?	$PS_{QUAL\_c} = \sum (D \,.\, PS_{QUAL\_c})_i \div \sum (U \,.\, PS_{QUAL\_c})_i$
What is your concern with respect to Product Quality?	$PQC_{QUAL\_c} = \sum (D \,.\, PQC_{QUAL\_c})_i \div \sum (U \,.\, PQC_{QUAL\_c})_i$
What is your concern with respect to Contract Compliance?	$CCC_{QUAL\_c} = \sum (D \,.\, CCC_{QUAL\_c})_i \div \sum (U \,.\, CCC_{QUAL\_c})_i$
What is your concern with respect to Brand Reputation?	$BRC_{QUAL\_c} = \sum (D \,.\, BRC_{QUAL\_c})_i \div \sum (U \,.\, CCC_{QUAL\_c})i$
What is your concern with respect to Flexibility?	$PFC_{QUAL\_c} = \sum (D \,.\, PFC_{QUAL\_c})_i \div \sum (U \,.\, PFC_{QUAL\_c})_i$
What is your concern with respect to Purchasing Price?	$PPC_{QUAL\_c} = \sum (D \,.\, PPC_{QUAL\_c})_i \div \sum (U \,.\, PPC_{QUAL\_c})_i$
What is your concern with respect to Total Product Cost?	$PTCC_{QUAL\_c} = \sum (D \,.\, PTCC_{QUAL\_c})_i \div \sum (U \,.\, PTCC_{QUAL\_c})_i$
What is your concern with respect to Warranty?	$PWC_{QUAL\_c} = \sum (D \,.\, PWC_{QUAL\_c})_i \div \sum (U \,.\, PWC_{QUAL\_c})_i$
What is your concern with respect to After Sales Service?	$PASC_{QUAL\_c} = \sum (D \,.\, PASC_{QUAL\_c})_i \div \sum (U \,.\, PASC_{QUAL\_c})_i$
What is your concern with respect to Product Reliability?	$PRC_{QUAL\_c} = \sum (D \,.\, PRC_{QUAL\_c})_i \div \sum (U \,.\, PRC_{QUAL\_c})_i$
What is your concern with respect to Product Safety?	$PSC_{QUAL\_c} = \sum (D \,.\, PSC_{QUAL\_c})_i \div \sum (U \,.\, PSC_{QUAL\_c})_i$
What is your concern with respect to Product Recycling?	$PRECYC_{QUAL\_c} = \sum (D \,.\, PRECYC_{QUAL\_c})_i \div \sum (U \,.\, PRECYC_{QUAL\_c})i$

Table 4.6: Customer Satisfaction Index (CSI) | Qualitative Key Concern Indicators (KCI_{QUAL})

[72] Toyota Production System

In a co-creative interactions mode (Anya et al., 2015) and from the S-S perspective, customers' traditional concerns, such as "price", are no longer quantitative, since the budget is placed "on the table" at a certain Step of the service process, and since under BIM operations, any product available must have the price as its fourth dimension (BIM-4D) (Han & Golparvar-Fard, 2015), accessible to everybody in the web IFC-web-libraries. Thus, although included in the CSI, for the Inov4.0|F price is a qualitative concern, whose result is obtained by the researcher from the answer to the question: "What is your concern with respect to Purchasing Price?" (Table 4.2).

CUSTOMER QUANTITATIVE MEASUREMENTS	CUSTOMER QUANITATIVE DATA
Step Process Time (days)	$STEP_{Quant\text{-}Global\text{-}Time}$
Customer Labour Time (hours)	$LABOUR_{Quant\text{-}Work\text{-}Time}$
Rejected Units by Costumer (m^2)	$REJECTED_{Quant\text{-}Units}$

Table 4.7: Customer Satisfaction Index (CSI) | Quantitative Measurements[73]

CUSTOMER QUANTITATIVE CONCERNS	CUSTOMER QUANTITATIVE KEY CONCERNS INDICATORS ($(KCI_{QUAN\_c})_i$)
Product Lead Time (days/m^2)	$PLTC_{QUAN\_c} = \sum(STEP_{QUAN\text{-}GLOBAL\text{-}TIME\_c})_i$
Product Labour Work Concerns (hours/m^2)	$PLWTC_{QUAN\_c} = \sum(Labour_{QUAN\_GLOBAL\_TIME\_c})_i$
Product Quality Concerns (Rejected m^2/m^2)	$PQC_{QUAN\_c} = \sum(Rejected_{QUAN\_UNITS\_c})_i \div \sum(Total_{QUAN\_UNITS\_c})_i$

Table 4.8: Customer Satisfaction Index (CSI) | Quantitative Key Concern Indicators (KCI_{QUAN})

As described previously, along the service process, CPMR-OS Companies' answers must be translated in terms of "UP" or "Down" in each move (service process step), and it is up to the researcher to interpret whether the customer's answer pulls up or down the proposal acceptance, with each question being indexed to a KCI_{QUAL} whose global value must be determined at the end of the service process, according to a set of equations

[73] "$STEP_{QUAN\text{-}GLOBAL\text{-}TIME\text{-}K}$" represents the time required; "$LABOUR_{QUAN\text{-}WORK\text{-}TIME\text{-}K}$" represents the number of manpower units; "$REJECTED_{QUAL\text{-}UNITS\text{-}K}$" represents the number of rejected units after leaving the factory and "$Total_{QUAL\_UNITS\text{-}k}$" and represents the number of output units produced per Step (i) from the stakeholder (k) perspective.

(Table 4.6). In every Step of the service process, direct shop-floor measurements (Table 4.7) will be carried out simultaneously with the qualitative questionnaire, so that qualitative results can also be confirmed quantitatively through Qualitative Concern Indicators (KCI_{QUAN}), indexed to a set of equations (Table 4.8).

4.2.7.1 Provider Key Concern Indicators

Providers’ concerns are traditionally related to companies’ "Productivity" (Merschbrock & Munkvold, 2015), defined as the relation between production outputs and the production factors used (Anya et al., 2015; Baraúna, 1996; Caggiano et al., 2015; Chesbrough & Spohrer, 2006; Jaca et al., 2012; Maglio, 2016; C. Y. Wang et al., 2010)

Although “lean thinking” is not the core of this research (Jaca et al., 2012), for various authors this mindset leads to increase productivity (Melton, 2005) as well as higher product quality, even in times of market turbulence (Chavez et al., 2015).

This mindset led by Japanese industry (Pinto, 2010) aims to counter the huge impact on the current reconfiguration of society and has led organizations with high productivity but low added value (typically production activities), to change their business towards greater added value (outsourcing production) (Naor et al., 2013). The exhaustive search for high productivity has led to the relocation of production and know-how with the consequent deindustrialization of traditionally industrial regions such as the United Kingdom, among others (HM Government, 2015). For this reason, the concerns of the modern producer must not be reduced to the classic sense of productivity as defined by Adam Smith in the eighteenth century, once as it can be observed from the practical cases around us, regardless of the type of product, customization is a trend increasingly appreciated by customers in particular and by markets in general, and also from a marketing perspective (J. Karimi & Walter, 2015). This leads us to the work of Vastag and Narasimhan (1998), where the Performance Index was introduced by Operations Management as a manufacturing score with several dimensions related to manufacturing efficiency and zero waste (Vastag, 2000). This concept is indeed in line with Service Science Theory (Storbacka et al., 2016), where ecosystems’ sustainability must be a transversal concern to all stakeholders (Robert F. Lusch et al., 2016; Maglio & Spohrer, 2008) and also aligned to BIM where the focus must be on efficiency (P. Smith, 2014b; Succar & Kassem, 2015). This means that OS-Provider concerns must be related to “Performance”, evaluated from five perspectives of analysis: customization, lead time, cost, sustainability and quality. For Inovstone4.0, these five concerns together will be designated the "Provider Performance Index" (PPI), matching the Threats identified in Chapter 2.

PROVIDER QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	PROVIDER QUALITATIVE KEY CONCERNS INDICATORS $(KCI_{QUAL\_p})_i$
What is your concern with respect to Customer Satisfaction?	$CSC_{QUAL\_p} = \sum (D \,.\, CSC_{QUAL\_p})_i \div \sum (U \,.\, CSC_{QUAL\_p})_i$
What is your concern with respect to Time to Receive the Product?	$TRP_{QUAL\_p} = \sum (D \,.\, TRP_{QUAL\_p})_i \div \sum (U \,.\, TRP_{QUAL\_p})_i$
What is your concern with respect to Product Sustainability?	$PS_{QUAL\_p} = \sum (D \,.\, PS_{QUAL\_p})_i \div \sum (U \,.\, PS_{QUAL\_p})_i$
What is your concern with respect to Product Maintenance Costs?	$PMCC_{QUAL\_p} = \sum (D \,.\, PMCC_{QUAL\_p})_i \div \sum (U \,.\, PMCC_{QUAL\_p})_i$
What is your concern with respect to Contract Compliance?	$CCC_{QUAL\_p} = \sum (D \,.\, CCC_{QUAL\_p})_i \div \sum (U \,.\, CCC_{QUAL\_p})_i$
What is your concern with respect to Brand Reputation?	$BRC_{QUAL\_p} = \sum (D \,.\, BRC_{QUAL\_p})_i \div \sum (U \,.\, CCC_{QUAL\_p})_i$
What is your concern with respect to Flexibility?	$PFC_{QUAL\_p} = \sum (D \,.\, PFC_{QUAL\_p})_i \div \sum (U \,.\, PFC_{QUAL\_p})_i$
What is your concern with respect to Product Safety?	$PSC_{QUAL\_p} = \sum (D \,.\, PSC_{QUAL\_p})_i \div \sum (U \,.\, PSC_{QUAL\_p})_i$
What is your concern with respect to Product Recycling?	$PRECYC_{QUAL\_p} = \sum (D \,.\, PRECYC_{QUAL\_p})_i \div \sum (U \,.\, PRECYC_{QUAL\_p})_i$

Table 4.9: Provider Performance Index (PPI) | Qualitative Key Concern Indicators (KCI_{QUAL})

PROVIDE QUANTITATIVE MEASUREMENTS	PROVIDER QUANITATIVE DATA
Machines Effective Operation Time (hours)	M_E_O_Time
Machines Setup Time (hours)	M_S_Time
Logistic Internal Time (hours)	L_I_Time
Idle Process Time (days)	I_P_Time
Labour Time (hours x man)	L_Time
Production Electricity Consumption (KWh)	P_E_Consum
Production Propane Consumption (Nm^3)	P_P_Consum
Production Diesel Consumption (Lts)	P_D_Consum
Production Raw Materials Consumption (m^3)	P_R_M_Consum
Production Raw Material waste (m^3)	P_R_M_Waste
Defective Units (Defect during process + raw materials) (m^2)	D_Units
Number of Operations (n)	N_Operations
Rejected Units by Costumer (m^2)	R_Units_byCustomer
Total Output Units (n)	T_O_Units
Number of Inspections (n)	NR_Inspect

Table 4.10: Provider Performance Index (PPI) | Quantitative measurements and variables[74]

PROVIDER QUANTITATIVE KEY CONCERNS INDICATORS (KCI_{QUAN-P}) RELATED TO THREAT 2 (FASTER DELIVERY TREND)

[74] "$OUTPUT_{UNITS-k}$", represents the number of units produced; "$M\_E\_O_{TIME-K}$" represents the production / machine time;"M_S_{TIME-K}" represents the setup / machine time in each Step (i), from the stakeholder (k) perspective "L_I_{TIME-K}" represents the occupation time of the logistic; "I_P_{TIME-K}" represents the stop time related to balancing, maintenance, etc; "$P\_R\_M_{CONSUM-K}$" represents the raw material units; "$P\_E_{CONSUM-K}$" represents the amount of energy units; "$D\_{UNITS-K}$", represents the amount of energy units; "$DEF_{-PER-INSPECT}$" represents the average number of defects detected in each inspection; "$NR_{-INSPECT}$" represents the average number of inspections; "$N\_{OPERATIONS}$" represents the number of operations and "P_E_CONSUM-k", represents the amount of energy units used in each Step (i), from the stakeholder (k) perspective

Market Interfacing Concerns	$MITC_{QUAN\_p} = \sum (M\_E\_O_{\_Time\_p})_i + \sum (M\_S_{\_Time\_p})_i + \sum (L\_I_{\_Time\_p})_i + \sum (I\_P_{\_Time\_p})_i$
Production Cycle Time Concerns	$PCTC_{QUAN\_p} = \sum (M\_E\_O_{\_Time\_p})_i + \sum (M\_S_{\_Time\_p})_i + \sum(L\_I_{\_Time\_p})_i$
Production Occupation Concerns	$POTC_{QUAN\_p} = \sum (M\_E\_O_{\_Time\_p})_i + \sum (M\_S_{\_Time\_p})_i$
Production Layout Ballance Concerns	$PLBC_{QUAN\_p} = \sum (I\_P_{\_Time\_p})_i$
Logistics Capability Concerns	$LCC_{QUAN\_p} = \sum (L\_I_{\_Time\_p})_i$

Table 4.11: Provider Performance Index (PPI) | Key Concern Indicators (KCI_{QUAN}) Related to Threat 2 (Lower Delivery Time Trend)

PROVIDER QUANTITATIVE KEY CONCERNS INDICATORS ($KCI_{QUAN\text{-}P}$) RELATED TO THREAT 3 (LOWER COST TREND)	
Labor Efficiency Concerns	$LWEC_{QUAL\_p} = \sum (L_{\_UNITS\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Raw Materials Efficiency Concerns	$RMEC_{QUAN\_p} = \sum(P\_R\_M_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Electricity Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Propane Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Diesel Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
First Time Through Concerns	$FFTC_{QUAN\_p} = \sum (D_{\_UNITS\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Rolled Throughput Concerns	$RTYC_{QUANT} = \sum ((1\text{-}Def_{\_UNITS\_p})_i \wedge \sum (N_{\_INSPECT\_p})_i)\wedge (N_{\_OPERATIONS\_p})_i$
Production Run Efficiency Concerns	$PREC_{QUAN\_p} =[\sum(M\_E\_O_{\_Time\_p})_i + \sum(M\_S_{\_TIME\_p})_i + \sum(L\_I_{\_TIME\_p})_i + \sum(I\_P_{\_TIME\_p})_i] \div \sum(O_{\_UNITS\_p})_i$

Table 4.12: Provider Performance Index (PPI) | Key Concern Indicators (KCI_{QUAN}) Related to Threat 3 (Lower Costs Trend)

For qualitative data, regarding OS-Provider concerns, the same four types of procedures as described for the OS-Customer will be used, the recorded data (Table 4.3) representing the researcher's interpretation of the OS-Provider's human resources' answers to the questionnaire, whose global value of KCI_{QUAL} must be determined at the end of the service process, according to a set of equations (Table 4.9).

Simultaneously with the recording of qualitative data, during the steps of the service process, direct measurements will be made regarding the equipment used in the production process, computers, databases, factory shop-floor and during visits to customer sites where the pieces are installed (Table 4.10). In this way, the quantitative data recorded can be used by the KCI_{QUAN} in all the subsets of concerns mentioned above and related to the Provider Performance Index (PPI): (1) customization, (2) lead time, (3) cost, (5) sustainability and (5) quality, trends that can lead to confirming the results of the KCI_{QUAL}, calculated from the equations represented (Tables 4.11, 4.12, 4.13 and 4.14), whose meanings are detailed in Appendix B of this thesis.

PROVIDER QUANTITATIVE KEY CONCERNS INDICATORS (KCI_{QUAN_p}) RELATED TO THREAT 4 (LOWER EMISSIONS TREND)	
First Time Through Concerns	$FFTC_{QUAN\_p} = \sum (D_{\_UNITS\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Raw Materials Efficiency Concerns	$RMEC_{QUAN\_p} = \sum (P\_R\_M_{CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Diesel Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Electricity Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Propane Efficiency Concerns	$EEC_{QUAN\_p} = \sum (P\_E_{\_CONSUM\_p})_i \div \sum (O_{\_UNITS\_p})_i$

Table 4.13: Provider Performance Index (PPI) | Key Concern Indicators (KCI_{QUAN}) Related to Threat 4 (Lower Emissions Trend)

Evaluation of the response to the Threat resulting from standardization imposed by BIM procurement will be through the outcome generated by the ISPAR methodological tool during each Step of the service process. In other words, for an OS-Provider to be able to commercialize customized products under BIM procurement, the $ISPAR_{\ OUTCOMES}$ must be *normative* at all Steps of the process, which can be checked through the service mapping. In practical terms, the Step Outcomes (SO) from the flow of the steps described in the S-Bprint maps, together with the IO resulting from the KCI_{QUAL} evolution (Table 4.3) and KCI_{QUAN} (Tables 4.11, 4.12, 4.13, 4.14) match the five Threats raised from the SWOT matrix presented in Chapter 2.

PROVIDER QUANTITATIVE KEY CONCERNS INDICATORS (KCI_{QUAN_p}) RELATED TO THREAT 5 (LOWER NON-QUALITY TREND)	
First Time Through Concerns	$FFTC_{QUAN\_p} = \sum (D_{\_UNITS\_p})_i \div \sum (O_{\_UNITS\_p})_i$
Rolled Throughput Concerns	$RTYC_{QUANT} = \sum ((1\text{-}Def_{\_UNITS\_p})_i \wedge \sum (N_{\_INSPECT\_p})_i) \wedge (N_{\_OPERATIONS\_p})_i$
Product Quality Ratio Concerns	$PQC_{QUAL\_p} = \sum (Rejected_{\_QUAN\_UNITS\_p})_i \div \sum (Total_{\_QUAN\_UNITS\_p})_i$

Table 4.14: Provider Performance Index (PPI) | Key Concern Indicators (KCI_{QUAN}) Related to Threat 5 (Lower Non-Quality Trend)

4.2.7.2 Competitor Key Concern Indicators

The literature on the reasons leading an organization to innovate is extensive (Antony et al., 2014; Bolton et al., 2007; Bunse et al., 2014; Kahkonen & Lintukangas, 2012; Stock & Seliger, 2016; Taylor, Haque, & Moore, 2004; D. Teece, Pisano, & Shuen, 1997; Yang, Hong, & Modi, 2011). In the literature reviewed, and regardless of whether the level of innovation is incremental or radical, many authors point out that, as happens with individuals (Kropotkin, 1902), organizations' struggle for survival appears to be the first reason for change (innovation). This innovation has costs, which are not always covered by the benefits acquired through change (Jones & Serafeim, 2013; Lee et al., 2014; Shannassy, 2008). These conclusions from the literature review are in line with Service Science Theory, where innovation is regarded as essential for the company to remain competitive and grow (Robert F Lusch & Nambisan, 2015; Maglio & Spohrer, 2008, 2013) with the associated costs and risks being the price to be paid to keep the company competitive and growing. This struggle for competitiveness and growth, for S-S, resulting from the existence of competition means this stakeholder becomes the main driver of sustainable innovation (Spohrer, Anderson, Pass, & Ager, 2008), which leads to excellence and pre-eminence of activities within an ecosystem (D. J. Teece, 2014). Due to its contribution to sustainable innovation, S-S Theory considers the competition as a primary stakeholder, whose concerns cannot be reduced to the narrow view in the traditional sense, as an alternative provider, but as the driver of the ongoing challenge to suppliers, to find the trade-off between environments of great stress (anxiety and risk of failure) and low stress (boredom and risk of success) (Keith et al., 2013), which gives rise to sustainable innovation. As for S-S Theory, also for Csikszentmihalyi (1990), (…)

"seeking a dynamic balance between anxiety and boredom helps to secure value through change" (as cited in Ismail, 2011). This is also the understanding adopted by Inov4.0|F by using the concept of "Sustainable Innovation Index" (SII) which will represent the OS-Competitor's concerns, as far as the OS-Provider may imagine them at the moment he puts the value proposition on the table. To collect qualitative data related to these concerns, the same four types of procedure described for the remaining stakeholders must be adopted in this framework, and the interviewer's interpretation of the OS-Competitor's responses recorded (Table 4.4), with the global value of the KCI_{QUAL} determined at the end of the service process, according to the set of equations (Table 4.15).

COMPETITOR QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	COMPETITOR QUALITATIVE KEY CONCERNS INDICATORS $(KCI_{QUAL\_cp})_i$
What is your concern with respect to Customer Satisfaction?	$CSC_{QUAL\_cp} = \sum (D . CSC_{QUAL\_cp})_i \div \sum (U . CSC_{QUAL\_cp})_i$
What is your concern with respect to Innovative Product?	$PIC_{QUAL\_cp} = \sum (D . PIC_{QUAL\_cp})i \div \sum (U . PIC_{QUAL\_cp})_i$
What is your concern with respect to Innovative Manuf. Process?	$PIMPC_{QUAL\_cp} = \sum (D . PIMPC_{QUAL\_cp})_i \div \sum (U . PIMPC_{QUAL\_cp})_i$
What is your concern with respect to Total Product Cost?	$PTCC_{QUAL\_cp} = \sum (D . PTCC_{QUAL\_cp})_i \div \sum (U . PTCC_{QUAL\_cp})_i$
What is your concern with respect to Product Recyclable?	$PRECYC_{QUAL\_cp} = \sum (D . PRECYC_{QUAL\_cp})_i \div \sum (U . PRECYC_{QUAL\_cp})_i$
What is your concern with respect to Contract Compliance?	$CCC_{QUAL\_cp} = \sum (D . CCC_{QUAL\_cp})_i \div \sum (U . CCC_{QUAL\_cp})_i$
What is your concern with respect to After Sales Response?	$PASC_{QUAL\_cp} = \sum (D . PASC_{QUAL\_cp})_i \div \sum (U . PASC_{QUAL\_cp})_i$
What is your concern with respect to Product Reliability?	$PRC_{QUAL\_cp} = \sum (D . PRC_{QUAL\_cp})_i \div \sum (U . PRC_{QUAL\_cp})_i$

Figure 4.15: OS-Competitor | Qualitative Key Concern Indicators (KCI_{QUAL_cp}), related to "Sustainable Innovation Index" (SII)

4.2.7.3 Authority Key Concern Indicators

The authorities aim to encourage organizations to improve operations through official rules, to transform the potentially negative environmental and social impacts resulting from their activities into a more sustainable environment and better living conditions for everyone (Boughnim & Yannou, 2005), these principles being a transversal concern in Service Science. Therefore, for S-S the authorities become a main stakeholder, whose concerns are organizations' activities conforming to rules (Spohrer & Kwan, 2009) which lead ecosystems to a more sustainable environment and better and healthier lives (Robert F. Lusch et al., 2016). This must also be the understanding of Inov4.0|F, using the "Conformity Index" (CI) concept, which will be the measure of the Authorities' concerns, as far as the stakeholder making the value proposition can understand.

AUTHORITY QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	AUTHORITY QUALITATIVE KEY CONCERNS INDICATORS $(KCI_{QUAL\_a})_i$
What concern with respect to Handling &Application Compliance?	$PH\&AC_{QUAL\_a} = \sum (D \,.\, PH\&AC_{QUAL\_a})_i \div \sum (U \,.\, PH\&AC_{QUAL\_a})_i$
What concern with respect to Product Manufacturing Compliance?	$PMC_{QUAL\_a} = \sum (D \,.\, PMC_{QUAL\_a})_i \div \sum (U \,.\, PMC_{QUAL\_a})_i$
What concern with respect to Product Transport Compliance?	$PTC_{QUAL\_a} = \sum (D \,.\, PTC_{QUAL\_a})_i \div \sum (U \,.\, PTC_{QUAL\_a})_i$
What is your concern with respect to Product Recyclable Compliance?	$PRECYC_{QUAL\_a} = \sum (D \,.\, PRECYC_{QUAL\_a})_i \div \sum (U \,.\, PRECYC_{QUAL\_a})_i$
What concern with respect to Product Moral Hazard Compliance?	$PM\&HC_{QUAL\_a} = \sum (D \,.\, PPM\&HC_{QUAL\_a})_i \div \sum(U \,.\, PPM\&HC_{QUAL\_a})_i$
What concern with respect to Product Legal Compliance?	$PLC_{QUAL\_a} = \sum (D \,.\, PLC_{QUAL\_a})_i \div \sum (U \,.\, PLC_{QUAL\_a})_i$
What concern with respect to Taxes & Fines application and execution?	$T\&FC_{QUAL\_a} = \sum (D \,.\, T\&FC_{QUAL\_a})_i \div \sum (U \,.\, T\&FC_{QUAL\_a})_i$

Table 4.16: Authorities | Qualitative Key Concern Indicators (KCI_{QUAL_a}), related to "Conformity Index" (CI)

To collect qualitative data related to these concerns, the same four types of procedure described for the remaining stakeholders must be adopted in this framework, and the interviewer's interpretation of Authorities' responses (Table 4.5), the global value of the KCI_{QUAL} being determined at the end of the service process, according to the set of equations (Table 4.16). In dealing with the authorities as a "faceless" stakeholder, data collection will be essentially through the interviewer's interpretation of documents and precepts that involve or may involve the authorities, with a good interconnection between authorities' information systems and other stakeholders being considered relevant.

4.2.8 Innovation Outcomes Analysis

As observed in the literature review, for S-S Theory, $IO_{QUAL\text{-}k}$ and $IO_{QUAN\text{-}k}$ represent the variation observed in the $KCI_{QUAL\text{-}k}$ and $KCI_{QUAN\text{-}k}$ indicators, resulting from the innovations along the service process (Edvardsson & Tronvoll, 2013). Therefore, for Inov4.0|F, stakeholders' concerns will be qualified and quantified based on the right metrics for each of the KCI_{QUAL} and KCI_{QUAN}, and so it is possible to assess each result before and after the innovation, with these differences, according to S-D Logic (Robert F Lusch & Nambisan, 2015), and consequently accepted by S-S, being called Innovation Outcomes (IOs) (Kwan et al., 2016).

Additionally, as mentioned above, in Inov4.0|F, each Step of the service process must use the ISPAR tool which classifies the Step-Outcome (SO) in ten possible outcomes (Spohrer, Anderson, Pass, Ager et al., 2008). In case of a non-normative SO (not allowing continuation to the next step), this probably means it is necessary to innovate in this step, which may involve the return to previous steps or even stopping the service process. If this is not possible, or the other stakeholder does not accept an alternative (innovative) proposal, it may lead to breaking off negotiations or even a legal dispute (Behera et al., 2015; Gollan et al., 2014; Stoshikj et al., 2016).

Once Inov4.0|F is applied to the sample group of CPMR-OS Companies, the $IO_{QUAL\text{-}k}$ and $IO_{QUAN\text{-}k}$ (Equation 4.1) will be determined in relation to the evolution of the main stakeholders' concerns. The results will lead to conclusions about the impact of the I4.0 operations mode on these companies' response to the threats resulting from BIM procurement.

As a key assumption of the mixed methodological approach, qualitative data and quantitative data must provide results that lead to similar conclusions. In other words, by using mixed methodology, if the results of the IO_{QUAL} combined with the IO_{QUAN} results are in the same direction, they will be robust enough to answer the RQs: what impact could Industry 4.0 have on CPMR-OS Companies' response to the threat posed by BIM procurement in the AECSC. However, to reach final confirmation of this impact, non-parametric average tests based on the Wilcoxon-Mann-Whitney statistic and t-Student tests will be carried out on the significance of the respective IO_{QUAL}, with the objective of confirming if they maintain the average assumptions, regarding stakeholders' concerns, when operations evolve from the CBP mode to the digital situation of I4.0.

4.3 CHAPTER SYNTHESIS

In this Chapter, it has been describe the methodology to be used in this research. From the Research Problem (RP) the Research Questions (RQ) have been formulated, directly related to the Threats and Opportunities raised by the digital economy to CPMR-OS Companies' current core business model. The main objectives of the thesis were stated, which are based on the conceptualization of an empirical framework through the lens of Service Science, which, once applied to a representative sample of the population, must provide sufficiently robust results to respond to the RQs formulated. Since this thesis is an exploratory research supported by Service Science Theory the Mixed Methodology of Parallel Convergence becomes the most appropriated. Thus, guided by the Pragmatist Paradigm, the specific objectives are defined and the reseach questions formulated considering the methodology and methodological tools.

In this Chapter is also identified the population to be studied, the criteria applied in forming the convenience sample, and the procedures for collecting qualitative and quantitative data, with which the stakeholders' Concern Indicators (KCI) will be determined, according to Service Science Theory.

Finally, it was presented the selected S-S methodological tools used by Inov4.0|F to map and evaluate SO, as well as the methodological sequence to be adopted in Chapter 5, (Framework Conceptualization) and from its application in Chapter 6 (Framework Application), is expectable to get exploratory results, robust enough, to answer the RQs and thus lead us to a RP solution.

CHAPTER 5

One thing I have learned in a long life:

That all our science, measured against reality, is primitive and childlike - and yet it is the most precious thing we have

Albert Einstein

5. INOVSTONE4.0 FRAMEWORK CONCEPTUALIZATION

According to some authors, a Conceptual Framework can be defined as a set of interrelated objectives and fundamentals, where the objectives identify the goals and the fundamentals are the underlying concepts that assist in achieving those same goals (Meynhardt et al., 2016).

Looking at the threats identified in Chapter 2 and following the convergent parallel methodology supported by Service Science, this Chapter will conceptualize the empirical framework, requiring the selection and adaptation of the methodological tools, as well as clarification of the Indicators related to the four main stakeholders' Concerns (S. Vargo & Lusch, 2016). Supported by Service Science Theory it will be constructed the Inovstone4.0 Framework (Inov4.0|F) throughout this Chapter, the Pragmatist Paradigm providing the guidelines for the selection and collection of data, the circumstances and baselines in which they will be used, and how they will be measured, summarized and interpreted (Breidbach & Maglio, 2016) (Figure 5.1).

From the literature review, it was concluded that for Service Science, just as there is no separation between tangible and intangible goods, nor is there any "value creator" versus "value destroyer", since all social and economic actors are resource integrators as expressed by FP9[75] S-D Logic (R. F. Lusch & Vargo, 2008). Entities such as suppliers, customers, families or any other actors involved in economic activities are "exchange service entities" with the common purpose of co-creating value it is all B2B (S. L. Vargo & Lusch, 2010).

[75] Service Dominant Logic Nineth Fundamental Premise (S. Vargo & Lusch, 2016)

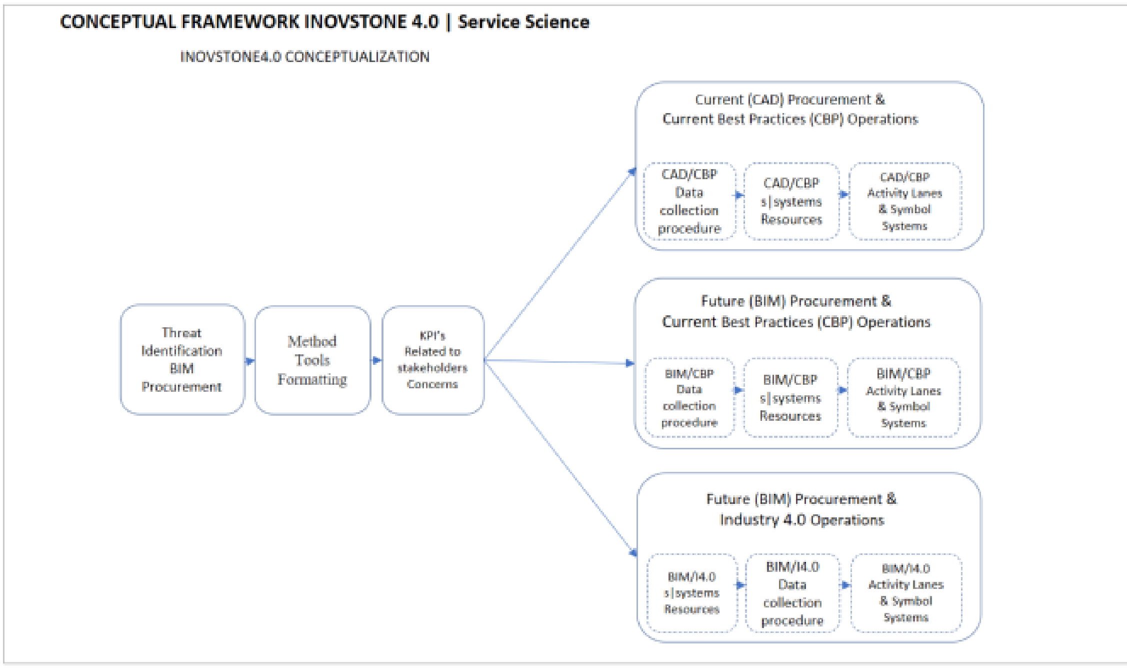


Figure 5.1: Inovstone4.0 Framework Conceptualization

In contrast to S-D Logic (Robert F. Lusch et al., 2010) but in line with Service Science, it will be assumed by the Inov4.0|F that there is a clear distinction between the four different types of main actors involved in co-creation interactions (Spohrer et al., 2007), also considering that all stakeholders will be value co-creators involved in the service exchange along the service process (Maglio et al., 2009; Storbacka et al., 2016).

5.1 THE INDUSTRY 4.0 THROUGH THE LENS OF SERVICE SCIENCE

As described in Chapter 4 of this thesis, the main objective of this research is to conceptualize an empirical framework supported by Service Science Theory, named "Inovstone4.0", which once applied as a case study to a representative sample of CPMR-OS Companies, will allow assessment of the impact of the Industry4.0 operations mode on the response to the threats arising from the upcoming BIM procurement in the AECSC (HM Government, 2015). It is important to keep in mind that innovation in the traditional concepts of the industry and service sectors (Newell, 1980) is differentiated only by the typology of resources or schemes (norms and rules) or how they are combined (Feller, Parhankangas, Smeds, & Jaatinen, 2013). Therefore, relevant for the conceptualization of Inovstone4.0 are the contributions of Wu, Liang-Chuan Wu and Liang-Hong Wu (2013). Although aligned with the S-D Logic mindset in that (...) "we believe that customers are the missing link in the supply chain", but diverging from the Fundamental Service Science

Principals when referring to S-S (…)" as the emerging discipline of Services Science, Management and Engineering (SSME)" (L.-C. Wu & Wu, 2013), these researchers have conceptualized a framework where the boundary between customer and supplier is classified as a *"melting boundary",* which produces innovation and service-exchange between the customer-provider binomial, making this a relevant aspect for Inov4.0|F.

Based on the approximations made by these researchers, and I4.0 being related to the digital production supported by CPS as a co-creative innovation facilitator of value propositions in the Industry 4.0 environment, for Inov4.0|F are proposed a set of approaches resulting from the Service Science mindset to facilitate the innovation of value propositions between service systems.

5.1.1 The Fingerprint I4.0

As described in Chapter 2, supported by Cyber-Physical-Systems in Industry 4.0 operation mode, products start as a single idea evolving into Smart Objects (Kagermann et al., 2013), and from this stage, in the factory-floor environment, products take on physical form until they are ready to be shipped to customers (Lasi et al., 2014). Therefore, as a means of streamlining and transporting the co-created specifications related to the product during the first phase of the service process, the transition to digital mode, Inov4.0|F, must consider the incorporation of a new concept of Fingerprint I4.0 (FP-I4.0), (CPMR, 2017) as a vehicle to transport the value co-created by the service systems' interaction, and from that into a Smart Object. This means that FP-I4.0, once generated, can indeed be considered the Global Outcome of the service process Phase 1, that is, the phase of product design and deal conclusion (Figure 5.2).

The roadmap consisting of successive and co-creative steps during phase one of the service process leads to the co-creation of the object's FP-I4.0, which along the way may require, in some stages of the process, uploading specific applications, such as drawing specific geometries of the object or others, and in parallel, involving traditional technical-commercial assistance through traditional technologies such as the phone or email, in order to achieve FP-I4.0 in full.

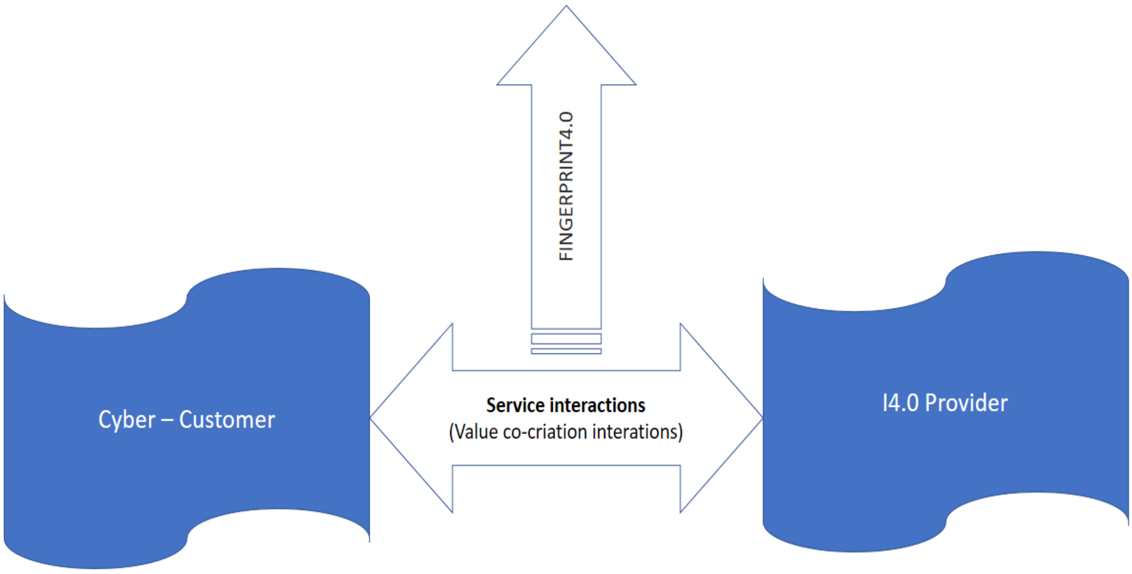


Figure 5.2: Fingerprint I4.0 Outcome in Digital Context

FP-I4.0 will thus be a kind of cargo vehicle with two compartments for complementary but different contents. In the first compartment, FP-I4.0 carries the descriptive content of the specifications of the co-created product, which may include comments, notes, remarks or other relevant information. In the second compartment, FP-I4.0 carries the IFC/XML code, as exported by the CPS post-processor and interpreted by the CPS, from which the Smart Object will be generated. Before accepting the value proposition, the CPS will make available the contents of both compartments of the FP-I4.0 available to the customer, which includes, in addition to the specifications co-created, additional information about the product, such as the ecological footprint, recycling process, associated compliance and any other relevant information for the customer, provider and authorities. Once the value proposition has been evaluated and confirmed by the customer, CPS will generate the product's Smart Object file.

5.1.2 The CPS-Cockpit I4.0

The researchers Wang, Wan, Zhang, Li, Di and Zhang, in their article entitled *Towards smart factory for Industry 4.0*, consider that in Industry4.0 mode, Smart Objects can be generated automatically, that is, without any human intervention (S. Wang et al., 2015). The feasibility of this level of automation must not be pointed out in simple cases such as the additive production mentioned before. However in complex processes, this would make the production process probably too rigid, and thus, contrary to the main objectives of I4.0 operations mode, inhibiting the advantage of providing flexibility to digital production (Stock & Seliger, 2016).

Despite the use of artificial intelligence algorithms as cognitive assistants being increasingly considered essential in service systems, the simple fact that they cannot be held responsible for their acts, since they are legally unpunishable machines having no rights and duties, means that they cannot, on their own, and for that reason, be considered as service systems according to Service Science[76] (Maglio et al., 2009). To overcome this limitation, Inov4.0|F considers that an interface feature within the CPS itself called "Cockpit" must be specified. Functioning as a humanized and efficient interface, Cockpit incorporates resources with rights, and thus acquires the service system classification through the lens of S-S Theory (Figure 5.3).

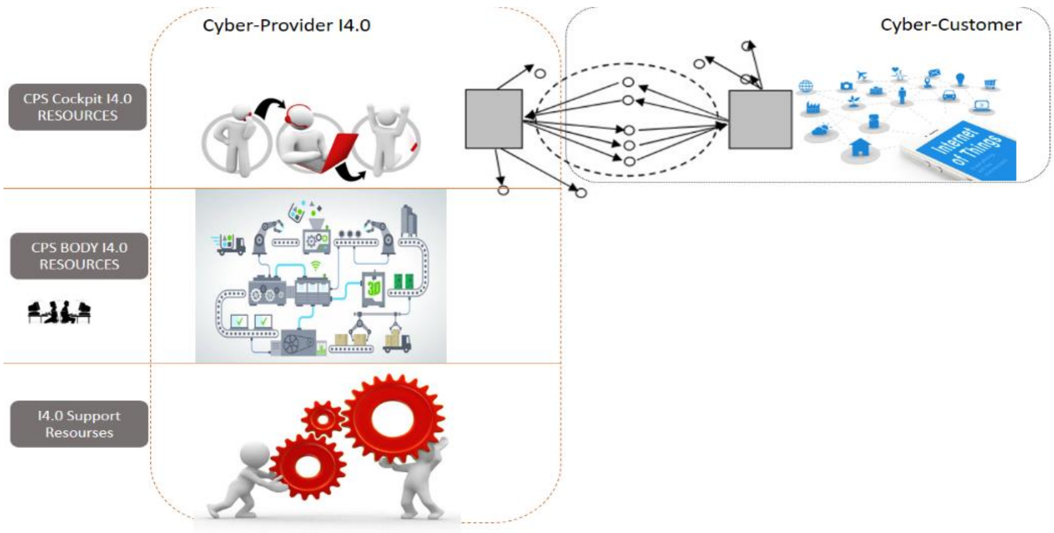


Figure 5.3: Internet of Things and Cyber-Physical-Systems Architecture through the lens of Service Science

With relative autonomy inside the CPS, Cockpit will thus play the double role of dialogue and interface entity, between the CPS and the cyber client and, on the other hand, the function of dialogue interface entity with the CPS Body as well as with the organization's support resources, such as the company's management. For Inov4.0|F, Cockpit will thus be a virtual feature of the I4.0 operations mode from the S-S perspective, which will be an integral and fundamental module of the Conceptual Framework itself. This means it is through Cockpit that it is possible to guarantee permanent and co-creative interaction with the customer along the entire service process, from the moment the customer intends to

[76] For Service Science, an s|system must contain at least one operant resource (with rights) (S. L. Vargo & Lusch, 2004a), which can be a company or a person (Maglio & Spohrer, 2013).

buy, until the product is recycled, Cockpit resources also being responsible for FP-I4.0 transforming into a Smart Object.

5.2 THREATS IDENTIFICATION

In the SWOT matrix introduced in Chapter 2, it was found that BIM generalization in the AECSC will result in threats to the companies operating in this Supply Chain, including CPMR-OS Companies (Ibem & Laryea, 2014).

From identification of these threats, the RP arose, resulting in the RQs presented in the chapter on Methodology. Given these assumptions, AECSC stakeholders, in which OS companies are included, will be faced with a new commercialization situation for their products, which have been splited into five threats: (i (standardization) – in the BIM context, the AECSC procurement model will tend to procure standard products; (ii), (faster delivery) – in the BIM context, construction time will tend to be less; (iii), (lower costs) – in the BIM context, building and maintenance costs will tend to be lower; (iv), (lower emissions) – in the BIM context, buildings will tend to be more environmentally sustainable; (v), (less non-quality) – in the BIM context, errors and mistake tolerance will tend to be reduced, when compared to current requirements.

5.3 THE POPULATION DESCRIPTION

As described in Chapter 4, from the research carried out in recent years and related to the Portuguese Ornamental Stone sector (I. Frazao, 2016; J. Frazao, 2016; Silva, 2013, 2014), it can be infered that the group of CPMR-OS Companies can be considered to represent Current Best Practices (CBP) within the Portuguese Stone sector. In this connection, CPMR-OS being formed of front-line OS companies operating in the global market, it may be considered that at the sectoral level, on one hand, these companies will be the first to feel the threats of BIM procurement, but on the other hand, may be better prepared to adapt their operations to the digital processes resulting from I4.0. Therefore, this population will be studied in this research, and it will be applied Inov4.0|F to a representative sample of this population.

5.4 SERVICE BLUEPRINTING METHODOLOGICAL TOOL

As found in the literature review, *service blueprinting* (S-Bprint) is a methodological tool recommended by S-S to map the shared access to S-System resources, (Bitner et al., 2008a; Kwan et al., 2016).

Starting from the original format as introduced by Kingman-Brundage (1989) the S-Bprint format to be adopted as part of Inov4.0|F must avoid theoretical causes and organizational pitfalls during its usage. Only suitably adapted can it be useful to managers in their decisions regarding their organizations' sustainable growth (Suhardi et al., 2015), especially allowing comparison of the different service innovation structures of the Fourth Industrial Era with a view to easily extracting the Concern Indicators (KCI) variations, which for S-S are designated Innovation Outcomes (IO) (Kwan et al., 2016).

This new S-Bprint format as developed for Inov4.0|F application is detailed (Appendix A) which keeps the separation of service interactions in individualized processes by horizontally represented steps, where each individual component (activity) belongs to a different lane, ordered vertically with each one representing, as in the Shostack model, a level of proximity to the customer. The higher in the map the lane of the provider's resources involved in the actions, the closer the level of interaction with the customer stakeholder.

5.5 ISPAR METHODOLOGICAL TOOL

In every Step of the service process, once the value proposition is made by one stakeholder, understanding depends on the perception of the value of the other stakeholder's resources, and its acceptance will depend on the combination of the different resources. If the proposal is refused, it means that no value results from the proposal.

Inov4.0|F uses the *Interact Serve Propose Agree Realize* (ISPAR) tool to classify the Outcome of value propositions, in terms of ten different possible SO (Figure 5.4) - (i) the value is performed as proposed; (ii) the proposal is not perceived; (iii) the proposal is not accepted; (iv) value is not realized but does not generate a dispute; (v) disputes are settled by agreement between the parties; (vi) disputes are not resolved by agreement between the parties; (vii) an interaction is after all a non-service interaction since it does not create value but is nonetheless peaceful for all, (viii) non-service interaction and is interpreted as illegal and may be a matter for the courts, (ix) the non-service interaction is interpreted as unlawful (x) non-service interaction is unwanted but the legal authorities do not confirm it as illegal or the culprit is not identified.

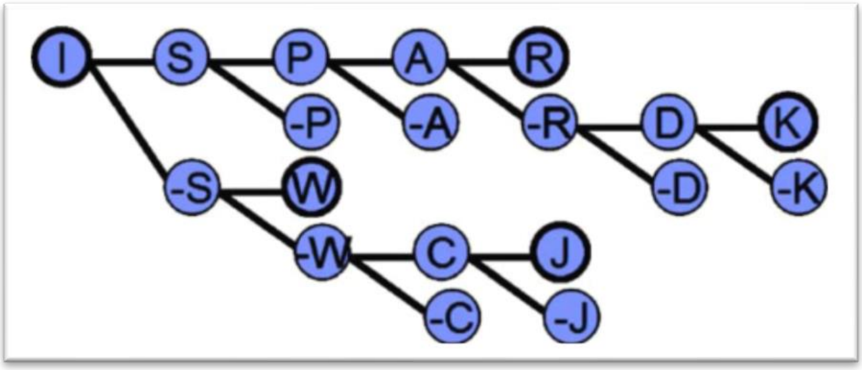


Figure 5.4: ISPAR Outcomes. Source (Maglio et al., 2009)

5.6 SERVICE SYSTEMS RESOURCES DESCRIPTION

As it was found in the literature review, for S-S the methodology must start with a description of the entities, being service systems in the form of abstract concepts composed of dynamic configurations of people, technologies, organizations and information (Spohrer, Anderson, Pass, Ager, & Gruhl, 2008). In the research field, it was also found that the resources of most CPMR-OS Companies (research population) do not vary greatly. Indeed, only the resources' dimensions are different, since some companies are larger than others, a similar situation being found in relation to typical OS-Customers.

5.6.1 Customer Resources in CAD Operation Mode

The term "CAD-Customer" will be used in this research to designate an ornamental stone customer entity that uses CAD[77], (in the current best practices situation), whose resources can be split into the following complementary and interdependent groups:

(i) FRONTAGE RESOURCES | Internet-connected CAD operator;

(ii) BACKSTAGE RESOURCES | experts in different building construction fields, from whom the CAD operator can get advice whenever it seems necessary;

(iii) ADMINISTRATION RESOURCES | investor, construction directors, among others;

[77]Computer-aided design (CAD) is the use of computer systems to create, modify, analyse or optimize a design.

(iv) PARTNERSHIP RESOURCES | public and private entities related to the building work or the company responsible for it;

(v) KNOW-HOW AND SHAREABLE INFORMATION RESOURCES | knowledge such as patents, technology transfer, cross-fertilization processes, temporary innovation initiatives, benchmarking information from multiple competitors, other shareable information or documents, etc.

5.6.2 Customer Resources in BIM Operation Mode

As previously specified, both FP-I4.0 and Cockpit concepts are integrant modules of Inov4.0|F, but the Cockpit is also the I4.0-OS-Provider interface resource that interacts with the BIM operator, from FP-I4.0 co-creation until the product-recycling stage. Thus, in the BIM procurement mode, the RO-Customer will be designated as the BIM-Customer, whose resources may be split into five complementary and interdependent groups:

(i) FRONTAGE RESOURCES | Internet-connected BIM operator;

(ii) BACKSTAGE RESOURCES | experts in different building construction fields, from whom the BIM operator can get advice whenever it seems necessary;

(iii) ADMINISTRATION RESOURCES | investor, construction directors, among others;

(iv) PARTNERSHIP RESOURCES | public and private entities related to building work or the company responsible for it;

(v) KNOW-HOW AND SHAREABLE INFORMATION RESOURCES | knowledge such as patents, technology transfer, cross-fertilization processes, temporary innovation initiatives, benchmarking information from multiple competitors, other shareable information or documents, etc.

5.6.3 Stone Provider Resources in Current Best Practices Operations

For the current CPMR-OS Companies, the operations mode is designated current best practices (CBP-OS-Provider), since this group of companies has stood out positively in the Portuguese OS sector, as described in Chapter 2. These Companies wanted, and showed they had the merit, to join the CPMR Association[78] (Valor Pedra, 2016) (Valorpedra, 2016) and their current resources, although of different dimensions, have similar configurations and are organized in a similar way.

This similarity of the companies in the Population studied facilitates sample composition for this research, because it allows the typical resource structure of the CBP-OS-Provider to be identified relatively easily. Thus, when one of these companies goes into availability mode to provide a product to a CAD-Customer, it becomes a service system according to the Service Science perspective and so its resources may be split into the following complementary and interdependent groups:

(i) FRONT-OFFICE CBP-OS-PROVIDER HUMAN RESOURCES | physical-with-rights resources, which include human resources that interact and collaborate directly with the CAD-Operator, such as sales people and others.

(ii) FRONT-OFFICE CBP-OS-PROVIDER CYBER RESOURCES | not-physical-with-no-rights, including cyber media that interact directly with the vendor, such as emails, telephone exchanges, TeamViewer applications, websites, among others.

(iii) BACK-OFFICE CBP-OS-PROVIDER ENGINEERING RESOURCES | human resources that interact and collaborate indirectly with the CAD-operator, made up of production specialists who help to adapt the customer's needs to the factory's production possibilities. They are physical people and thus considered physical-with-rights resources.

(iv) BACK-OFFICE CBP-OS-PROVIDER ICT RESOURCES | resources with-no-rights, which include the media and information support, and therefore interact indirectly with the CAD Operator, such as the email servers, among others.

(v) BACKSTAGE CBP-OS-PROVIDER OPERATORS, MAINTAINERS & CONTROLLERS HUMAN RESOURCES | human resources that operate, repair and control the factory's production and logistics facilities, and thus physical people as physical-with-rights resources, which may include: quarry equipment operators; factory equipment operators; equipment maintenance technicians in a quarry; equipment maintenance technicians in a factory; head of section for the production of natural stone blocks; head of section for the transformation of natural stone

[78]https://www.clustermineralresources.pt/

blocks; people making samples and prototype pieces in natural stone and quality control technicians.

(vi) BACKSTAGE CBP-OS-PROVIDER MACHINERY (PRODUCTION AND LOGISTICS) | means of production and logistics, physical-with-no-rights, which include: block production equipment in quarries; production equipment and optimization of natural stone plate; equipment for surface texture in natural stone; natural stone cutting and machining equipment; equipment for the finishing of natural stone pieces; equipment for the execution of technical functionalities in natural stone; stone cleaning equipment for natural stone; packaging equipment for natural stone pieces; equipment for the execution of prototypes and samples in natural stone; test equipment and quality control for natural stone; warehouse blocks; intermediate sheet metal warehouse; warehouse of intermediate pieces; intermediate warehouses of parts; logistic means for blocks; logistic means for plates; logistic means for parts; logistic means for pallets; test and quality control equipment; equipment for making samples and prototypes in natural stone.

(vii) SUPPORT PARTNERSHIPS RESOURCES | public or private entities outside the company, with which it collaborates permanently or occasionally, and thus usually not-physical-with-rights resources: local and national authorities; professional training center; unions; stone federation; technological centers; acpmr; universities; exhibition centers; banks and credit entities; logistic companies; manpower outsourcing companies; catering companies; consulting companies; certification authorities; energy providers; raw materials suppliers; legacy outsourcing and insurance companies.

(viii) KNOW-HOW AND SHAREABLE INFORMATION RESOURCES | specific knowledge that can make the difference now when the value creation proposal is evaluated by the CAD operator and thus are not-physical-with-no-rights resources, such as patents, technology transfer and cross-fertilization, pilot projects and temporary innovation initiatives, among others.

(ix) SUPPORT TECHNOLOGY RESOURCES | technologies, which although traditional continue to be essential to the company's operation, which is why they will have to be integrated in production and so are physical-with-no-rights resources such as CRM server, accounting server, among others.

(x) SUPPORT MANAGEMENT & QUALITY RESOURCES | formed by the human resources of the organization's management in the CBP mode and, thus being physical people are physical-with-rights resources, such as managing directors, legacy staff, accounting staff, marketing staff, among others.

5.6.4 Provider Resources in Industry 4.0 Operations Mode

For Inovstone4.0, the resources that an Ornamental Stone Company needs to operate in I4.0 mode should guarantee its division into six groups: Cockpit, Cyber Physical System I4.0 Body, Management and Marketing I4.0 Resources, Support Partnerships, Know-How and Shareable Information and Support Technology.

Although Cockpit 4.0 operates as the CPS front-end, it is not the provider itself, but only an I.40-OS-Provider resource, within which there will be people, and for that reason, they are physical resources with rights. When a I.40-OS-Provider goes into availability mode to supply a stone product to a BIM-Customer, it becomes a service system whose resources may be divided into ten complementary and interdependent groups:

(i) COCKPIT4.0 FRONT-OFFICE HUMAN RESOURCES | physical-with-rights, which include the human resources that interact and collaborate directly with the BIM operator, such as experts in interface and BIM applications, sales staff, among others.

(ii) COCKPIT4.0 FRONT-OFFICE CYBER OS RESOURCES | formed of not-physical-with-no-rights resources which include cyber media that interact directly with the provider, such as dialogue interface BIM-Customer, BIM-Libraries, Website, email, phone, among others.

(iii) COCKPIT 4.0 BACKOFFICE HUMAN RESOURCES | human resources that interact and collaborate indirectly with the BIM operator, including experts in I4.0 / Smart-Objects, which means physical-with-rights.

(iv) COCKPIT 4.0 BACKOFFICE CYBER-PHYSICAL RESOURCES | with-no-rights, which include cyber-physical means and therefore end up interacting though indirectly with the BIM operator, such as the main server, cognitive assistant algorithms, smart object generation algorithms, among others.

(v) CPS BODY 4.0 OS HUMAN RESOURCES | CPS 4.0 Body that interacts, repairs and controls all means of production and logistics of the CPS and thus, physical-with-rights resources, which include: equipment technicians for the quarry; equipment technicians in the stone processing factory; block production controllers; production controllers and optimization of stone slabs; controllers for textured surfaces; cutting and milling controllers; controllers of finishing processes; controllers of technical function processes; controllers of cleaning processes; process controllers for the packaging and palletizing of stone pieces; controllers of samples and prototype parts in stone; controllers of tests and quality assurance processes.

(vi) CPS BODY I4.0 CYBER-PHYSICAL RESOURCES | cyber-physical means that support the physical activity of CPS industry 4.0, physical-with-no-rights, which includes: quarry block systems; production systems and optimization of sawed raw materials, integrated in CPS; surface textured systems, integrated in CPS; cutting and milling systems integrated in CPS; finishing systems for stone pieces; systems of execution of technical functionalities, integrated in CPS systems of cleaning of pieces of stone; parts packaging systems, integrated in CPS; systems of execution of prototype parts and samples, integrated in CPS; test and quality control systems, integrated in CPS; warehouse for blocks, buffer intermediates of raw materials and parts in the process, integrated in CPS; logistic means for blocks, raw materials, parts and pallets and integrated in CPS.

(vii) SUPPORT PARTNERSHIPS RESOURCES | public or private entities outside the company, with which it collaborates on a permanent or occasional basis, and thus are not-physical-with-rights resources such as: local and national authorities; professional training centers; unions; stone federations; technological centers; acpmr; universities; exhibition centers; banks and credit entities; logistic companies; manpower outsourcing companies; catering companies; consulting companies; certification authorities; energy providers; raw materials suppliers; legacy outsourcing; insurance companies.

(viii) KNOW-HOW AND SHAREABLE INFORMATION RESOURCES | specific knowledge that can bring competitive advantages when the value-creation proposal is evaluated, such as patents, technology transfer, cross-fertilization projects, pilot projects, temporary innovation initiatives, among other resources, characterized as not-physical-with-no-rights.

(ix) SUPPORT TECHNOLOGY RESOURCES | technologies that although traditional are essential to the company's operation in both CBP and I4.0 operations mode, and thus, must be integrated in CPS, such as CRM server, accounting server, and other physical-with-no-rights resources.

(x) MANAGEMENT AND MARKETING | human resources related to the company's top management, so being people are physical-with-rights, including managing directors, legacy staff, accounting staff, marketing staff, among other resources.

5.7 RESOURCES ACTIVITY AND SYMBOL SYSTEMS IN DIFFERENT OPERATION CONTEXTS

According to the literature review, the formal use of Symbols and Symbol Systems as proposed by Service Science Theory (Akaka et al., 2014; Maglio & Spohrer, 2013; Newell, 1980) may guarantee a flow of co-creative communication among all resources, a concept that underlies the Inovstone4.0 Conceptual Framework. Therefore, for Inovstone4.0, it is by using the symbolic structure presented by the S-Bprint layout and the respective evaluation of Outcomes by ISPAR that it is intended to guarantee in the three types of operations described below, the success of the service exchange between OS-Customers and OS-Providers along the process.

On the other hand, for S-S, study of the co-operative interactions between service systems must start from the description of service systems - abstract concepts consisting of dynamic configurations of people, technologies, organizations and information (Breidbach & Maglio, 2016; Edvardsson & Tronvoll, 2013; Maglio et al., 2009; Matthies & D'Amato, 2016; Spohrer, Anderson, Pass, Ager, et al., 2008; S. L. Vargo & Lusch, 2010).

5.7.1 Operations Context OC1 | CBP-Providing in CAD-Procurement

Observing the resources of the CPMR-OS companies (the population to study), they are not very different from each other, varying only in size, a similar situation also being found in relation to the typical customer interface resources.

Based on the current activities of the Companies operating in CBP mode (CBP-OS-Provider), distribution of their resources in the service blueprint will be carried out in horizontal lanes, according to the format developed for this purpose (Appendix B).

Starting from the left side of the S-Bprint map, the description in each service process Step requires the manager to know the access rights to each of these resources, and so there will be four action lanes for both CAD-Customer and CBP-OS-Provider resources separated by dashed lines (Figure A.3, Appendix A).

As shown in Figure A.3 (Appendix A), (i) the "CAD-Customer Action Lane" represents the actions of the CAD-Customer entity and whose outcome-evidences will be described in the lane immediately above named "Evidences and Outcomes". The co-creative actions with the provider take place through the “Line of Interaction”; (ii) the "CBP-OS-Provider Operations Lane" represents the area where the activities in which the supplier's resources participate in value creation, involving the interface and production resources, separated by a continuous line, which means they do not interact with the CAD-Customer; (iii) finally, the "Support Actions CBP-OS-Provider Lane" is where the support resources are located and carry out their activities along the co-creative process. In this way, the CBP-OS-Provider resources are arranged in ten plans, framed by three main lines, the CAD-Customer interface lane being located above the supplier resource plans. The CBP-OS-Provider Front-Office (cyber and human) resources are in the plan immediately below the CAD-Customer plan, which means proximity between these resources of two different entities. Immediately below are located the engineering and production resources, designated "Back-Office CBP-OS-Provider & Controllers Resources".

For Inovstone4.0 the Supporting Resources made up of partnerships and specific know-how, such as patents, etc, are located immediately below the “Line of Internal Interaction”, as well as the Organization's Management. The existence of interactions presupposes that both service systems (CAD-Customer and CBP-OS-Provider) use common symbol-systems such as terminologies and compatible communication and information technologies (Akaka et al., 2014; Newell, 1980).

5.7.2 Operations Context OC2 | CBP-Providing in BIM-Procurement

In this case, the operations mode did not change in the Provider (CBP), so the OS-Provider resources remain the same, as for case 1, so once the CBP-OS-Provider becomes available to provide stone to a BIM-Customer, both stakeholders become a service system, according to Service Science Theory. In BIM procurement mode but keeping the current operations production mode (CBP), the resource framing must be carried out in such a way that it becomes possible to map the activities of these resources along the service process, involving the BIM-Customer on the one hand and CBP-OS-Provider on the other.

To map the process in these market conditions (buying & selling) through the S-Bprint tool, the "BIM-Customer Action Lane" must represent the actions of the BIM-Customer, whose outcome-evidences must be placed in a lane immediately above, designated "Evidences/Outcomes" and the co-creative interactions flow with the CBP-OS-Provider crossing the “Line of Interaction”. In these market conditions, the "CBP-OS-Provider Operations Lane" will continue to represent the area where the main activities of the supplier's resources are located, which covers all the interface and production resources and where the means of production are found, separated by a continuous line, which means they do not interact at all with the BIM-Customer and the "Support Actions CBP-OS-Provider Lane" containing the support resources and their activities throughout the service process. In this way, the CBP mode provider resources will continue to be arranged in 10 plans, framed by 3 main lines, with the BIM-Customer interface feature above the CBP-OS-Provider resource plans and the "Support Actions CBP-OS-Provider Lane" plan containing the support resources and activities along the service process. Thus, in this business mode, the CBP-OS-Provider resources will continue to be arranged in ten layers, framed by three main lines, the BIM-Customer interface resources being located above all the CBP-OS-Provider layers.

5.7.3 Operations Context OC3 | I4.0-Providing in BIM-Procurement

As mentioned above, Inovstone4.0 introduces a new concept in the OS companies operating in I4.0 mode, with FP-I4.0 becoming the vehicle that transports the descriptive component of the object the customer intends to receive, but also the code component in IFC format. It is from FP-I4.0 that the Cyber-Physical System generates Smart Objects, essential elements to operate in I4.0 mode (Heidari et al., 2014). In the same connection, for Inovstone4.0, Cockpit as previously defined, operates as the entity of dialogue and interaction during the service process, that is, from the beginning of the customer-provider relationship till product recycling at the end of its life.

In functional terms, before the value proposition is accepted by the customer, the Cockpit generates FP-I4.0 making it available to the BIM-Operator, including the specifications and concepts co-created as well as additional information related to the product dimensions such as the ecological footprint, the final recycling process, legal aspects and other information relevant to the BIM-Customer.

Using the S-Bprint tool (Figure A.5, Appendix A), in which four lanes are defined to separate the BIM-Customer and I.40-OS-Provider resources, the arrangement of the I.40-OS-Provider resources in S-Bprint will be in horizontal lanes from the left of the S-Bprint and the description at each Step of their involvement requires knowledge of the access rights to each resource. The "BIM-Customer Action Lane" lane represents the actions of the BIM-Customer, whose evidence will be described in a lane immediately above, called "Cyber-physical Evidences", and co-operation with the provider, represented by the "Line of Cyber Interaction ".The "CPS Cockpit Actions Lane" represents the area where the Cockpit is located, and the activities in which this resource participates in the form of value creation exceed the limits of this lane, as represented by the "Cyber-Physical Interaction Area " (Figure A.5, Appendix A). The plan represented under the heading "CPS I4.0 OS Body Actions Lane" is the area of action of the CPS I4.0 OS Body resources, within which the means of production, among others, are separated by discontinuous lines, which means that it interacts remotely in full vertical, even with the BIM-Customer if necessary.

The "Support Actions I4.0 OS Lane" is where Support Resources carry out their activities in the service process, once again separated by discontinuous main lines, with some secondary dashed lines between them (Figure A.5, Appendix A). The secondary line, "Cockpit Front Line", separates inside the Cockpit human resources from technical resources. The BIM-Customer interface must be separated by a virtual secondary line from the Technical Human Resources of the Cockpit with which the client does not interact directly, as is the case of the technical experts involved in the transformation of FP-I4.0 into Smart Objects. Also, the secondary line "Control Industry 4.0 OS Line" separates the Supporting Resources belonging to subcontracted entities from the organization's Management Support Resources.

Therefore, at the top of the S-Bprinting map along the 36 main stages of the service process, there are the Cyber or Physical Evidences or just the Outcomes resulting from the co-operative actions between the Customer represented in the lane immediately below and the OS-Provider, represented by the "Stone Provider OS Interaction Area" lane. The Human and Cyber Resources of the CPS Cockpit OS Front-Office make up the lane immediately below the BIM-Customer lane, which means proximity to the BIM-

Customer resources. Immediately below will be located the human and Cyber-Physical resources of the CPS Cockpit OS Back-Office immediately followed by the human resources and Cyber-Physical lanes related to the CPS I4.0 BODY, that is, of the means of production.

In I4.0 operations mode, support resources formed of Partnerships and Specific Know-How (patents etc.), while maintaining support resource status, are also part of the CPS's own resources, so in S-Bprint mapping, these resources must be located immediately below the "CPS I4.0 OS Line", at the bottom of the map as if they were supervising the entire service process, where the Organization’s Management is located.

5.8 CHAPTER SYNTHESIS

Supported by Service Science Theory and using the Convergent Parallel Mixed Method, in this chapter it has been conceptualized the Inov4.0|F, to be applied to a representative sample of CPMR-OS Companies in three different scenarios. From this it is intended to draw relative conclusions in terms of Innovation Outcomes, and from these, evaluate the impact of I4.0 on companies’ response to the threats resulting from BIM procurement in the AECSC.

From the above, it may be considered that the layout of the O Provider Resources in CBP Operations mode on S-Bprint maps (Figure A.3, Appendix A) is a particular case, more restrictive in terms of the co-operative options, of operations in mode I4.0 (Figure A.5, Appendix A). This means that the blueprint for the operations’ lay-out in CBP mode ends up being contained in the layout of the I4.0 operations mode. In I4.0, the resources of the I4.0-OS-Provider are also arranged in ten horizontal lanes, framed by three main lines and two secondary lines. All the lines (main or secondary) must be discontinuous, which means they do not block the service process co-creation from the bottom provider resources vertically, to the top Customer Resources, this being the main difference between the CBP and the I4.0 layouts.

Thus, Inov4.0|F was conceptualized considering that it will use the symbolic structure inherent to the S-Bprint as adapted for this research, that the service exchange between the OS-Customer and the OS-Provider along the process will be successful. This understanding is in line with the conclusions drawn from the literature review, where the

S-S perspective proposes the formal use of Symbols and Symbol Systems as one of the pillars of value co-creation between service systems and one of its four principles.

Once brought to the practical field of Portuguese OS Company business, and as mentioned in Chapter 2, Portugal is considered a producer of excellence in stone products, more than ever before the acceptance of these products into the Supply Chain of the Construction Industry will depend on the willingness, knowledge and interest of the BIM operator's architects, so the coordination of all these meanings and Symbols during the value creation process is increasingly essential. Thus, the adoption of specific normative practices in the context of BIM procurement for Portuguese OS Companies may even be vital. Dimensions such as Sustainability (6D-BIM), where RO are in fact more environmentally friendly products than other competing products used in ICSC, such as cement, must be commercially exploited in a coordinated way, keeping records of origin, as a means of ensuring credibility and growth in the demand for stone in the context of BIM procurement at AECSC.

The framework described in this chapter includes its implementation methodology and basic concepts without which it must not be used or else the results obtained may not be considered reliable. At the basis of these concepts is the fact that the co-creative process must be built on the good faith of the OS-Customers and OS-Provider resources, because for S-S value only exists if it is for the benefit of both the entities these resources represent (Maglio et al., 2009). This process implies, from the outset, the sharing of expectations of interaction and the mutual wish for innovation during the value propositions by using simulations, executing pre-prototypes and tests and other activities that guarantee the success of the service innovation until the products are recycled.

CHAPTER 6

Science is simply common sense at its best, that is, rigidly accurate in observation, and merciless to fallacy in logic.

Thomas Henry Huxley

6. INOVSTONE4.0 FRAMEWORK APPLICATION

By using the Pragmatist Worldview guidelines and Parallel Convergent Mixed Methodology supported by Service Science Theory, the purpose of this Chapter is to apply the Inov4.0|F, as conceptualized in Chapter 5, to a sample of OS companies, members of the CPMR.

6.1 SAMPLE DESCRIPTION

Given the specificity of this study and as proposed in the Methodology Chapter, the sample must be of convenience. The companies must be selected intentionally from the population of OS companies, members of the CPMR, since the orders to use in this study must be real and the data observed in real time as the resources of the stakeholders involved co-create value throughout the service process.

In this context, the first selection criterion for a company to belong to the sample is being an OS company, member of the CPMR, as the second selection criterion, the negotiation, execution and delivery of orders must be achievable within the period for carrying out this research, as the third selection criterion, there must be similarity of the orders to follow up, so that it is possible to use the average value of the data collected from the different orders. After a first screening, it became necessary to add more selection conditions. For the strict purposes of this research, the companies must allow the researcher access to their analytical and accounting data, customer names related to the orders followed, management systems and fiscal accounting, among other confidential matters. As a final selection criterion, orders were sought where it was possible to identify other potential providers involved, that is, competitors of the main provider and from whom the data might be collected. This was a very hard task, involving several trips to the countries where these competitors have their head offices.

Constitution of the sample was therefore complex, only possible with the collaboration of all CPMR companies, with which there was always a permanent constructive dialogue for more than two years. Finding similar orders in terms of raw material, surface finish, typology and functionalities, so that the only difference was in size in terms of the m2 provided, was the way to ensure that the evolution of $KCI_{QUAL\text{-}j\text{-}k\text{-}i}$ and $KCI_{QUAN\text{-}j\text{-}k\text{-}i}$, could result in comparable $IO_{QUAL\text{-}j\text{-}k\text{-}i}$ and $IO_{QUAN\text{-}j\text{-}k\text{-}i}$.

The sample consisted of 31% of the CPMR-OS Companies, which is the population to study, these companies being directly involved in the negotiation, production and delivery of the case orders studied. For each of the orders in CAD-Procurement mode as well as for each one evaluated in BIM-Procurement mode, the SOs were observed and the qualitative and quantitative data collected in all steps of the ten service processes, before March 2017.

As the orders were placed by international customers, it was necessary to make several trips to collect the data from the customers and competitors[79], from the customer's intention to buy until the product's application on site. All the orders studied were related to cut-to-size ventilated facade, in *moleanos*[80] limestone, 30mm thick and with a *fischer*[81] anchoring system, each order being destined to a different customer.

6.2 DATA COLLECTION | CBP-PROVIDING IN CAD-PROCUREMENT (OC1)

For the data collection in CBP-Providing in CAD-Procurement (OC1), the monitoring of each order was carried out in a different company, within the sample, from the negotiation Step where the customer introduced the CAD project and production in CBP operations until the products are delivered to the right customer.

As mentioned above, for all data to be comparable, all orders were executed in the same stone type, with the same thickness, finishing and anchoring system (Table 6.1).

[79] For each monitored order, at least one competitor was identified and evaluated.
[80] "Moleanos" is the name by which a compact limestone is also known and with two distinct colour areas - cream and grey - consisting of darker grains and fossils of small to medium size. Due to its versatility and hardness, it is suitable for façades, masonry and floors subject to heavy traffic.
[81] Concealed fixing by means of anchoring holes

Context 1 | CBP-OPERATIONS IN CAD-PROCUREMENT								
Providers	Customers	Competitors	Stone Type	Thickness (mm)	Average Area per unit (m2)	Anchoring type	Order size (m2)	Quantity Unities
A	I	X	Moleanos	30	0,36	Fischer	331	919
B	II	Y	Moleanos	30	0,56	Fischer	224	400
C	III	Z	Moleanos	30	0,25	Fischer	197	788
D	IV	U	Moleanos	30	0,25	Fischer	298	1192
E	V	V	Moleanos	30	0,36	Fischer	328	911
Average				30	0,356		275,6	842

Table 6.1: List of orders monitored in Operations Context 1 CBP-Providing in CAD-Procurement (OC1)

What differs from one order to another is size, so that in all the five orders executed in each operation context (OC), the absolute values observed and measured have been converted into relative values (per net unit area), allowing us to work in terms of the average value of the five orders. Thus, all values shown in every table of this Chapter, regardless of the context of operations, will represent the average value collected in the five orders, and consequently, also the respective SOs, KCIs and IOs will reflect the average value of the five orders in each context. After mapping the CBP-Provider resources through the S-Bprint in different interaction lanes as defined in Chapter 5, the activities of these resources were mapped along the service process, executed simultaneously with the data collection resulting from value interactions. In S-Bprint maps, access to resources will be referenced by unidirectional or bidirectional arrows and their activities by rectangles (Appendix A). During the orders' execution in OC1, at each Step of the service process SO evaluation was carried out by the ISPAR.

As conceptualized in Chapter 5 and detailed (Appendix A), application of Inov4.0|F assumes that the service process is sub-divided into 36 main steps. In the steps where the SO resulting from interactions has not been normative[82], there is a need to innovate in this step, and thus, the process returns to previous steps and can even definitely stop the service process or lead to disputes, a situation, however, not verified in the OC1 under analysis.

6.2.1 Operations Context OC1 | Phase 1 (Steps 1 to 9)

We began the process of data collection in the context of CBP-Providing and CAD-Procurement (OC1), in the first nine steps of the service process. The service process started in the orders under analysis with the "CAD-Workstation Project-Drawing" action

[82] service outcomes (SO) that interrupt the normal flow of the service process are considered non-normative

(Step 1), which represents architects or designers operating their CAD workstation, connected to the Internet and searching for stone suppliers in the “Searches-On-The-Web-For-Stone-Providers” action, looking for stone products for their projects (Step 2), (Figure C.1, Appendix C). In these first two steps, CBP-OS-Providers’ proposals were limited to traditional web-promotion actions which were therefore not related to the CAD operators’ intention to purchase.

In Step 3, the "Stone Types and Providers Pre-selection" actions of the CAD operators mean they have stone product web-sites from which they have obtained pdf catalogues automatically, generating a normative SO[83] in all cases studied. The electronic catalogues contained photos of previous work done by these OS-Providers, which apparently led to CAD-Customers trusting them (Provider Brand Reputation = U), and being happy (Satisfaction = U). Based on the satisfaction generated from the catalogues, the CAD-Customers requested material samples of different stone and with different types of finishes by email (Step 4), to which some of the CBP-Providers typically responded with delivery times between two and three weeks. After some exchanges of emails and phone calls, all the CBP-Providers agreed to produce and send the samples within two weeks.

In this fourth stage, several customers were worried about the time to wait for the samples (Time to Receive the Product = U^D), but also happy with the CBP-Providers’ effort (Satisfaction = U). In some cases (three of the five cases) customers did not have to pay for the samples, which they greatly appreciated (Product Total Cost = U), but they were worried about the safety level of the Fischer anchoring system in a limestone ventilated facade (Product Safety = U ^ D). In turn, some of the CBP-Providers expressed concerns about the short delivery time customers might demand if they placed the order (Time to Deliver the Product = U^D) and the aspect of anchoring safety left them apprehensive (Product Safety = U^D). From the questions asked to competitors[84] using the questionnaire guidelines, it was possible to deduce that customers were transmitting a negative feeling about the ability to comply with the delivery time, and it was therefore felt that customers were not fully happy with the CBP-Providers (Customer Satisfaction = U ^ D). The transition from Step 4 to Step 5 resulted in CAD-Customers appreciating the catalogues and samples provided by the CBP-OS-Provider, which resulted in a normative outcome in all cases, i.e. CAD-Customers appreciated the catalogues and

[83]The service process has flowed to the next step
[84] OS-Competitor questionnaire guidelines

samples, generating SO="S" by ISPAR. If the evaluations had been negative, the SO generated would have been "-S" as described in Chapter 4. However, in the case of SO="-S", it would certainly not have been due to CBP-OS-Providers' technical incapacity, but rather to CAD-Customers' personal options.

In Step 3, O="S" was the outcome in all cases monitored, the CAD-Customers performing the "Stone Samples Requesting Request" (Step 4) by email, thus creating a lead in the CRM server (Figure C.1, Appendix C). Once the stone samples were received, the CAD-Customers began a sequence of email exchanges, phone calls and even some meetings in the case of two of the sample companies, in order to discuss and evaluate the different types of finishing and raw materials, in the "Surface discussion / Final Samples Request" action (Step 5). It was observed from the registered documentation that in all cases the fees relating to the accounting value of the samples (Taxes and Fines Applications = U) were also paid and that in the documentation required by the transporters, which was filed by the shipping companies, suppliers state that the products shipped were legal and (product legal = U) non-hazardous (Moral Hazard Compliance = U) and therefore could be transported and handled by people (Transport and handling Compliance = U). In this step, CAD-Customers positively appreciated the CBP-OS-Providers' attitude in terms of after-sales warranty, but when asked if the homogeneity of raw materials could be guaranteed, all the Providers reported that it would not be possible since they were natural materials and variations can occur in texture and colour. This defensive explanation given by all the CBP-OS-Providers in the sample raised some concerns (Provider Contract Compliance = U^D) and thus results in (Satisfaction = U^D). Almost all the CBP-OS-Providers in the sample were concerned about these customers' concerns related to the material's non-homogeneity (Customer Contract Compliance = U^D), since they could make complaints in the future, once the products were on site (Customer Satisfaction = D). These CBP-OS-Provider concerns were reflected in the moralizing of some of the observed competitors, thus obtaining (Customer Satisfaction = U^D). But with all being kept, (SO = S), the process evolved to the "CAD Operator Draw Pieces Geometries (2D)" action (Step 6), in which the CAD operators drew the parts one by one, a hard task, and then sent them in vectorized format by email to the CBP-OS-Providers, in the "Project Outline including pieces 2D Geometries" action (Step 7). In Step 7 the "Project Outline including Units 2D Geometries" action, there were once again endless sequences of emails and phone calls between the CAD-Customers and the CBP-OS-Providers in the sample, mainly about the problem of product homogeneity (Product Quality = U^D), as well as aspects related to safety and the anchoring type in limestone (Product Safety = U ^ D). As a result, some of the CBP-OS-Providers raised concerns regarding contract compliance (Contract Compliance U^D), which is apparently too rigid regarding the materials' homogeneity, a situation that was appreciated positively by the competitors. The Fisher anchoring system was also much discussed by the different actors, raising concerns from the customers regarding safety, which also resulted in a provider concern (Product Safety = U^D). All the CBP-OS-Providers involved always showed great openness in terms of flexibility, which was appreciated by customers (Product Safety U ^ D) and disappointed the competitors (Innovative Product = U). The definition of thickness was introduced (Step 8) in the "Thickness Definition" action, by emails and telephone calls, followed by definition of the technical functionalities of the Fisher fixation parts in the "Functionalities Definition" action (Step 9). Still in Step 8, many conversations and email exchanges took place, including technical visits in some of the orders monitored, which left some customers less than pleased (Satisfaction = U ^ D) again due to the homogeneity of raw materials (Product Quality = U^D) and safety (Product Safety = U ^ D) but they were very positive in relation to the providers' flexibility (Production Flexibility = U). The sustainability issue addressed by some of the sample clients left concerns in some of the providers (Sustainability = U^D), especially because it could be exploited by competitors (Product Recyclable = U^D). The same was true in terms of maintenance costs (Maintenance Costs = U^D). Some suppliers showed the facades in a virtual form, which became a concern for the competitors (Innovative Product = U^D). Using the drawings of the pieces in vector format, a new sequence of emails and telephone calls started to define the functionalities in each of the pieces, in the "functionalities definition" action (Step 9).

In Step 9, customers' concerns were varied. These included safety concerns related to the anchoring system (Product Safety = U^D), the reliability of the Fisher system (Product Reliability = U^D), the after sales response = D), the warranty (Warranty Period = U ^ D) and even in some cases, customers had concerns about the supplier's ability to comply with the contract (Contract Compliance = U^D). This Step took a long time (16 days was the mean value of the monitored cases), which significantly delayed delivery in all cases, involving clients on average in about 30 hours of their own work. The competitors involved in the case studies were generally pessimistic on moving to Step 9, as shown in the map of observations, where practically all the indicators show a "U" value, the success of the value propositions leaning more to the CPMR-OS- Provider side than to the competitor.

It has been concluded data collection in the first nine steps of the service process. The observations and measurements shown in Table D.1 (Appendix D) are related to the CAD-Customers' Concerns; the observations and measurements shown in Table D.2, (Appendix D) are related to the CBP-OS-Providers' Concerns; the observations shown in Table D.3 (Appendix D) are related to OS-Competitors' Concerns and the observations shown in Table D.4 (Appendix D) are related to the Authorities' Concerns.

6.2.2 Operations Context OC1 | Phase 1 (Steps 10 to 18)

Step 10 begins with the "Drawing pieces Functionalities One by One" action (Figure C.2, Appendix C), an operation that required working piece-by-piece interactively in CAD, a task that on average for the five CAD-Customers resulted in eighteen hours of work by the CAD operators and on average three days spent on the service process. Therefore, the CAD-Customers were not happy, as they believed this task should be done by the provider resources, (Customer Satisfaction=D), and expressed concerns about the impact on the product delivery due to the time spent on this step, (Time to Receive the Product = D). Likewise, CBP-OS-Providers showed serious concerns about (Time to Deliver the Product=D) and their reputation spread by the competitors (Customer Satisfaction=D), because some competitors gracefully agreed to carry out development of the technical functionalities in the pieces in CAD (Brand Reputation=D).

Represented by the "Complete Specifications for Quotation" action (Step 11), the specifications of the additional requirements of the facade parts were described, resulting in a new exchange of emails and telephone calls between CAD-Customers and the CBP-OS-Providers, regarding additional clarifications of the requirements, an action represented as "Technical Details Discussion" (Step 12). During steps 11 and 12, there were many exchanges of emails and telephone calls between customers and suppliers to clarify specifications. These tasks required on average eleven hours of direct involvement by CAD-Customer human resources and thirteen hours' average involvement by CBP-OS-Providers human resources. Some customers raised concerns about products' sustainability (Product Sustainability = U ^ D), their homogeneity (Product Quality = U ^ D) and delivery time (Time to Receive the Product = D), which would lead, in their view, to suppliers not complying with contracts (Contract Compliance = U^D). One of the competitors contacted one of the customers, arguing that the supplier would not be able to provide the product according to the required quality (Provider Contract Compliance = D).

Now begins the first crucial Step for the success of the co-creation interaction - discussion of delivery times “Delivery Time Discussion” (Step 13). In this step, as shown in (Figure C.2, Appendix C), a lot of Provider resources were involved, particularly their production departments, in order to find the right propositions in terms of delivery time as required or requested by the customers. For customers, delivery time concerns (Delivery Time = U ^ D) are also related to the quality suppliers can guarantee (Quality = U^D), thus fulfilling the contracts (Provider Contract Compliance = U^D) to be established. Two of the suppliers accepted penalty clauses in the case of non-compliance, which allayed some customers' concerns (Satisfaction = U^D) related to this issue. Step 13 took four days, involving clients’ human resources for fifteen hours on average, and suppliers’ resources for nineteen hours. Competitors were also active at this stage, putting pressure on customers by telling them the suppliers would not meet the deadlines (Provider Contract Compliance = U^D) and claiming they would not meet the contracted quality.

Especially from the commercial point of view, the "Reads Technical & Commercial Proposal" action (Step 14) continued the sequence of decisive steps in the service process, since it might be in this Step that customers would select the provider, whether in favour of the CPMR-OS-Providers or the Competitors, thus verifying (SO = P)[85] in Step 13. At this stage, CBP-OS-Providers' concerns focused on the positive aspect of their production flexibility (Provider Flexibility = U), while the cost of purchase (Purchasing Price = D) and transport (Product Total Cost = D), as well as the deadline, did not satisfy the customers, who generally expressed dissatisfaction (Satisfaction = D), an outcome that in some cases seemed to be a commercial bluff to lower the price and speed up the delivery time. This was followed by the "Commercial Discussion for Final Offer" action (Step 15), involving once again many emails, phone calls and visits to four of the sample companies. The final proposals were sent in the "Reads Technical & Commercial Final Proposal" action (Step 16), in which the CBP-OS-Providers mobilized their top resources to ensure

[85]Outcome ISPAR (P) stands for "Proposal Communicate"; (-P) stands for "Proposal Not Communicated"

the best possible value propositions, so as to result in final acceptance of the proposals by the CAD-Customers.

Steps 14, 15 and 16, involved the human resources of CAD-Customers on average for twenty-four hours for twelve days, while on the CBP-OS-Provider side, their human resources were involved, on average, twenty-three hours. Arriving at Step 16 of the service process, because of their business experience, all CBP-OS-Providers had already realized that CAD-Customers were seriously interested in closing deals, but felt they would only place orders if given an additional discount together with a written commitment to delivery time. In order to overcome this situation, the proposals were reviewed in terms of delivery time and price (Purchasing Price = D), but it became necessary for all Providers to accept penalties if the contracts (Contract Compliance = D) were not complied with concerning delivery time (Delivery Time = D). In these decisive steps, OS-Competitors were once again very active, particularly raising concerns related to lead time (Delivery Time = D) and quality of products contracted (Quality=D). This lack of confidence motivated three of the CAD-Customers to come to the CBP-OS-Providers' factories to evaluate the manufacturing resources, where they were reassured by the world-class level of the factories and quarries (Innovative Manufacturing Processed = U) and the products (Innovative Products = U).

After all diligences from the provider side, in the "Proposal Acceptance" action (Step 17) CAD-Customers would decide to accept the value proposition or not. When customers accepted the value propositions (Step 17), CRM[86] classified the "opportunity" as a "win-opportunity" and the ISPAR Outcome in all companies studied in the sample was SO = A[87], meaning that CAD-Customers accepted the proposals, and so the process went to Step 18. It must be said that if the ISPAR Outcome in any of the cases studied had been (SO = - A), CRM would have recorded it as a "lost-opportunity." The actions in steps 17 and 18, "Proposal Acceptation and Payment", involved suppliers' human resources for thirteen hours on average, with twenty days elapsing, while on the provider side, human resources were involved, on average, for seven hours. Even after accepting the order, customers remained concerned about the delivery time (Time to Receive the Product U^D), products' ecological footprint (Product Sustainability = U^D), homogeneity of raw materials (Product Quality = U^D), supplier compliance (Provider Contract Compliance

[86] Customer Relation Management
[87] ISPAR Step Outcome (A) "Agreement"; (-A) Agreement not Reached

= U^D), and raised concerns related to cost and transport costs (Product Total Cost = U^D).

Even though it is not part of the data collection process, it must be mentioned that although in the cases studied all the proposals were accepted by the clients, it was found that during the period in which has been monitored these five orders, many other proposals under discussion in the same companies were not accepted by customers due to the manual process of generating specifications and demonstrating the value of products. In a few cases, it was found that customers opted for more standardized products such as ceramic materials or others, because for them (customers), these kinds of materials involved less risk regarding heterogeneity, less time and travel expenses, and fewer resources involved during the purchase stage.

Coming back to the case studies, all the orders monitored resulted in (SO = A) in Step 17, and so the service process went to Step 18 in which CAD-Customers made payment in the "Makes the Payment" action (Figure C.2, Appendix C), thus finishing phase 1 of the service process with success in all cases. During these steps, data collection related to steps 9-18 in OC1 operations mode was concluded successfully, directly from the observations and measurements related to the five CAD-Customer Concerns as shown in Table D.5 (Appendix D), the five CBP-OS-Provider Concerns (Table D.6, Appendix D), the OS-Competitor Concerns (Table D.7, Appendix D) and the Authorities Concerns (Table D.7, Appendix D). With the down payment made by CAD-Customers, the respective legal fees were executed by AT[88], and there was written commitment in the contracts that all supplies would comply with the strict labour, environmental, tax and environmental laws (Official Compliance = U).

6.2.3 Operations Context OC1 | Phase 2 (Steps 19 to 27)

Phase 2 is related to "Order Execution", that is, the availability of suppliers to execute the products co-created with CAD-Customers. It is a phase in which the most involved stakeholder is naturally the supplier, customers being responsible for monitoring operations, conducting production inspections as they wish. It is the authorities' responsibility to supervise the conformity of the suppliers in terms of production means, legal labour regulations, etc.

---

[88] Portuguese Tax Authority

From the observations on the shop-floor, Step 19 (Figure C.2, Appendix C) corresponded to preparation of the raw material blocks, taking 15 days on average, since the blocks of raw material in stock were not of the quality required for these orders. During this period, operations could be followed up by the customers in the "Tracking By Email Phone or Local Visits" action, as well as in Step 20, which represents the blocks being transformed into slabs, an operation taking six days on average, when customers remained happy (Satisfaction = U) but with concerns regarding the time spent on this Step (Time to Receive the Product = D) and its impact on the delivery date. In Step 20, the gang saws were occupied for 21 hours on average, consuming an average of 2187KWh, plus 6 hours of manpower.

All these orders required flaming[89] texturing. The "Flaming" action represents the full flaming of the sheets, which was accompanied by e-mail and telephone. In this stage, which took an average of 14 days, the flaming machines were occupied for 63 hours, consuming on average 688KWh of electricity and 88m^3 of propane gas, with average set-up times of 22 hours plus 19 hours of logistics and 119 hours of human resource occupation on average. Concerns were raised from providers and customers in terms of compliance (Time to deliver the Product = D) and thus compliance with the contract (Contract Compliance = D) began to be an interesting issue for the competitors.

The textured slabs were then transported to the cutting machines, where the operators began to perform the operation of "Nesting Vectorized Images of Optimized Slabs", after which they performed the cutting. In Step 24, the CBP production systems in the CPMR-OS-Providers in the sample had been developed in co-promotion in the Mobilizing Projects already mentioned in Chapter 2, technologies that already optimize the textured raw materials as the "Slabs Yield Checked After Cut" action, followed by their automatic registration on the servers, in the "Photos of Pieces Cut and Milled" action (Step 25) for further tracking or report checking.

In steps 24 and 25, Customer Concerns dropped substantially as they were able to see the photos used from the servers for the first time and that the cutting operations were performed fairly quickly, these tasks being performed in just 5 days. Mainly because of raw material failures and the 7 logistical operations, there was still an average waste of 94 m^2 in this operation. During the cutting process, average energy consumption was

[89]Surface textured process executed by a gas flame torch, directly on the surface of the stone

730KWh for an average effective operating time of 37 hours, with an average of 4 hours for set-up and 7 hours for logistic operations.

In Step 26, representing the Pieces Functionalities actions, the functional mechanization execution centres make the necessary holes for anchoring the parts and texture some of the visible tops, from the programs previously elaborated by the companies' engineering, in piece-by-piece mode (Figure C.3, Appendix C). This task, although executed in 36 hours and consuming 425KWh, with 12 hours of set-up and 15 hours of logistics, took 14 days to be completed due to production balancing problems and specialized manual operations for which not enough human resources were available. At this stage, average raw material waste of $33m^2$ was found due mainly to incidents during the 8 necessary logistics operations. Once the parts were executed, it was necessary to wait for the parts to dry before being packed. However, in the cases monitored, pressure was observed at this Step of the process to ensure that the products were delivered to the customer as soon as possible, because in all cases the contract deadlines had already been exceeded, as well as the costs. This pressure to ship products to customers as soon as possible because of the penalties for delay meant the average drying time was 4 days less than it should be, which will probably originate problems in the final quality of the products, since the final texture cannot be checked properly when surfaces are wet.

Even under pressure to deliver the products, in Step 27, the CBP-OS-Providers took on average 66 hours for packaging, 26 hours of set-up and 20 hours of logistics, plus 5 hours of labour. For customers, concerns were all "on the rise" at the end of Phase 2. The product had been packaged moist and ready to ship, the deadline had expired and all other parameters were a mystery that could only be checked after the material arrived at the site. For all CBP-OS-Providers it became clear they would have to pay penalties to the customers, but worse than that was the anxiety about the customer's evaluation of their products when they arrived at the site. For the competitors, there was still an expectation that things would be unsatisfactory for customers, as this would increase the probability of their own success in the next order, whereas for the authorities, non-conformities had so far been verified concerning transport, security and taxes. With the end of Step 27, corresponding to the "Packing Execution" action, Phase 2 of the service process finished, related to execution of the orders, and the ISPAR Outcome also finished, resulting in (SO = A) for all cases monitored until this Step (Figure C.2, Appendix C). Thereby, Phase 2 was successfully completed, as was data collection related to the sequence of steps 19-27 in OC1 Operations Mode.

During these Steps, the data collection related to steps 19-27 in OC1 operations mode was concluded successfully, directly from the observations and measurements related to the five CAD-Customer Concerns (Table D.9, Appendix D), the five CBP-OS-Provider Concerns (Table D.10, Appendix D), the OS-Competitor Concerns (Table D.11, Appendix D) and the Authorities Concerns (Table D.12, Appendix D).

6.2.4 Operations Context OC1 | Phase 3 (Steps 28 to 36)

Phase 3 is related to "Shipping, Using & Recycling" operations, which for CBP-OS-Providers means the ability to deliver the products in stone to the CAD-Customer (Figure C.4, Appendix C). Step 28 represents the "Transport to Building Site" action, related to transporting the goods to the customer, which took on average 3 days. It was also observed that the Providers do not have an on-line transport tracking system. Once the products arrived at the building sites, the customers received the pallets (Step 29), followed by one of the most important steps of the process, that is, the "Quality Checking" action (Step 30).

In Step 29, it took several hours to unload the material at the site, and customers generally expressed displeasure because of the delay in delivery, as in all cases this meant alteration of the building plan and negotiating with the different building specialities involved in the construction.

In Step 30, which the researcher witnessed physically in all the cases monitored, customers began by opening the pallets one by one and placing the material on the ground in a dry-laying manner to physically evaluate the products in terms of homogeneity, dimensions and technical qualities, to report their opinions on these quality-related parameters to the Provider. The parts considered as having quality issues were rejected there, these being Steps ISPAR Outcome (SO = R), with the statement from the CBP-OS-Providers that they would replace all the rejected units, or else the CAD-Customers would not allow the process to go to Step 31. Even so, the average amount of rejected parts was found to be $25m^2$, involving 12 hours of work by the customer and 2 days of waiting to be installed on the site. Meanwhile, (Time to Receive the Product = D) remained in "Down", and concerning quality level, although the first impact was negative in all the cases witnessed, with the replacement of low-quality pieces customers became happy in terms of quality. The remaining feelings of CAD-Customers were found to be mixed and without consensus, with practically all concerns resulting in (D^U).

Fortunately for CBP-OS-Providers, despite several (SO = - R), because of rejected parts, no case monitored went to dispute, since the prompt action of the Providers in replacing rejected parts and paying all costs avoided this unpleasant situation. In two cases, however, the replacement parts had to be transported by air with the costs fully charged to CBP-OS-Providers. In the absence of any dispute, the process evolved into the "Installation Instructions Requesting" action (Step 31), when the customer requested by phone and email several clarifications regarding installation of the goods provided, as well as in steps 32 and 33, regarding handling and product installation on site. As in Step 33, it was not possible to collect data, since these steps represent use of the products until the end of the life-cycle. In the opinion of some architects, whenever there is a need to replace a stone part (Step 35), it creates a huge problem and also according to these customers resources (the architects), the typical process of demolishing buildings (Step 36) so far does not involve the material providers, or even the architects themselves. During data collection, it was possible to observe from the accounting data provided by the companies that all the CBP-OS-Providers were in a satisfactory financial situation, had fulfilled their fiscal commitments and had order portfolios that allowed them to face the coming years with optimism.

In this way, service process analyses were concluded in CBP-Providing in the CAD-Procurement Context (OC1) and this was also the end of data collection for this research, in all cases the ISPAR Outcome being (SO = A), (Figure C.3, Appendix C). During these steps, the data collection related to steps 28-36 in OC1 operations mode was concluded successfully and the observations and measurements related to the five CAD-Customer Concerns (Table D.13, Appendix D), the five CBP-OS-Provider Concerns (Table D.14, Appendix D), the OS-Competitor Concerns (Table D.15, Appendix D) and the Authorities (Table D.16, Appendix D).

By applying Inov4.0|F to the CBP-Providing in CAD-Procurement Context (OC1), the service blueprint maps (Figures 6.1, 6.2, 6.3 and 6.4) show that the service process flows naturally, from the first to the last step. In fact, if the result were different, the applicability of Inov4.0|F itself would be questionable, as this is the current "modus operandi" of the CPMR-OS Companies. It was also found (Tables d.1 to 6.16) that application of the

Inov4.0|F allowed successful collection of the qualitative and quantitative data, with which the KCI_{QUAL_k} and KCI_{QUAL_k} related to the concerns of the stakeholders (k) in OC1 as defined in Chapter 5 must be computed.

6.3 DATA COLLECTION: CBP-PROVIDING IN BIM-PROCUREMENT (OC2)

In CBP-Providing in BIM-Procurement operation mode (OC2) the supplier companies (CBP-OS-Providers) will be the same as in OC1. However, as the orders to be studied are new, the customers will be different, because in this case it was necessary to ensure that the customer was a BIM user instead of a CAD user, and thus become a BIM-Customer.

Searching for similar orders in the sample OS companies was the way to ensure the results could be comparable. The orders found in OC2 were placed by international clients and as in OC1 cut-to-size facade, using *moleanos* limestone of 30mm thickness, *Fischer* anchoring and for different clients. Also in OC2, the only difference between orders was the size of the area to be covered in stone (Table 6.2), with the only differentiating factor in case studies in BIM-Procurement mode being the size of the order, and so by reducing to specific values (per unit area), the resulting KCIs are independent of the size of the order. In BIM procurement mode, BIM-Customer resources are different from CAD-Customer resources, so the actions and evidence at each Step of value interaction with the Provider are necessarily different.

Context 2 & 3 | CBP-OPERATIONS IN BIM-PROCUREMENT								
Providers	Customers	Competitors	Stone Type	Thickness (mm)	Average Area per unit (m2)	Anchoring type	Order size (m2)	Quantity Unities
B	1	K	Moleanos	30	0,36	Fischer	12	33
A	2	L	Moleanos	30	0,264	Fischer	8	30
B	3	M	Moleanos	30	0,36	Fischer	9	25
A	4	I	Moleanos	30	0,36	Fischer	10	28
B	5	J	Moleanos	30	0,56	Fischer	14	25
Average				30	0,3808		10,6	28

Table 6.2: List of orders monitored in Operations Context 2 CBP-Providing in BIM-Procurement (OC2)

On the other hand, by keeping the operations in CBP mode, the resources of the CBP-OS-Provider, as defined for application of the Inov4.0|F in OC1 operations mode, will be placed as before in lanes, below the line of interaction of the S-Bprint service process mapping. The process of collecting data on the stakeholders involved in the CBP-Providing in BIM-Procurement (OC2) context, as represented in (Figure C.5, Appendix C), was started in all the companies in the sample, with the "BIM Workstation & Internet Connection" action (Step 1).

Action 2 "Web Searches for BIM Libraries Stone Providers" meant that, somewhere in the world, BIM operators were using their workstations to search for BIM Libraries on the web where there are products in stone (Step 2). As in OC1, in the first two steps the CBP-OS-Provider suppliers' propositions were limited to promotion actions and so far, not related to the BIM operator's initiatives.

In Step 3, BIM operators during the "Stone Provider Selection" action have found BIM web libraries with stone products, with attractive examples provided by the suppliers, which led the BIM operators to download the catalogues in the "Stone Provider Selection" action. This gave the first normative outcome. It may be considered that, as in the previous context, also in OC2 the catalogues must have transmitted a positive image of the suppliers, otherwise the BIM-Customers would not have gone to the next step. Observing the S-Bprint mapping (Figure C.5, Appendix C), to date no non-normative outcomes are identified in any of the companies in the sample. Simultaneously with downloading the catalogues, the CRM recorded this BIM-Customer as a potential customer searching for products in stone, thus automatically generating a lead in the Customer Relations Management (CRM) server. The flow from Step 3 to Step 4, where the outcome of the "Direct Connection to Stone Provider" action was dependent on how BIM-Customers appreciated the electronic catalogues, was (SO = S) in all monitored cases.

In Step 4, "Searching for the most suitable standard products", all the potential BIM-Customers wanted IFC products in stone, as placed in the BIM- Libraries, to fit (cut-to-size) the real geometries of their projects. However, because the BIM-WEB-Libraries only contained standardized products, this resulted in non-normative ISPAR Outcomes (SO = -S)[90]in all monitored cases in Step 5. These (-S) Outcomes had stopped the service process in all the cases, and thus it was not possible for BIM-Customers to buy cut-to-size products from the CBP-OS-Providers through the BIM-WEB-Libraries, and so immediately lost interest in pursuing the acquisition process, claiming that in standard mode they would go to search for alternative materials instead of natural stone. In fact, in standard product mode, price becomes one of the main factors in the purchasing decision in the ICSC, where CPMR-OS companies find it difficult to compete against their Asian competitors and ceramic materials, as detailed in Chapter 2 of this thesis.

[90]No Service Interaction

It was this discrepancy between the competitiveness of the CPMR-OS companies and the BIM-Procurement that resulted in (SO = - S) in all cases and in one of the cases the Outcome was even worse (SO = - W)[91](Spohrer, Anderson, Pass, Ager, et al., 2008), and thus, the service process did not go through (Figure C.5, Appendix C). This situation was somewhat predictable, since one of the purposes of official support for BIM-Procurement is precisely to guide the AECSC to standardized products (HM Government, 2013). Faced with the impossibility of purchasing cut-to-size products, BIM-Customers would tend to buy lower priced alternative products, and be no longer interested in purchasing standard stone products, turning instead to ceramic materials where homogeneity is guaranteed.

Predicting that this problem might happen, the sample CPMR-OS companies agreed to prepare an alternative which was ready to be proposed to all five BIM-Customers in OC2 operations mode, with whom contact had not yet been broken.

As soon as the BIM-Customers were contacted one by one, it was proposed that they agree to link their BIM platforms to Cockpit of the "prototype mini-factory I4.0", as presented in Chapter 4, i.e., tracking of the orders would become the I4.0 digital mode of operations, and the data collected are presented in the next section. It was in this context that all BIM-Customers were contacted one by one, inviting them to connect their BIM-Workstations to the Cockpit of the "mini-factory I4.0 prototype", as introduced in Chapter 4, that is, tracking of the orders would pass to I4.0 digital operations, and the data collected and resources activities will be presented in the next section.

6.4 DATA COLLECTION: I4.0-PROVIDING IN BIM-PROCUREMENT (OC3)

As mentioned before, at the time orders were selected to be executed in BIM procurement context (Table 6.2), it was anticipated that the CBP mode of operations would generate a non-normative OS.

Globally, there was not identify any OS company operating in I4.0 mode. From the outset, it was considered that these orders might be small enough to be executed in the *I4.0 prototype mini-factory* as descibed in Chapter 4.

In 2015, as part of the Strategic Portuguese Initiative for Smart Priorities[92], related to cross-cutting technologies and their applications, a Demonstrator Project was started

[91]Step Service Outcome resulted in "not-welcome service interaction”
[92] Portuguese Government Initiative

under the acronym Flexstone[93]. In this Project, CEI, Inocam, Solancis, Torre ITM and the entities of the National Scientific System (ESCN), Évora University, Cevalor and Portalegre Polytechnic Institute, whose outputs were innovative prototypes which can be incorporated as modules of a I4.0-OS-Company: (i) “OS Samples production system" and (ii) “OS customized Kitchen Tops system" with which it was possible, as described in Chapter 4, to have a basic "mini-factory-I4.0", although only with a scale for sample production or very small orders in I4.0 operations mode.

In addition, in order for the I4.0 mini-plant to operate in I4.0 mode, it would be necessary to associate a Cockpit, as defined in Chapter 5, to which on the customer side, BIM operators could connect their BIM-Workstations and from them, perform the procurement of materials in stone for their projects.

It was in the context of Flexstone's outputs that in 2016 the ACPMR[94] proposed to the Cluster members a task force to evaluate what would be necessary to develop for OS companies to be able to operate in full Industry 4.0 operations mode. This task force resulted in the *Inovstone4.0 Consortium*, including eighteen Companies and seven ESCN (Universities and Research Centers), which together have launched a new Mobilizer Project under the acronym “Inovstone4.0[95]”, with four structuring axes: (i) convergence with BIM's global mandatory legislation in the AECSC. (ii) OS products valorising in the digital procurement BIM context (to turn stone into a smart product); (iii) convergence of the operations to Industry4.0 mode, and finally; (iv) convergence with the global Green Building Initiatives. As the main goal of this Mobilizing Project mindset, the 25 members of the Inovstone4.0 Project agreed to concentrate efforts to develop techniques and technologies that would transform the operations model of OS from the BP to I4.0. As part of this strategic plan, defined by the Inovstone4.0 consortium, a CPS for OS companies was developed, including a CPS-Cockpit and a CPS-Body (CPMR, 2017).

In the descriptive memorandum of the Inovstone4.0 Mobilizer Project, as introduced by the consortium of 25 entities, not only were the OS CPS components described, including the Cockpit, but also all I4.0 OS mode productions, from product specifications until the building’s demolition. From these studies included in Inovstone4.0, a *CPS-Cockpit Prototype*” was developed, where all communication between the BIM-Customer and the

[93]http://www.poci-compete2020.pt/noticias/detalhe/Proj6375_FlexStone; https://www.clustermineralresources.pt/projetos
[94]Cluster Portugal Mineral Resources Association
[95]http://portal.i9magazine.pt/da-pedra-cloud-na-era-4-0

“mini factory I4.0” made it possible to evaluate and measure the data related to Phase1 in I4.0 mode, in which the Fingerprint results from the Design Proposal Discussion and Order Processing, as well as the data related to Phases 2 and 3.

Once the I4.0-Provider resources were formatted in the different S-Bprint interaction lanes, as detailed (Chapter 5 and Appendix B), the activities of these resources were mapped throughout the service process, recording the value creation interactions between BIM-Customer and I4.0-OS-Provider (OC3) as well as the access rights to the resources, referenced by unidirectional or bidirectional arrows, as in the previous contexts OC1 and OC2.

6.4.1 Operations Context OC3 | Phase 1 (Steps 1 to 9)

The service process mapping and data collection began in the stakeholders involved in the five orders in I4.0-Providing in BIM-Procurement Context (OC3), where, as represented in the S-Bprint map (Figure C.6, Appendix C), the first action of the service is "BIM Workstation & Internet Connection" (Step 1), which means that the five BIM operators were using their BIM workstations connected to the Internet and searching for BIM-WEB-Libraries, looking for stone products for their projects (Step 2).

In Step 3, the “Stone Provider Selection” action, the BIM-Operators will have found BIM-WEB-libraries with stone products, and decided to download high resolution catalogues with technical information though the Cockpit, in the "Stone Provider Selection" action, which resulted in normative outcomes (SO = S).

To move from Step 3, whose action is “Direct Connection to Stone Provider” to the next step, meant that BIM-Customers positively appreciated the electronic catalogues available, thus generating (SO = S). Connected to I4.0-OS-Providers Cockpit in the "Server Industry 4.0 RO" action (Step 4), (Figure C.6, Appendix C), BIM operators start the interactive dialogue process with the Cockpit, in particular with its I4.0 Dialogue Interface resource, while CRM follows up these potential customers. Once the remote connection of the BIM-Cockpit resources is guaranteed, the BIM operators now have all the I4.0-OS-Providers’ resources available as if they were their own resources. This communication facility made them very pleased (satisfaction = U). Additionally, it was verified that the modern mode of "opening" up production to clients generates high levels of trust (Contract Compliance = U), the level of reputation of the brand (brand reputation

= U), and also raises the potential quality of products (Product quality = U). In turn, suppliers appreciated customer happiness (Customer Satisfaction = U), while for the competition it became more difficult to access the customer-supplier interactions as they were carried out remotely and without interruptions.

It was therefore in this interactive dialogue that BIM operators performed the "Stone Types and Surface Selection" actions, followed by Step 5 in which the Cockpit provided high resolution photos of the different types of finishes in the catalogue of materials. Simultaneously, the BIM screens showed there were professionals on the Provider side, available to assist if necessary. It was also this collaborative environment of a close customer-supplier relationship that had facilitated the transition from Step 4 to Step 5 through the Step outcome (SO = S). The availability of "Virtual Samples" (Step 5) in I4.0 mode meant that if customers wanted to get real specific samples, they could monitor the process in real time and in an interactive way.

It was in this context that suppliers, after a virtual evaluation by the customers, sent the physical samples executed by normal (less cost) freight, since the service process was not pending the reception of these by the client. This avoided waiting several days and increased customer satisfaction (Satisfaction = U), (Brand Reputation = U), (Contract Compliance = U) and (Quality = U), as well as technical concerns such as (After Sales Response = U) or safety (Product Safety = U). Data related to the Authorities and Competition stakeholders, up to this Step (Step 5), were similar to those in OC1 mode. Providers were happy since the customers were happy (Customer Satisfaction = U).

Once guaranteed (SO = S) in Step 5, the process moves to the "Project Outlines Drawing" action (Step 6), where BIM-Workstations automatically provide the Cockpit (Step 7) with the layout of the façade to be covered in stone, without any time wasted in this step. No emails or phone calls were needed, as happened in OC1. It was observed that customer satisfaction remained "Up", as well as brand confidence levels, compliance and product quality.

Using virtual samples of the raw material types including their finishing's, the BIM modelers performed the "Plays on Pieces Dimensions Interactively" action (Step 8), where they could visualize the total space to cover, changing the base unit dimension of each shape element interactively. At this stage, much of the Cockpit's resources, both human and technological, were involved (Figure C.6, Appendix C). Being a task entirely led by the criteria of the BIM-Operator, without any restriction in unit geometries and with the flamed lines oriented according to their criteria, satisfaction was observed, as well as confidence in the quality, the seriousness of the supplier and the product's technical characteristics, leading to several "U" results.

After Step 8 was over, the process moved to the "Selects the Materials Thickness" action (Step 9), where BIM operators could choose the thickness of the stone parts, after which they were invited to select the "Automatic Cut-to-size Option" (Step 10). It was confirmed that until this Step 9 of the service process, the deadline for product delivery had not yet become a concern for BIM-Customers or the sample I4.0-OS-Providers, probably because the information provided through the Cockpit, showed the estimated delivery time clearly enough to everybody.

It was finished the data collection related to the first nine steps of the service process. The observations and measurements shown in Table D.17 (Appendix D) are related to BIM-Customer Concerns; the observations and measurements shown in Table D.18 (Appendix D) are related to I4.0-OS-Provider Concerns; the observations shown in Table D.19 (Appendix D) are related to OS-Competitor Concerns and the observations shown in Table D.20 (Appendix D) are related to Authorities Concerns. Operations Context OC3 (I4.0-Providing in BIM-Procurement) Phase1 (steps10-18 | Resources Activities and Data Collection).

6.4.2 Operations Context OC3 | Phase 1 (Steps 10 to 18)

The Step 10 was critical, because it was here the Cockpit automatically "adjusts" the parts to the limits of the available facade, with formats as close as possible to the base dimension chosen by the BIM modelers. It is also in this Step (Step 10) that, in OC3 mode, the products had been converted to the customer's needs for standard products, thus cleverly satisfying the requirements of the BIM procurement, that is, the Cockpit sets out from the products customized by the BIM modeller, remotely, and makes them available to BIM as if they were standard, thus solving one of the main issues resulting from BIM procurement.

In the "Geometry List of Cut-to-Size Pieces" action (Step 11), the Cockpit directly put the question to the BIM operators - whether or not they should accept, from a technical point of view, the proposed parts list, resulting in (SO=P) in Step 10 (Figure C.7,

Appendix C). Given this question asked by the Cockpit to the BIM modeler, the resulting outcome (Step 11) might be "A". In cases where customers accepted, the process moved to Step 12, and in the cases of (SO = -A), the process returned to Step 8. On the first or second attempts, (SO = A) was confirmed in all monitored cases, therefore normative, allowing the service process to proceed to the next step, the “Schedule for Delivery” action (Step 12), that is, knowing the period (5D-BIM) in which the customer wishes to receive the stone products. Having received this input from the BIM operators, the Cockpit automatically generated the complete parts list with their eight BIM dimensions (Step 13) - geometries (3D), prices (4D), delivery time (5D), footprint (6D), maintenance (7D) and safety (8D).

Additionally, according to the ISPAR methodological tool, in Step 13 the stakeholders face an interaction whose Outcome for most of the sample OS companies was (SO = -A) at the first attempt, that is, at the second attempt clients accepted almost all the customer conditions and thus, the system moved to Step 14. In one case, however, (SO = - A) was found, and thus the service process regressed to Step 12, but at the second attempt, (SO = A) was found in Step 13, joining the remaining cases under study. When accepting the parts list and respective BIM specifications, the Cockpit immediately made a value proposition (Step 14) and, similar to Step 10, also in Step 13 if (SO = - A) was verified. At the outset, it would not have been due to the technical incapacity of the I4.0 supplier, but perhaps due to the customer’s personal choice.

Additionally, in Step 13, according to the ISPAR methodological tool, it was dealing with an interaction whose Outcome in most of the sample companies was (SO = A) at the first attempt, and thus the service process moved to Step 14. In one monitored case, however, (SO = - A) was the outcome, and thus, the service process returned to Step 12, but at the second attempt, (SO = A) was found in Step 13, this Company joining the remaining cases under study. When accepting the parts list and respective BIM specifications, the Cockpit immediately placed the value proposition with the BIM-Operator (Step 14). As in Step 10, also in Step 13 if (SO = - A) was found, it would not have been due to the I4.0-Provider’s technical incapacity, but just to customer choice.

From the commercial point of view, in Step 14 a sequence of decisive steps began, since here the customers would decide whether to place the order or not. In Step 14, has been faced with a value proposition, which for CRM was treated as an "opportunity" and whose Outcome would be "A" if customers accepted it and in that case the system would progress to Step 18. To avoid the potential situation of (SO = - A), providers did not give up on "forcing" the service process to move to Step 15, so all I4.0-OS company's resources were called upon to provide assistance, including the Managing Directors, to adapt and discuss the proposals with clients, including meetings whenever necessary.

In Step 16, BIM-Customers evaluate the value proposition in the "Reads the Technical & Commercial Final Proposal" action. After Step 17, if the Outcomes were "A", it would mean the proposals were accepted and the service process would move to Step 18. In cases where at the first attempt the outcome was (SO = - A), suppliers interacted with the customer and did not let the opportunity disappear, returning to Step 15 until they won the order. Thus, in all cases, the process moved to Step 18, in which BIM-Customers confirmed payment in the "Makes the Payment" action (Step 18).

After confirmation of payment, Phase 1 of the co-creation process in which the Fingerprint of the objects was created, is over. At this Step of the process, all parts were now available as an eight dimensions Fingerprint and ready to be transformed into Smart-Objects, through interactions between the Cockpit and the CPS-Body, during the transition from Step 18 to Step 19 and all the orders monitored had resulted in (SO = A) in Step 17.

During all these steps, the data collection related to steps 9-18 in OC3 operations mode was concluded successfully directly from the observations and measurements related to the five BIM-Customer Concerns (Table D.21, Appendix D), the five I4.0-OS-Provider Concerns (Table D.22, Appendix D), the OS-Competitor Concerns (Table D.23, Appendix D) and the Authorities Concerns (Table D.24, Appendix D).

6.4.3 Operations Context OC3 | Phase 2 (Steps 19 to 27)

The Phase 2 is related to production of the order, that is, in the I4.0-Providing in BIM-Procurement context is the phase in which the Cockpit becomes available to transform the Smart Objects, resulting from the Fingerprint, into physical products.

This phase of the process (Figure C.8, Appendix C) also comprises nine main steps, where Step 19 corresponds to preparation of the stone blocks. In OC3, this operation was monitored remotely (online) by the BIM-Customers' "Tracking Blocks Execution" action, as well as in Step 20, corresponding to transformation of the blocks into slabs.

We may thus consider that up to Step 20 of the OC3 production process, at the shop floor level everything remained similar to OC1. Actually, only the customer level became different, since the customers were able to follow the process progress in real time. However, from Step 20 onwards the productive operations change substantially in digital operations mode I4.0 (Figure C.6, Appendix C), when compared to the CBP operations mode (OC1), (Figure C.3, Appendix C).

If, on the one hand, in the CBP production mode (OC1), for example (Figure C.3, Appendix C), the "Surfacing operations" (Step 20) evidence meant flaming the full slab surface, in I4.0 production mode this evidence meant that the stone slabs had been scanned first, vectorized and QR[96] coded, a real-time operation remotely monitored by the BIM-Customer.

For the ISPAR tool (Step 21) there was were faced with the realization or not of value creation, whose SO would be (R) if the customers accepted the raw materials and in that case the service process would progress to Step 22 or, if the SO became (-R), the process would return to Step 19, to avoid disputes. Through the observations, the outcomes from Step 21 were (SO = R) in all the cases studied, so the service process moved to Step 22, in which optimizations of raw materials were performed, using artificial intelligence algorithms, in virtual mode, from the vectorizations as performed in Step 21. However, the physical raw materials had been kept at this Step in the warehouse, which meant a reduction of the internal logistics operations.

After reading the slab QR code (Step 23), only the useful area of the raw materials was flamed, according to the optimization previously performed by the Cockpit, which resulted in significant energy savings as well as occupied equipment time, when compared to the CBP operations mode (OC1), in which the flaming operation was executed on the full surface of the slabs (useful and non-useful). In Step 24, the geometries of the already flamed pieces were executed (the pieces were cut), by reading the QR code of the slab, followed by the pieces' QR code printing, operations followed by the customers in real time.

In Step 25, the CPS controlled machines automatically performed functions such as anchoring holes and polishing tops, among others, from the QR parts interpretation, i.e.

---

[96]QR code (abbreviated from Quick Response Code) consists of black squares arranged in a square grid on a white background, which can be read by an imaging device such as a camera, and processed. The required data is then extracted from patterns that are present in both horizontal and vertical components of the image.

during the manufacturing process the parts informed the machines about what they must do, at a micro co-creation process level inside the CPS.

Step 26 corresponds to the "Pieces Drying Execution" action, where once again the customers were asked about the realization of the value through the parts, which were already dry, the result being (R) in some cases and (-R) in cases where customers remotely considered the products to be inconsistent with their expectations. Since in this case (only one piece was recorded as non-quality), the process returned to Step 22, moving at the second attempt to Step 27, joining all the other cases where the Outcome had been (R) at the first attempt, without any dispute.

With "Packing Execution” evidence (Step 27), Phase 2 regarding execution of the orders in the OC3 operations context was completed. In this Phase (2) there was huge activity by the CPS resources in all steps, from preparation of the raw materials up to product packaging ((Figure C.8, Appendix C).

From conclusion of Step 27, in all five cases monitored, Outcomes (SO = A) had resulted, and the data collected related to the sequence of steps 19-27 of the service process in OC3 operations mode concluded successfully, obtaining observations and measurements related to the five BIM-Customer Concerns (Table D.25, Appendix D), the five CBP-OS-Provider Concerns (Table D.26, Appendix D), the OS-Competitor Concerns (Table D.27, Appendix D) and the Authorities Concerns (Table D.28, Appendix D).

6.4.4 Operations Context OC3 | Phase 3 (Steps 28 to 36)

The Phase 3 is related to “Shipping, Using & Recycling operations”, which for I4.0 means the ability to deliver products and participate in customer value co-creation until the building’s demolition (Figure C.9, Appendix C). Step 28 represents the "Transport Building Site" evidence, which meant the products were transported from the suppliers to the customers, which were on-line tracked in all cases by the BIM-Customers, after which they received the pallets (Step 29), followed by of the most important steps of the process, quality checking in the "Quality Checking" action performed by the customer on site (Step 30).

It is in Step 30 that customers physically check the products, after which they report to the providers on the quality and value found in the delivered products, where the SO will be (R) if the customer considers the products are as expected and agreed, meaning the service proceeds to Step 31, or on the contrary, SO will be (-R) if the customer considers that products have not been delivered with the expected value, which may even reach a legal dispute with the supplier. In the specific cases monitored in the OC3 operations context, all the BIM-Customers followed the orders' execution remotely in real-time, and made "on-line evaluations" in Steps 21 and 26. This means that before the decisive Step 30 there was already (virtual SO=R), and thus (SO = R) was also expected to occur in Step 30 in CB3. It was in this context that the physical products delivered to customers were checked and according to the customers whether they were delivered as agreed, and so the service process moved to the "Installation Instructions Reading" (Step 31) action, where the Cockpit resources were placed at the BIM-Customer's disposal once again for any clarification, as well as for the subsequent Steps 32 and 33, regarding the handling and application of products on site.

Thus, it has been reached Step 34, which represents use of the products by the Customer, a situation that will occur during the next decades. However, during the period of use, the customer may request digital support from the BIM-Operator regarding product maintenance or parts replacement (Steps 34 and 35), (Figure C.9, Appendix C), related to the "Building site Pieces maintaining" actions and " Building site Pieces replacing". For the researcher and for the scope of this thesis, the data collection process ended in Step 33, since from this stage, the time of each action does not coincide, for obvious reasons, with the time to accomplish this research.

In Step 36, corresponding to the "Building demolition and recycling" evidence, the service process in the I4.0-Providing in BIM-Procurement Context (OC3) is over. During Steps 27-33[97] it was possible to collect data, a situation not possible after Step 33, the "pieces application" action, giving a Step Outcome in all the monitored cases of (SO = A), and thus, up to Step 33, observations and measurements of BIM-Customer Concerns (Table D.29, Appendix D), observations and measurements of the five I4.0-OS-Provider Concerns (Table D.30, Appendix D), observations regarding the OS-Competitor Concerns (Table D.31, Appendix D) and observation regarding the Authorities Concerns (Table D.32, Appendix D) have been recorded.

By applying Inov4.0|F in the context of I4.0-Providing in BIM-Procurement (OC3), it was possible to map the service process (Figures c.6, c.7, c.8 and c.9 Appendix C) and

[97]Evaluation of the service processes finished in Step 33 because no mode data was possible to collect

collect the qualitative and quantitative data, with which the KCI_{QUAL_k} and KCI_{QUAL_k} related to the concerns of stakeholder (k) in OC3 as defined in Chapter 5, must be computed.

6.5 QUALITATIVE KCI AND IO | COMPUTING AND ANALYSIS OF RESULTS

In the previous section, the qualitative and quantitative data were collected and recorded, as well as the Step Outcomes in each service process step, for the ten cases monitored and in the Operation Contexts - (OC1) CBP-Providing in CAD-Procurement; (OC2) CBP-Providing in BIM-Procurement and (OC3) I4.0-Providing in BIM-Procurement. The tables give the average data value of each set of five monitored cases, for each Operation Context (Tables D.1 to D.32, Appendix D).

In this section, following the methodological procedures detailed in Chapter 4, these data will be used to compute $KCI_{QUAL\text{-}K,}$ $IO_{QUAL\text{-}k}$, $KCI_{QUAN\text{-}k,}$ IO_{QUAN_k} related to the main Stakeholder Concerns (k), (Customers, Suppliers, Competitors and Authorities), their discussion and interpretation of their evolution.

6.5.1 Customer Qualitative KCI and Innovation Outcomes

As discussed in Chapters 4 and 5, for Inov4.0|F the OS-Customer Concerns are related to the "Customer Satisfaction Index" (CSI) concept, which considers a set of qualitative and quantitative indicators along all steps of the service process. From the qualitative data for the five cases monitored as recorded in Tables D.2 to D.32 (Appendix D) related to the OS-Customer and using the appropriate equations (Appendix B), the KCI_{QUAL_c} and IO_{QUAL_c} have been computed in both CBP (OC1) and I4.0 (OC3) contexts (Table 6.3).

We found (Table 6.3) that the KCI_{QUAL_c}, indexed to the CSI and related to the OS-Customer Concerns, had reduced considerably, resulting in a positive IO_{QUAL_c}, when the operations context changes from OC1 to OC3.

CUSTOMER QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	KCI_{QUAL_c} OC1-CBP	KCI_{QUAL_c} OC3-I4.0	IO_{QUAL_c}
What is your concern with respect to Time to Receive the Product?	1,54	0,16	90%
What is your concern with respect to Product Sustainability?	1,00	0,14	86%
What is your concern with respect to Product Quality?	0,58	0,25	57%
What is your concern with respect to Contract Compliance?	0,64	0,18	71%
What is your concern with respect to Brand Reputation?	0,43	0,25	42%
What is your concern with respect to Flexibility?	0,29	0,29	0%
What is your concern with respect to Purchasing Price?	0,80	0,20	75%
What is your concern with respect to Total Product Cost?	0,67	0,17	75%
What is your concern with respect to Warranty?	0,40	0,20	50%
What is your concern with respect to After Sales Service?	0,50	0,33	33%
What is your concern with respect to Product Reliability?	0,50	0,25	50%
What is your concern with respect to Product Safety?	0,80	0,20	75%
What is your concern with respect to Product Recycling?	1,00	0,20	80%

Table 6.3: Customer Satisfaction Index (CSI) | KCI_{QUAL_c} e IO_{QUAL_c} | Evolution results from OC1 (CBP) to OC3 (I4.0)

Analysing in detail the IO_{QUAL_c} related to OS-Customer Stakeholder Concerns, it was found that the concerns reduction generating the greatest impact on the CSI were related to the delivery time, ecological footprint, cost, safety and product recycling. These major gains in terms of concerns reduction may be justified by the fact that in I4.0 mode (OC3) production efficiency tends to increase when more modern technologies are used, leading to higher efficiency. Also, the permanent involvement of the OS-Customer during the whole service process in I4.0 mode puts greater permanent pressure on production efficiency.

Paradoxically, it was found that from the customer perspective, I4.0 does not increase flexibility, which at first glance is counter-intuitive since one of the challenges of I4.0 is to provide production with flexibility. The justification for this result may be related to the fact that all CPMR-OS companies have adopted the LH and therefore, are already operating in customized mode, which is in fact one of their main competitive advantages currently.

However, as introduced in the SWOT matrix in Chapter 2, what the sample CPMR-OS Companies are searching for through I4.0 is not to increase flexibility but rather to maintain their main competitive advantage (one of the strong points), which is exactly "their flexibility" with which they already operate, and additionally, in the context of BIM procurement and through I4.0, they expect to reduce costs, reduce lead time, reduce the ecological footprint and reduce incidences of non-quality found internally and externally in products. This positive evolution of concerns found from the OS-Customer perspective is clearly visible in the $KCI_{QUAL\text{-}C}$ tending towards zero (Chart 6.1).

Chart 6.1: Customer Qualitative Concerns | Evolution from CBP (OC1) to I4.0 (OC3)

6.5.2 Provider Qualitative KCI and Innovation Outcomes

As discussed in Chapters 4 and 5, for Inov4.0|F the OS-Provider Concerns are related to the "Provider Performance Index" (PPI) concept, which considers a set of qualitative and quantitative indicators in all steps of the service process. From the qualitative average data of the five cases monitored, related to OS-Provider and using the appropriate equations (Appendix B), the KCI_{QUAL_p} and IO_{QUAL_p} have been computed in both CBP (OC1) and I4.0 (OC3) contexts (Table 6.4).

PROVIDER QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	KCI_{QUAL-p} OC1-CBP	KCI_{QUAL-p} OC3-I4.0	IO_{QUAL-p}
Customer Satisfaction Concern	1,33	0,33	75%
Time to deliver Concern	2,14	0,40	81%
Sustainability Concern	0,67	0,33	50%
Maintenance Costs Concern	1,75	0,67	62%
Compliance Concern	1,80	0,50	72%
Brand Reputation Concern	3,25	0,36	89%
Expected Flexibility Concern	2,00	0,67	67%
Product Safety Concern	1,40	0,50	64%
Product Recyclable Concern	1,00	0,43	57%

Table 6.4: Provider Performance Index (PPI) | KCI_{QUAL_p} e IO_{QUAL_p} | Evolution results from OC1 (CBP) to OC3 (I4.0)

It was found (Table 6.4) that the KCI_{QUAL-p}, indexed to the PPI and related to the OS-Provider Concerns, had reduced considerably, resulting in positive IO_{QUAL-p}, when the operations context changes from OC1 to OC3. Checking in detail the IO_{QUAL_p} related to the OS-Provider Stakeholder Concerns (Table 6.4), it was found a reduction over 50% in all concerns associated with the PPI, with greater reductions of the KCI_{QUAL_p} indexed to brand reputation, delivery time and customer satisfaction. This positive evolution of concerns found from the OS-Provider perspective is clearly visible through the KCI_{QUAL_p} tending towards zero (Chart 6.2).

Chart 6.2: Provider Qualitative Concerns | Evolution from CBP (OC1) to I4.0 (OC3)

6.5.3 Competitor Qualitative KCI and Innovation Outcomes

As discussed above, for Inov4.0|F the OS-Competitor Concerns are related to the "Sustainable Innovation Index" (SII) concept, which considers a set of qualitative and quantitative indicators in all steps of the service process. From the qualitative average data on the five cases monitored, related to OS-Competitor and using the appropriate equations (Appendix B), the KCI_{QUAL_cp} and IO_{QUAL_cp} have been computed in both CBP (OC1) and I4.0 (OC3) contexts (Table 6.5).

Analysing in detail the IO_{QUAL_cp} related to the OS-Competitor Stakeholder Concerns (Table 6.5), it was found that the concerns reductions generating the greatest impact on the SII were related to Contract Compliance, Products Quality and Customer Satisfaction.

COMPETITOR QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	$KCI_{QUAL\text{-}cp}$ OC1-CBP	$KCI_{QUAL\text{-}cp}$ OC3-I4.0	$IO_{QUAL\text{-}cp}$
Customer Satisfaction Concern	1,06	0,33	69%
Innovative Product Concern	0,17	0,17	0%
Manufacture Process Concern	0,17	0,17	0%
Product Total Cost Concern	0,25	0,25	0%
Product Recyclable Concern	0,83	0,67	20%
Contract Compliance Concern	0,80	0,21	73%
After Sales Response Concern	0,33	0,15	54%
Product Reliability Concern	0,75	0,20	73%

Table 6.5: Sustainable Innovation Index (SII) | KCI_{QUAL_cp} e IO_{QUAL_cp} | Evolution from OC1 CBP) to OC3 (I4.0)

Nevertheless, it was found there was no reduction in relation to Total Costs, Products Innovative and Manufacturing Innovative concerns. A possible explanation for this zero concerns reduction may be related to the delay in OS-Competitors' perception. Since the OS-Providers involved in these inquiries, according to the OS-Competitors perspective, are those with the best practices in the sector, they may already be seen as the most innovative in terms of process, products and production efficiency. However, there is a tendency of concerns moving towards zero from the SII perspective (Graph 6.3). No negative evolution of concerns was found from OC1 to OC3 operations mode according to the OS-Competitor perspective, clearly visible through the KCI_{QUAL_cp} tend towards zero (Chart 6.3).

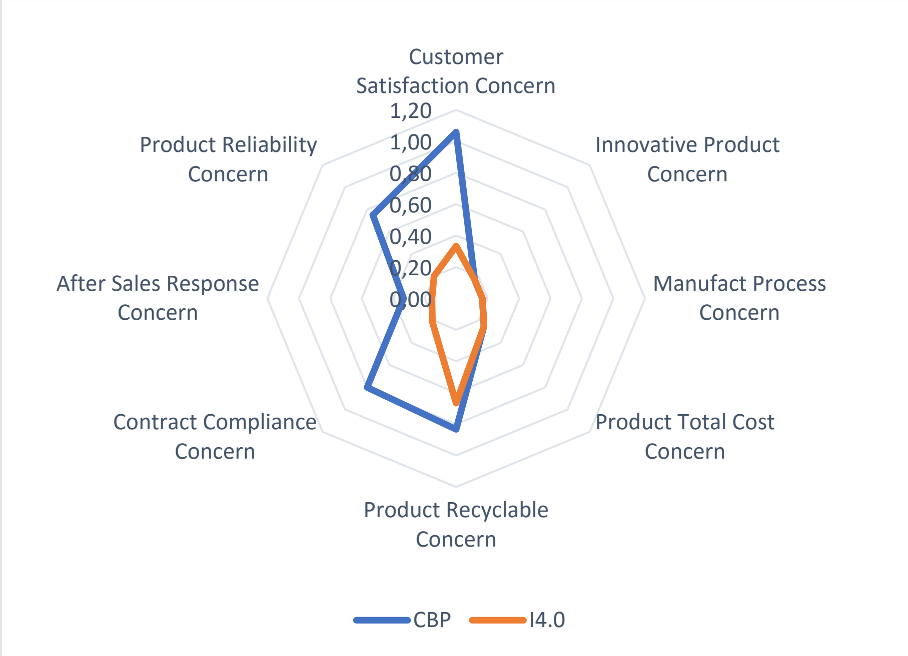


Chart 6.3: Competitor Qualitative Concerns | Evolution from CBP (OC1) to I4.0 (OC3)

6.5.4 Authority Qualitative KCI and Innovation Outcomes

As for previous stakeholders, the Authorities' concerns are related to the "Conformity Index" (CI) concept, which considers a set of qualitative and quantitative indicators in all steps of the service process. From the qualitative average data on the five cases monitored, the KCI_{QUAL_a} and IO_{QUAL_a} have been computed in both CBP (OC1) and I4.0 (OC3) contexts (Table 6.6).

AUTHORITY QUALITATIVE CONCERNS QUESTIONNAIRE-GUIDELINES	KCI_{QUAL_a} OC1-CBP	KCI_{QUAL_a} OC3-I4.0	IO_{QUAL_a}
Handling Compliance Concern	0,25	0,00	100%
Manufacturing Compliance Concern	0,29	0,00	100%
Transport Compliance Concern	0,38	0,14	62%
Recycling Compliance Concern	0,43	0,17	61%
Moral Hazard Compliance Concern	0,38	0,14	62%
Product Legal Concern	0,25	0,00	100%
Taxes and Fines Concern	0,38	0,14	62%

Table 6.6: Conformity Index (CI) | KCI_{QUAL_a} e IO_{QUAL_a} | Evolution from OC1 (CBP) to OC3 (I4.0)

We found (Table 6.6) that the KCI_{QUAL_a}, indexed to the CI and related to the Authorities Concerns had reduced considerably, resulting in positive IO_{QUAL_a}, when the operations context changes from OC1 to OC3. Checking in detail the IO_{QUAL_a} related to the Authority Stakeholder Concerns (Table 6.4), it was found that the reduction is higher than 60% in all concerns associated with the CI, with greater reductions in the KCI indexed to Product Handling and Production and Legality. One of the possible explanations for these concerns reduction gains may be related to the fact that in I4.0 mode the authorities can evaluate business activities online, especially between customers and providers, both in accounting terms and in receiving and delivering goods. This positive evolution of concerns found from the Authority perspective is clearly visible through the KCI_{QUAL_a} tending towards zero (Chart 6.4).

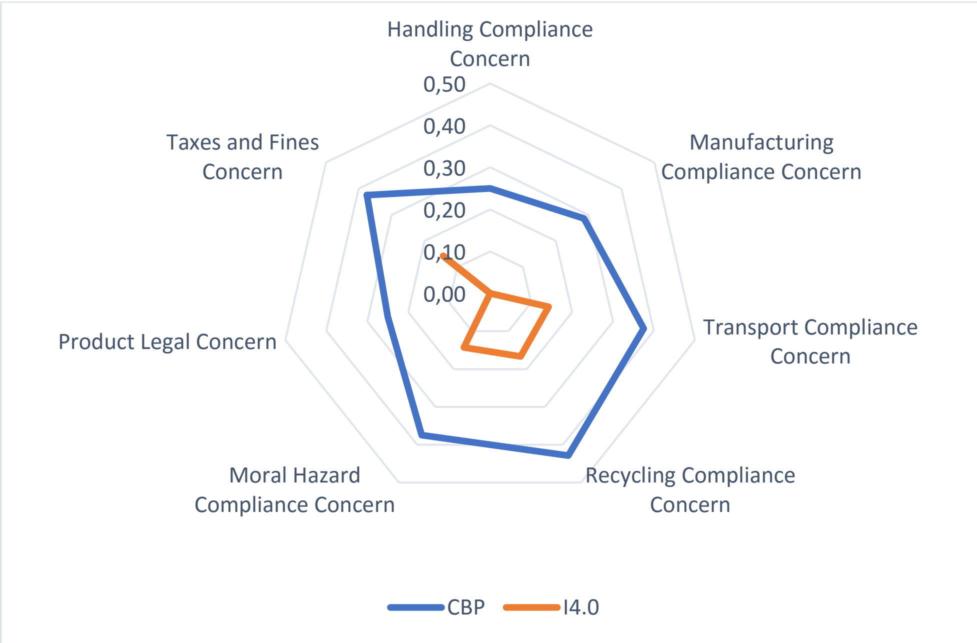


Chart 6.4: Authorities Qualitative Concerns | Evolution from CBP (OC1) to I4.0 (OC3)

6.6 QUANTITATIVE KCI AND IO: COMPUTING AND ANALYSIS OF RESULTS

As detailed in Chapter 4, Methodology, the key assumption of the mixed methodological approach is that qualitative data and quantitative data, while providing different types of information, taken together must produce convergent results, this being the main advantage of mixed methodology.

6.6.1 Quantitative KCI and IO | I4.0 Response to Customer Concerns

Observing the $IO_{QUAN\text{-}C}$, related to CSI, resulting from the evolution of the KCI_{QUAN_c} from the context of operations OC1 (CBP-Providing in CAD-Procurement) to OC3 (I4.0-Providing in BIM-Procurement), (Table 6.7), there was found a gain in concerns reduction of 58% in the $PLTC_{QUAL\_c}$ "Lead-Time Concern", thus confirming $TRPC_{QUAL\_c}$ related to evolution of "Time-to-Receive-the-Products concerns", which, as it has been found in the previous section, recorded a 90% concern reduction, according to the OS-Customer perspective.

CUSTOMER QUANTITATIVE CONCERNS	$KCI_{QUAN\text{-}c}$ OC1-CBP	$KCI_{QUAN\text{-}c}$ OC3-I4.0	$IO_{QUAN\text{-}c}$	Units
Product Lead Time Concerns	0,52	0,22	58%	h/m2
Product Labor Work Concerns	0,57	0,40	30%	h/m2
Product Quality Concerns	0,08	0,04	53%	h/m2

Table 6.7: Customer Satisfaction Index (CSI) | KCI_{QUAN_c} and IO_{QUAN_c} | Evolution from the context OC1 to OC3

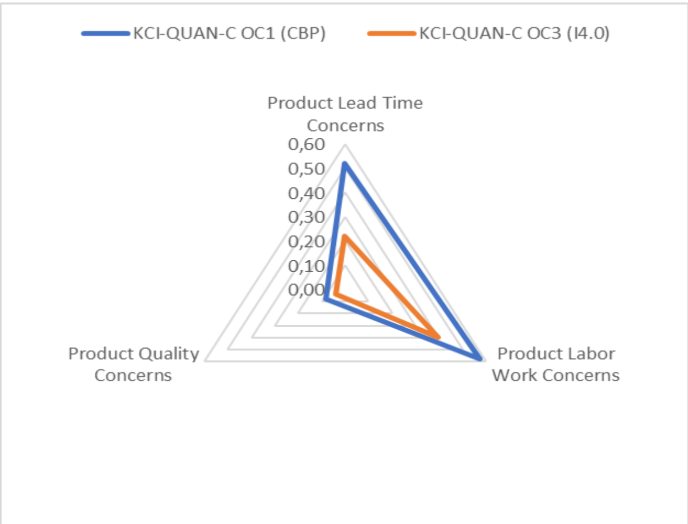


Chart 6.5: OS-Customer Concerns | Evolution from CBP (OC1) to I4.0 (OC3)

In the same way, a gain was found in terms of concerns reduction of 53% in the $PQC_{QUAN\text{-}c}$ "Product Quality Concerns", confirming PQC_{QUAL_c} related to "Product Quality" evolution, which recorded a 57% concern reduction. Moreover a gain was found in terms of concerns reduction of 30% in the $PLWC_{QUAN\_c}$ "Product Labour Work Concerns", confirming $PTCC_{QUAL\_c}$ related to "Product Total Cost" evolution, which recorded 75%

of concern reduction, according to the OS-Ccustomer perspective, confirming the qualitative KCI_{QUAL_c} evolution (Figure C.1, Appendix C). This positive evolution of concerns found from the Customer perspective is clearly visible through the KCI_{QUAL_c} tending towards zero (Chart 6.5), confirming the qualitative KCI_{QUAL_c} evolution (Table 6.3)

6.6.2 Quantitative KCI and IO | I4.0 Response to Provider Concerns related to Threat 1 (Standardization Trend)

As previously mentioned, the IO_{QUAL_p} indexed to Provider Performance Index (PPI) when the Operations Context moves from OC1 (CBP-Providing in CAD-Procurement) to OC3 (I4. 0-Providing in BIM-Procurement), (Table 6.4) was found to point towards significant concerns reduction in all $KCI_{QUAL\text{-}p}$, according to the OS-Provider perspective. Additionally, from the S-Bprint maps (Figures 6.6, 6.7, 6.8 and 6.9), It was found that in OC3 (I4.0-Providing in BIM-Procurement), the service process flowed without non-normative SOs from the first to the last steps, in contrast to what happened in OC2 (Figure C.5, Appendix C), where the service process stopped definitively at Step 5, because of non-normative Outcomes (SO = -S) or (-W) in all monitored cases.

Analysing in detail the S-Bprint maps (Figures C10, C.11, C.12 and c.13 Appendix C), It was found that the Cockpit resources were the most active during service process Phase1, from which it can be deducted, that these were the resources responsible for the normative Outcome of the Step and thus, the normative flow of the process during this phase, in which the FP-I4.0 vehicle has transported the value co-created to the CPS-Body, thus converting the BIM standardized product requirements into cut-to-size products. In all steps of OC3 (I4.0), there were found normative SO as happened in OC1(CBP), which meant that the service process evolved naturally in cut-to-size, regardless of the procurement model. This meant that OS-Providers might retain in OC3 (BIM Procurement) one of their key competitive advantages, which leads us to conclude that I4.0 appears to respond positively to Threat 1 (Standardization Trend).

6.6.3 Quantitative KCI and IO | I4.0 Response to Provider Concerns related to Threat 2 (Faster Delivery Trend)

Observing the IO_{QUAN_p} related to PPI and to Threat 2 (faster delivery trend), resulting from the evolution of the KCI_{QUAN_p} when the Operations Context moves from OC1 to

OC3 (Table 6.8), it was found that the most significant gains in terms of concerns reduction occurred during service process Phase 1, especially in the $PCTC_{QUAN\_p}$ KCI, related to "Marketing Interface Concerns", which appeared to happen as the result of Cockpit resources reconfiguration, responsible for the agility of the I4.0 interface process compared to the BIM-Operator (Figure C.6, Appendix C). Additionally, from the S-Bprint maps, it was found that it is by the collaborative action between Cockpit resources and BIM resources that the FP-I4.0 of the products was achieved, from which the Smart-Objects will be developed later through the Cockpit and CPS-Body interactions.

PROVIDER QUANTITATIVE CONCERNS RELATED TO THREAT 2 (FASTER DELIVERY TREND)	$KCI_{QUAN\text{-}p}$ OC1-CBP	$KCI_{QUAN\text{-}p}$ OC3-I4.0	$IO_{QUAN\text{-}p}$	Units
Market Interfacing Concerns	12,88	4,71	8,17	h/m^2
Production Cycle Time Concerns	1,29	0,89	0,40	h/m^2
Production Occupation Concerns	1,05	0,72	0,33	h/m^2
Production Layout Balance Concerns	0,48	0,19	0,29	h/m^2
Logistics Capability Concerns	0,24	0,17	0,07	h/m^2

Table 6.8: Provider Performance Index (PPI) | KCI_{QUAN_p} and IO_{QUAN_p} related to Threat 2 "Faster Delivery Trend" | Evolution results from OC1 to OC3

Because of the interactions described in the S-Bprint maps and $IO_{QUAN\text{-}p}$, maps related to Threat 2 (Faster Delivery Trend), (Table 6.8), the OS-Provider concerns are significantly reduced when, in the context of BIM procurement, CBP-Operations change to I4.0-Operations, in line with IO_{QUAL_p} (Table 6.4).

Observing in detail the $IO_{QUAN\text{-}p}$, related to PPI Threat 2 (Faster Delivery Trend), since they result from the KCI_{QUAN_p} evolution from OC1 (CBP-Providing in CAD-Procurement) to OC3 (I4.0-Providing in BIM-Procurement), (Table 6.7), there were also found gains in concerns reduction, of 0,4 h/m^2 in the $PCTC_{QUAN\_p}$ "Production Cycle Time Concerns", of 0,33 h/m^2 in the $POTC_{QUAN\_p}$ "Production Occupation Concerns", 0,29 h/m^2 in the $PLBC_{QUAN\text{-}p}$, "Production Layout Balance Concerns", and 0,07 h/m2 in the LCC_{QUAN_p} "Logistics Capability Concerns", thus confirming $TRPC_{QUAL\_p}$ related to the evolution of "Time-to-Receive-the-Products Concerns" (Table 6.4), which, as it has been found in the previous section, recorded an 81% concerns reduction, according to the OS-Provider perspective.

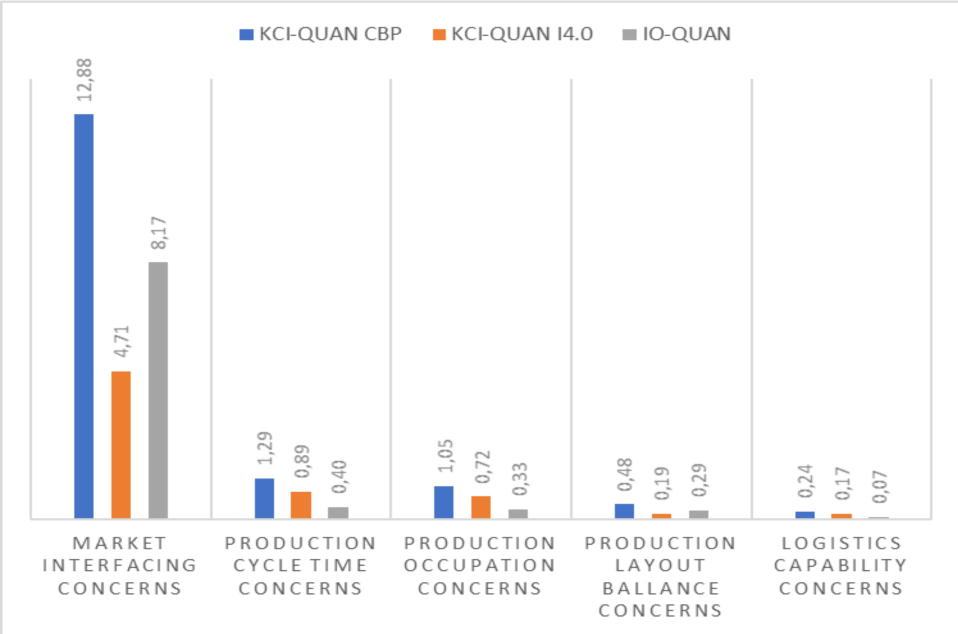


Chart 6.6: Provider Quantitative Gains (h/m^2) related to Threat 2 (Faster Delivery Trend) | Evolution from OC1 (CBP) to I4.0 (OC3)

Analysing the results graphically (Chart 6.6), it is clear the great contribution to the concerns relief coming from the $MITC_{QUAN\_p}$ KCI of 8.17 h/m2 which means that in I4.0 mode, the interface Provider-Customer becomes much lean.

6.6.4 Quantitative KCI and IO | I4.0 Response to Provider Concerns related to Threat 3 (Lower Costs Trend)

Threat 3 is related to the trend towards reduced construction costs in BIM, a trend that will put pressure on the prices set by all AECSC providers. In this sense, to compute the cost base in the OC1 context, has been used the average cost per hour of work[98], the costs of the different forms of energy being computed by the average value paid by the OS-CPMR Companies in the years 2015 and 2016[99].

As discussed in Chapters 4 and 5, for Inov4.0|F the OS-Provider Concerns are indexed to the "Provider Performance Index". There was found as a result of the KCI_{QUAN_p} evolution when operations move from the OC1 to OC3 (Table 6.9), gains in concern reduction in all of the IO_{QUAN_p} except EEC_{QUAN_p} KCI "Elect-Energy-Efficiency". Analysing in detail

[98]Average cost of work for OS companies from CPMR 12,36 € / hour (I. Frazao, 2016)
[99]Diesel 1,25 € / litre; Propane 2.74 € / m3; Electricity € 9.15 / KWh and Raw Materials 10€/m2

the steps of the production process (Phase 2) of the S-Bprint map (Figure C.8, Appendix C), it was found that the energy consumption per m^2 has actually been lower in all steps in OC3, except in Steps 26 and 27. However, in a deeper analysis of the resource interactions in these two steps, it was found that the global electric energy consumption has not been reduced because a new process of drying pieces was added prior to packaging the parts in I4.0 mode (OC3). Thus, In I4.0 mode, the additional power consumption in Steps 26 and 27 is consumed in the automation of production processes and parts drying, by replacing the traditional "dry-lays" (CBP) executed manually and occupying extensive manufacturing areas and huge amounts of labour. The addition of these new technologies in I4.0 operations mode may have resulted from the need identified in CBP mode to avoid frequent disputes, in most cases because of inefficient waterproofing and packaging not being properly dry[100]. It may thus be considered that in I4.0 mode, the additional electricity consumption was the technological way to avoid potential non-normative outcomes and disputes. Nevertheless, and despite the additional consumption of electric energy in automation, the overall electric energy consumption of the process remained the same when operations evolved from CBP to I4.0[101].

Observing in detail the $IO_{QUAN\text{-}p}$, related to PPI Threat 3, since they result from the KCI_{QUAN_p} evolution from the context of OC1 operations (CBP-Providing in CAD-Procurement) to OC3 (I4.0-Providing in BIM-Procurement), (Table 6.9), It has been found that there was percentage quantified concerns reduction resulting from $FFTC_{QUAN\text{-}P}$, $RTYC_{QUANT\_p}$ and $PREC_{QUAN\text{-}P}$, concerns relief was found for all KCI_{QUAL_p} and the most significant concerns relief was related to $LWEC_{QUAL\_p}$ and $RMEC_{QUAN\text{-}p,}$ thus confirming the CSC_{QUAL_p} related to “Customer Satisfaction concerns" evolution (Table 6.4), which as it was found in the previous section, recorded a 75% concern relief, according to the OS-Provider perspective. From this positive evolution in the $KCI_{QUAN\text{-}P}$, indexed to the PPI and related to the Costs Reduction Threat, when the service process moves from OC1 to OC3 (Graph 6.7), there is a quantitative reduction cost of €13.60/m2 (Table 6.9), in line with the evolution of KCI_{QUAL_p} (Graph 6.2).

[100]The application of a waterproofing agent to the products in stone that are not properly dried makes the waterproofing ineffective, and therefore, especially porous stone products, for example limestone, changes colour when they absorb humidity.
[101]In OS plants connected to the natural gas network, these drying systems can be heated from this source of energy, thereby reducing overall energy costs.

PROVIDER QUANTITATIVE CONCERNS RELATED TO THREAT 3 (LOWER COSTS TREND)	$KCI_{QUAN\text{-}p}$ OC1-CBP	$KCI_{QUAN\text{-}p}$ OC3-I4.0	$IO_{QUAN\text{-}p}$	Units
Labor Efficiency Concerns	20,47	12,72	7,75	€/m^2
Raw Materials Efficiency Concerns	19,49	14,01	5,48	€/m^2
Electricity Efficiency Concerns	0,02	0,02	0,00	€/m^2
Propane Efficiency Concerns	0,87	0,55	0,32	€/m^2
Diesel Efficiency Concerns	0,58	0,53	0,05	€/m^2
First Time Through Concerns	0,24	0,13	55%	%
Rolled Throughput Concerns	1,14	0,18	96%	%
Production Run Efficiency Concerns	1,29	0,89	40%	%

Table 6.9: Provider Performance Index (PPI) | KCI_{QUAN_p} and IO_{QUAN_p} related to Threat 3 "Lower Costs Trend" | OC1 (CBP) to I4.0 (OC3)

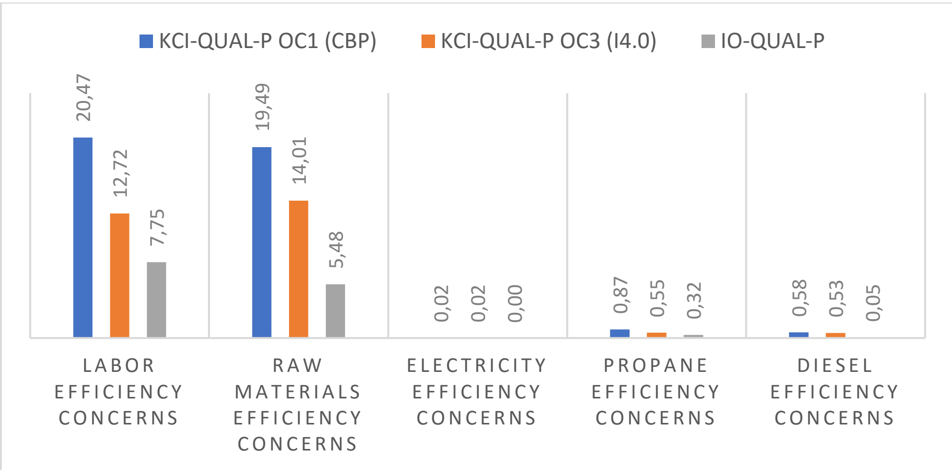


Chart 6.7: Provider Quantitative Gains (€/m^2) related to Threat 3 (Lower Costs Trend) | Evolution from OC1 (CBP) to I4.0 (OC3)

6.6.5 Quantitative KCI and IO | I4.0 Response to Provider Concerns related to Threat 4 (Lower Emissions Trend)

The Inov4.0|F was conceptualized from Service Science Theory, for which Sustainability must be considered a cross-cutting concern regardless of the stakeholder and service processes (Matthies & D'Amato, 2016; Spohrer, Anderson, Pass, Ager, et al., 2008). This top concern of S-S is shared by the BIM (HM Government, 2015), BIM Technology (Tarandi, 2015) where objects' footprint represents its 5th Dimension (5D-BIM).

Although the evolution of the KCIs FFT_{CQUAN_p} and $RMEC_{QUAN\_p}$ is more qualitative than quantitative, their relative variation must be considered to evaluate Sustainability Innovation (Table 6.10).

PROVIDER QUANTITATIVE CONCERNS RELATED TO THREAT 4 (LOWER EMISSIONS TREND)	KCI_{QUAN_p} OC1-CBP	KCI_{QUAN_p} OC3-I4.0	IO_{QUAN_p}	Units
First Time Through Concerns	0,24	0,13	55%	%
Raw Materials Efficiency Concerns	1,95	1,40	72%	m^2/m^2
Diesel Efficiency Concerns	1,24	1,13	0,11	$KgCO_2/m^2$
Electricity Efficiency Concerns	0,07	0,06	0,00	$KgCO_2/m^2$
Propane Efficiency Concerns	5,80	3,66	2,15	$KgCO_2/m^2$

Table 6.10: OS-Provider | Provider Performance Index (PPI) | KCI_{QUAN_p} and IO_{QUAN_p} related to Threat 4 (Lower Emissions Trend) | OC1 (CBP) to I4.0 (OC3)

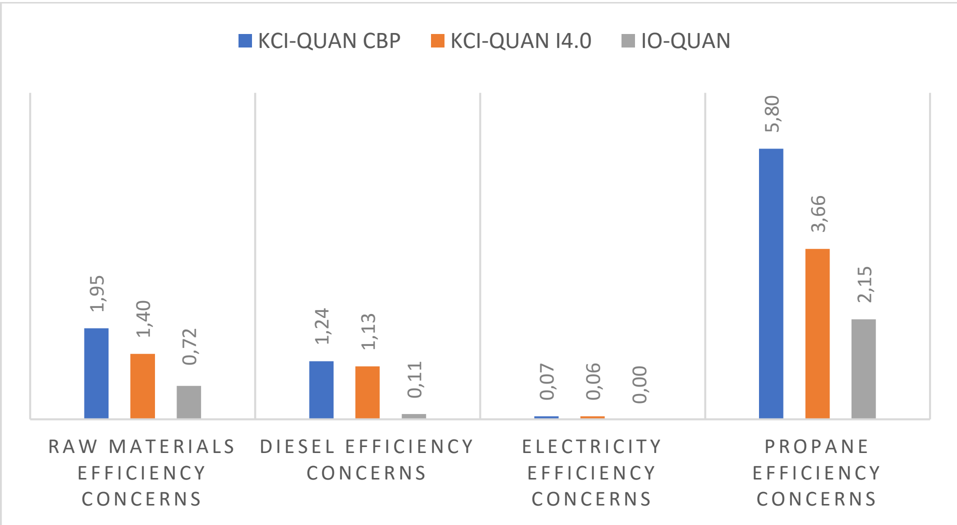


Chart 6.8: Provider Quantitative Gains (CO_2 Kg/m2) related to Threat 4 (Lower Emissions Trend) | Evolution from OC1 (CBP) to I4.0 (OC3)

Observing in detail the $IO_{QUAN\text{-}P}$, related to PPI Threat 4 (Lower Emissions Trend), as they result from the KCI_{QUAN_p} evolution, from OC1 to OC3 (Table 6.10), There was found gains in concerns reduction of 0,11$KgCO_2/m^2$ in the EEC_{QUAN_p} related to “Diesel Efficiency Concerns” and 2,15 $KgCO_2/m^2$ in the EEC_{QUAN_p} related to “Propane Efficiency Concerns”. Additionally, There was found a 55% relief related to “First Time

Through Concerns" and 72% relief related to "Raw Materials Efficiency Concerns", according to the OS-Provider perspective (Chart 6.8).

6.6.6 Quantitative KCI and IO | I4.0 Response to Provider Concerns related to Threat 5 (Lower Non-Quality Trend)

For Inov4.0|F, quality is a cross-cutting concern to both customers and suppliers, with the goal of ensuring long-term relationships based on permanent service innovation mechanisms between these two service systems.

From the analysis of S-Bprint maps (Figures c.6 to c.9, Appendix C), it was found that in OC3 the relationship between OS-Providers and OS-Customers became close, where customers become essential as FP-I4.0 and production Step inspectors, contributing naturally to higher quality output. Comparing the IO_{QUAL_p} (Graph 6.2) with the IO_{QUAN_p} (Graph 6.9), there was found concern relief mainly in $RTYC_{QUANT\_p}$ "Rolled Throughput Concerns" which can be interpreted as the probability that a unit of production or service will be produced/delivered correctly or of acceptable quality without it being scraped or rejected. This average $RTYC_{QUANT\_p}$ reduction in the five cases monitored might be directly related to the fact that I4.0 operation processes ensured that production actions were performed with fewer errors through automatic processing and real-time production management, centred on the CPS and executed from the Smart Objects generated by the Cockpit.

PROVIDER QUANTITATIVE CONCERNS RELATED TO THREAT 5 (LOWER NON-QUALITY TREND)	KCI_{QUAN_p} OC1-CBP	KCI_{QUAN_p} OC3-I4.0	IO_{QUAN-p}	Units
First Time Through Concerns	0,24	0,13	55	%
Rolled Throughput Concerns	1,14	0,18	96	%
Product Quality Ratio Concerns	0,08	0,04	55	%

Table 6.11: OS-Provider | Provider Performance Index (PPI) | KCI_{QUAN_p} and IO_{QUAN_p} related to Threat 5 (Lower non-Quality Tolerance) | OC1 (CBP) to I4.0 (OC3)

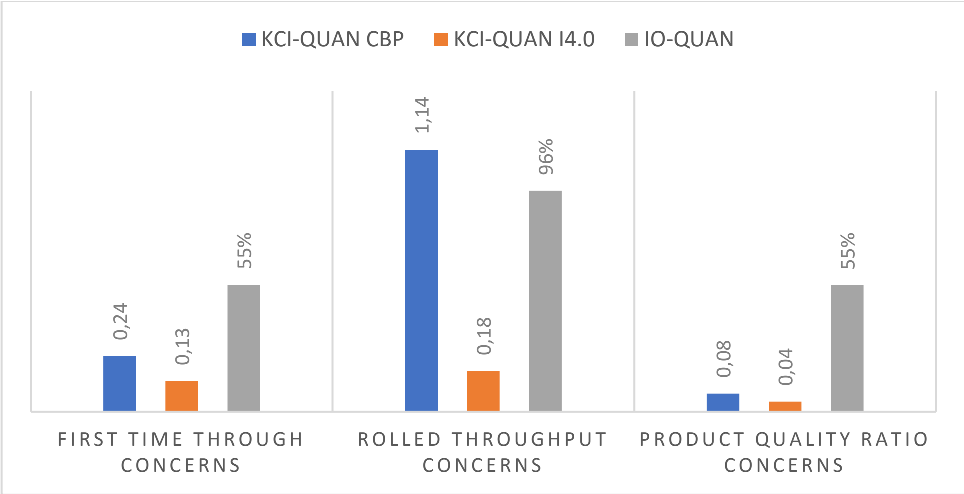


Chart 6.9: Provider Qualitative Gains (%) related to Threat 5 (Lower non-Quality Tolerance) | Evolution from OC1 (CBP) to I4.0 (OC3)

Observing in detail the IO_{QUAN-P}, related to PPI Threat 5 there were found gains in concern reduction, of 55% in the $FFTC_{QUAN\_p}$ related to "First Time Through Concerns", and 96% in the $RTYC_{QUAN\_p}$ related to "Propane Efficiency Concerns". Additionally, there was found 55% relief related to "Rolled Throughput Concerns" and 55% of concern relief related to the PQC_{QUAL_p} "Product Quality Ratio Concerns", according to the OS-Provider perspective (Table 6.11 and Chart 6.9). A possible explanation for the reduction of errors detected on site by the customer might be related to I4.0's greater production efficiency and to the real-time monitoring of the production by the customer, in all steps of the process.

6.7 KCI AND IO STATISTICAL ANALYSIS

In an attempt to find final confirmation of the trends, this time through the significance of the KCI_{QUAL_k} and IO_{QUAL-K}, non-parametric means comparison tests were carried out based on the *Wilconxon-Mann-Whitney*[102] and *t-Student*[103] statistic tests.

[102]Non-parametric test applied to two independent samples.
[103]The Student is a hypothesis test that uses statistical concepts to reject or not a null hypothesis when the test statistic follows a "t" Student distribution.

6.7.1 Test Conditions and Hypotheses

Through these tests, it has been intended to check if there was an effective decrease (in average terms) of stakeholder concerns, when operations evolved from the OC1 (CBP) to OC3 (I4.0) context. In global terms, the statistical approach is as follows:

(i) The *Wilconxon-Mann-Whitney* test was applied to compare samples of each stakeholder (k), to compare the distribution functions and conclusions about the respective KCI_{QUAL_k} medians. The hypotheses tested are:

   a. H0: Median of the KCI_{QUAL_k} in CBP mode, (OC1-KCI_{QUAL-k}) = Median of the KCI_{QUAL} in I4.0 mode, (OC3-KCI_{QUAL-k})[104]

   b. H1: Median of the KCI_{QUAL_k} in CBP mode, (OC1-KCI_{QUAL-k}) > Median of the KCI_{QUAL} in I4.0 mode, (OC3-KCI_{QUAL-k})

The small number of observations was the main reason for selecting a non-parametric test, more specifically, the *Wilconxon-Mann-Whitney* test for comparison of medians. Nonetheless, there was also carried out equivalent Student t-tests (parametric) and the results corroborate those found in the non-parametric test.

(ii) In order to test whether IO_{QUAL_k} would be statistically significant (i.e., non-zero), the Student t-test was applied to the following hypotheses:

   a. H0: Mean of the $IO_{QUAL\_k} = 0$

   b. H1: Mean of the $IO_{QUAL\_k} \neq 0$

It should be noted that in this case, non-parametric equivalent tests were also applied, and the results corroborate those obtained by the t-Student statistic.

In order to evaluate the $IO_{QUAL-GLOBAL}$ of all stakeholders (global) as a whole, the test of comparison of the means based on the t-Student statistic was performed. From the 35 observations and assuming pairwise samples, the results are also shown, which were compared with non-parametric approaches (being corroborated by those tests), for which there were tested the following hypotheses:

   a. H0: Mean of the $IO_{QUAL-GLOBAL}$ in CBP mode, (OC1- $IO_{QUAL-GLOBAL}$) = Mean of the $IO_{QUAL-GLOBAL}$ in I4.0 mode, (OC3- $IO_{QUAL-GLOBAL}$)

[104] Despite the *Wilconxon-Mann-Whitney* test being based on the median comparison, the conclusions may be drawn for the respective probability distribution function and consequently the means.

b. H1: Mean of the $IO_{QUAL-GLOBAL}$ in CBP mode, (OC1- $IO_{QUAL-GLOBAL}$) > Median of the KCI_{QUAL} in I4.0 mode, (OC3- $IO_{QUAL-GLOBAL}$)

6.7.2 Results of the Statistical Analysis

Table 6.12 presents the *Wilconxon-Mann-Whitney* test results for the KCI_{QUAL_k} median equality, in OC1(CBP) and OC3 (I4.0), related to each k stakeholder.

Analysing the outputs (Table 6.12), it was found there was rejection of the null hypothesis of equality of the medians for the four main stakeholders, assuming a level of significance of 5%. The results also point to a reduction of the OC3-KCI_{QUAL_k} values, which means that stakeholder concerns are tendentially relieved when operations change to I4.0 mode, thus confirming the previously found results.

However, it must be noted that, on average, the differences appear to be less evident with respect to the OS-Competitors, confirming once again the results found previously, which might be due to the still immature state of I4.0 technologies in all sectors of the economy, some of the inherent concerns not yet being felt, or at least clearly identified, by all competitors.

KCI_{QUAL-c} RELATED TO OS-CUSTOMERS		N	Mean Rank	Sum of Ranks	Statistics	OC3-KCI_{QUAL-c} (I4.0) - OC1-KCI_{QUAL-c} (CBP)
OC3-KCI_{QUAL-c} (I4.0) - OC1-KCI_{QUAL-c} (CBP)	Negative Ranks	11	6.00	66.00	Z	-2.936
	Positive Ranks	0	0.00	0.00	p-value	.003
	Ties	1				
	Total	12				
KCI_{QUAL-p} RELATED TO OS-PROVIDERS		N	Mean Rank	Sum of Ranks	Statistics	OC3-KCI_{QUAL-p} (I4.0) - OC1-KCI_{QUAL-p} (CBP)
OC3-KCI_{QUAL-p} (I4.0) - OC1-KCI_{QUAL-p} (CBP)	Negative Ranks	8	4.50	36.00	Z	-2,521
	Positive Ranks	0	0.00	0.00	p-value	.012
	Ties	0				
	Total	8				
$KCI_{QUAL-cp}$ RELATED TO OS-COMPETITORS		N	Mean Rank	Sum of Ranks	Statistics	OC3-$KCI_{QUAL-cp}$ (I4.0) - OC1-$KCI_{QUAL-cp}$ (CBP)
OC3-$KCI_{QUAL-cp}$ (I4.0) - OC1-$KCI_{QUAL-cp}$ (CBP)	Negative Ranks	5	3.00	15.00	Z	-2,023
	Positive Ranks	0	0.00	0.00	p-value	.043
	Ties	3				
	Total	8				
KCI_{QUAL-a} RELATED TO AUTHORITIES		N	Mean Rank	Sum of Ranks	Statistics	OC3-KCI_{QUAL-a} (I4.0) - OC1-KCI_{QUAL-a} (CBP)
OC3-KCI_{QUAL-a} (I4.0) - OC1-KCI_{QUAL-a} (CBP)	Negative Ranks	7	4.00	28.00	Z	-2,388
	Positive Ranks	0	0.00	0.00	p-value	.017
	Ties	0				
	Total	7				

Table 6.12: *Wilconxon-Mann-Whitney* tests for Customers, Providers, Competitors and Authorities concerns results

The results found by the *Wilconxon-Mann-Whitney* test for the comparison of medians were corroborated by the results of the significance of the Innovations Outcomes (Table 6.13), where the null hypothesis of having an IO_{QUAL_k} with zero mean was rejected with 1% significance for all k stakeholders. This means there was a significant relief of stakeholder concerns when operations changed from CBP to I4.0 operations mode.

It must be noted that the concern relief was more significant in the OS-Providers and Authorities stakeholders, which may be justified by the fact that many of the OS-

Competitors were not aware of the competitive advantages resulting from I4.0 digital production, and also because during data collection for this research, these stakeholders did not have direct access to the close relationship between customers and providers characterizing the I4.0 operations mode.

$IO_{QUAL\text{-}K}$	N	Mean	Std. Deviation	Std. Error Mean	T-Statistics	Df	P-Value	Mean Difference
$IO_{QUAL\text{-}c}$ (OS-Customers)	12	0.587	0.256	0.074	7,952	11	0.000	0.587
$IO_{QUAL\text{-}p}$ (OS-Providers)	8	0.701	0.121	0.043	16.342	7	0.000	0.701
$IO_{QUAL\text{-}cp}$ (OS-Competitors)	8	0.353	0.335	0.118	2.982	7	0.020	0.353
$IO_{QUAL\text{-}a}$ (Authorities)	7	0.776	0.209	0.079	9.807	6	0.000	0.776

Table 6.13: Outputs of the significance test of the mean value of IO_{QUAL_k} for each stakeholder.

In the third test, where it has been compared the concern mean of the four stakeholders, there is a clear evidence of the rejection of equality of means in OC1 compared to OC3 (Table 6.14). It must be noted that being a unilateral test at the right, it is easy to see that the mean value of the concerns tends to decrease significantly in I4.0 operations.

$IO_{QUAL\text{-}GLOBAL}$	Mean	N	Std. Deviation	Mean Difference	Std. Deviation	t	Df	p-value
OC1 CBP and CAD Context	0.8438	35	0.68183	0.57870	0.59625	5.742	34	0.000
OC3 I4.0 and BIM Context	0.2651	35	0.16936					

Table 6.14: Outputs of the means test of comparison of the global concerns, through the *t-Student* statistic for paired samples

From the overall results, it seems clear that concerns present smaller values in the I4.0 context. It is important to mention that the sample is very small. However, it is also important to state that the sample is representative of the population (31% of CPMR-OS companies). Its small size could be problematic, but non-parametric tests were performed to overcome any potential gap that parametric tests might present. Although the tests performed point to clear relief of stakeholder concerns in I4.0 operations mode, indicating clear improvement in business conditions, it is not intended here to generalize results, but rather demonstrate the potential digital reality may bring to the CPMR population which represents CBP in the front-runners of a strategic Portuguese sector, as referred to in Chapter 2.

6.8 CHAPTER SYNTHESIS

In this Chapter, there was applied the Inov4.0|F to a sample of OS companies representative of the CPMR, as defined in Chapter 5 and following the methodology defined in Chapter 4, the conditions were established for data collection in three different operation contexts: (OC1) CBP-Providing in CAD-Procurement operations mode, in which providers have produced in CBP mode and customers have carried out the procurement as in the AECSC; (OC2) CBP-Providing in BIM-Procurement operations mode, in which suppliers kept the production in CBP mode and customers shifted procurement to BIM and (OC3) I4.0-Providing in BIM-Procurement operations mode, in which suppliers shifted operations to mode I4.0 and customers kept the procurement in BIM.

From the results, it has been found that Inov4.0|F as supported by Service Science Theory made it possible to measure the different stakeholder (k) Concerns through specific qualitative indicators and metrics ($KCI_{QUAL\text{-}k}$), and the respective confirmation by quantitative indicators ($KCI_{QUAN\text{-}k}$) in the three operations contexts (OC), from which it was possible to measure the evolution of these Concerns by using IO_{QUAL_k} and IO_{QUAN_k} Innovation Outcomes (Robert F Lusch & Nambisan, 2015). Supported by S-S theory, where *service innovation* (Stoshikj et al., 2016) is the result of the interactions between service systems, Inov4.0|F revealed that in OC3 (Figure C.10, Appendix C) there were 24 direct interactions between BIM-Customer and I4.0-Provider, mainly involving the Cockpit Back-Office resources.

Analysing the second set of 9 steps of the S-Print process (Figure C.11, Appendix C), the FP-I4.0 of the products was found to be terminated and from that, their Smart Object generated. It was also found that during Steps 10-18, all the human and technological Cockpit resources were called upon to intervene in every step, finding 54 interactions between the I4.0-Provider and BIM-Customer, ending Step 18, with confirmation of payment and the digital information shifting from FP-I4.0 status to Smart Object status.

During product execution, Phase 2 of the service process, the number of interactions remained high (56 interactions), which meant that the BIM-Customer had significant interest in remote monitoring of production operations executed by I4.0-OS-Provider resources (Figure C.12, Appendix C).

In Phase 3, Cockpit Back-Office resources were found to be most requested and were active in all steps of this phase, with thirty-four interactions between BIM-Customer and the I4.0-Provider being recorded in steps 28-37, ending with recycling of the product at the end of its life cycle (Figure C.13, Appendix C).

As a result of these value-creation interactions, it was possible through application of Inov4.0|F to measure the Customer Satisfaction Index evolution, through the evolution of concerns associated with the quantitative indicators (KCI_{QUAN_c}), finding that in BIM-Procurement when production shifts from CBP mode to I4.0 mode, the IO_{QUAL_c} $PLTC_{QUAN\_c}$ associated with "Product Lead Time Concerns" relieved 58%, the $PLWTC_{QUAN\_c}$ associated with "Product Labour Work Concerns" relieved 30% and the PQC_{QUAN_c} associated with "Product Quality Concerns" relieved 53% (Figure C.10, Appendix C), thus confirming the average relief of 59% found in qualitatively assessed concerns.

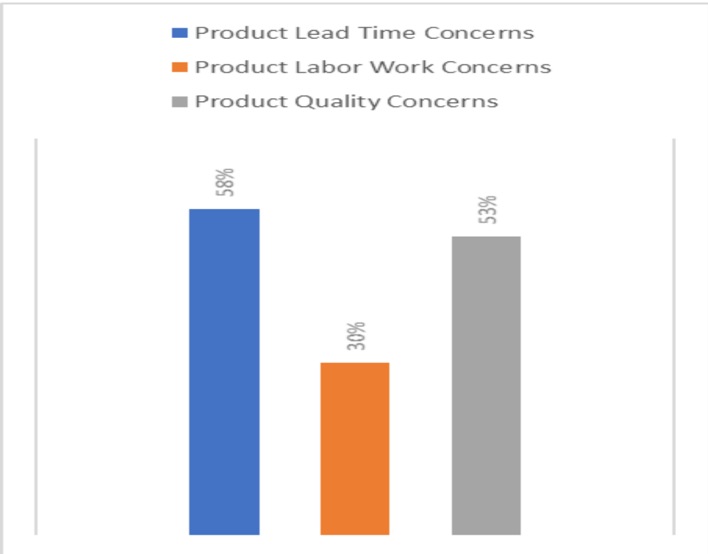


Chart 6.10: Customer Satisfaction Index (CSI) I4.0 Quantitative Impact | Customer Concerns Relief (%)

Likewise, by applying Inov4.0|F, it was also possible to measure the Provider Performance Index evolution, through the concerns associated with the Provider concern indicators ($KCI_{QUAL\text{-}p}$), (qualitative) in the BIM-Procurement context and the production shifts from CBP to I4.0, where it was found an average trend in concern relief of 69%, confirmed by IO_{QUAN_p} (quantitative), where the concerns related to Threat 2 (faster delivery trend) relieved 51%, the concerns related to Threat 3 (lower costs trend) relieved 33%, the concerns related to Threat 4 (lower emissions trend) relieved 32% and the concerns related to Threat 5 (lower non-quality tolerance) relieved 31% (Chart 6.11).

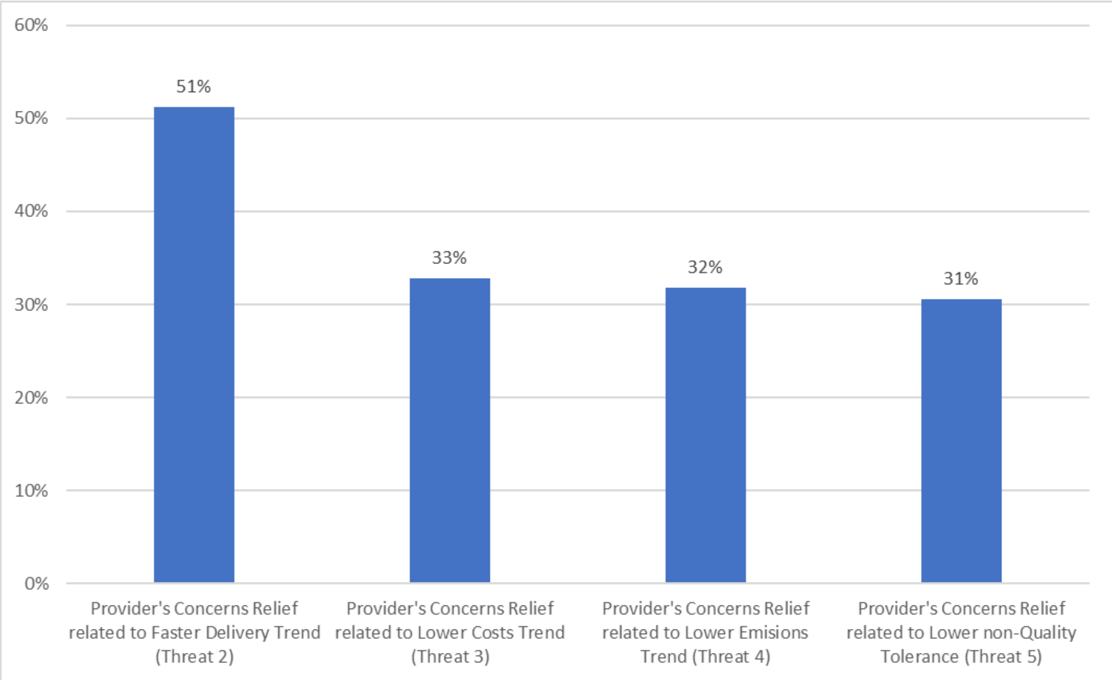


Chart 6.11: Provider Performance Index (PPI) I4.0 Quantitative Impact | Provider Concerns Relief (%)

It was also possible to measure evolution of the Sustainable Innovation Index and the Conformity Index through the evolution of OS-Competitor Concerns ($KCI_{QUAL\text{-}CP}$) and Authorities Concerns (KCI_{QUAL_a}), which in both cases, in the BIM-Procurement context when production shifts from CBP to I4.0, there was found an average gain in IO_{QUAL_cp} of 36% and an average gain of 78% in IO_{QUAL_a}, in the sense of favouring the OS-Provider business if it produces in I4.0 mode.

Finally, in an attempt to find final confirmation of the trends of KCI_{QUAL_k} and $IO_{QUAL\text{-}K}$, non-parametric tests were performed to compare medians, based on the Wilconxon-Mann-Whitney and t-Student statistic tests, also finding clear relief of stakeholder concerns when production shifted from CBP to I4.0.

CHAPTER 7

We make a living by what we get,
but we make a life by what we give.

Winston Churchill

7. CONCLUSIONS

This thesis enabled an exploratory evaluation of the I4.0 impact on the design of a response to face the Threats resulting from the BIM procurement in the Portuguese Ornamental Stone companies.

The INOVSTONE4.0 Framework (Inov4.0|F) is a representation developed by pursuing an abductive logic within a pragmatic paradigm, requiring multiple transactions between practice and theory, in order to express 36 process steps from each one of the different order fulfilment requirements occurring in each one of the anticipated Operations Contexts (OC) for the Current Best Practices Ornamental Stone (CPMR-OS) firms.

To increase Industry of Construction (IC) efficiency, in recent years some governments have implemented Official Initiatives to support and promote the generalization of digital technologies in the IC for management, design and procurement, designated BIM, from which they expect to achieve a substantial reduction in the initial cost of construction and the whole life cost of built assets, a reduction in overall time, from inception to completion, for newbuild and refurbished assets and a reduction in greenhouse gas emissions in the built environment.

The BIM generalization will give rise to a new procurement concept (BIM-Procurement) in the Architecture, Engineering and Construction supply chain (AECSC), which may result in threats to the companies belonging to the IC supply chain, such as Portuguese OS companies: (i) threat 1 (standardization trend) - in BIM, procurement will be oriented towards standardized products; (ii) threat 2 (faster delivery trend) - in BIM, procurement will be oriented towards a shorter overall time, from inception to completion, for newbuild and refurbished assets; (iii) threat 3 (lower costs trend) - in BIM, procurement will be oriented towards a lower cost of construction and the whole life cost of built assets; (iv) threat 4 (lower emissions trend) - in BIM, procurement will be oriented towards lower greenhouse gas emissions in the built environment; (v) threat 5 (lower non-quality tolerance) - in BIM, procurement will be oriented towards lower non-quality tolerance of errors and mistakes, which results in time wasted, increased costs and a larger ecological footprint.

Given the drift towards the digital economy witnessed, the Research Problem (RP) of this thesis is focused mainly on these threats, but also on the opportunities currently open to the Portuguese OS sector. On the one hand, these companies will have to face the threats resulting from the shift in procurement, on the other hand, which competitive advantage may arise from the digitalization of productive processes supported by CPS and designated as Industry 4.0 (I4.0)? This dichotomy resulted in the Research Problem (RP) of this thesis: What impact could Industry 4.0 have on the response of CPMR-OS companies to the threats posed by BIM procurement in the AECSC?

Supported by the RP, the Research Questions (RQs) were defined, to which answers were obtained by applying the Inov4.0|F to a representative sample of CPMR-OS companies:(i) RQ1 - will Industry 4.0 operations, in the context of BIM-Procurement (standardization trend), allow CPMR-OS companies to retain their main current competitive advantage of customizing their products? (ii) RQ2 - will Industry 4.0 operations, in the context of BIM-Procurement (faster delivery trend) reduce the delivery time of CPMR-OS companies' products when compared to the current way of operating? (iii) RQ3 - will Industry 4.0 operations, in the context of BIM Procurement (lower costs trend), reduce the cost of CPMR-OS companies' products when compared to the current way of operating? (iv) RQ4 - will industry 4.0 operations, in the context of BIM Procurement, reduce the ecological footprint of CPMR-OS companies' products, when compared to the current way of operating? (v) RQ5 - will Industry 4.0 operations, in the context of BIM Procurement (lower non-quality tolerance), reduce the non-quality of CPMR-OS companies' products when compared to the current way of operating?

From the CPMR-OS companies population in which CBP are considered, has been used a convenience sampling process, selecting 31% of the companies in the whole population. These were the companies directly involved in the negotiation, production and delivery of the orders monitored in this research: (i) in the operations context of CBP-Providing in CAD-Procurement (OC1), (ii) in the operations context of CBP-Providing in BIM-Procurement (OC2) and finally, (iii) in the operations context of I4.0-Providing in BIM-procurement (OC3). During the orders' follow-up, qualitative and quantitative data were collected and the normative nature of the Step Outcomes (SO) was also observed in all steps of the service process.

It was for these Operations Contexts that the Inov4.0|F was conceptualized, from the Service Science perspective and keeping in mind that the digital economy has a high level of complexity, in terms of actors and interactions occurring simultaneously and globally.

Once the challenges of conceptualizing Inov4.0|F were overcome, through its application, the challenge was to evaluate the impact of I4.0 on the response of the OS companies from the CPMR to the threats from BIM procurement, achieving the following objectives: (i) OC1 - stakeholder resources were described and configured, in the context of providers in CBP operations mode (CBP-Providers) and customers in current CAD-Procurement; (ii) OC2 - stakeholder resources were described and configured in the context of CBP-Providers and customers in BIM-Procurement; (iii) OC3 - stakeholder resources were described and configured in the context of providers in Industry 4.0 operations mode (I4.0-Providers) and customers in BIM-Procurement; (iv) the Step Outcomes (SO) and Key Concern Indicators (KCI) were determined in each Step of the service process, in the three contexts of operations (OC1, OC2 and OC3); (v) the Innovation Outcomes (IO) were determined in the three contexts of operation (OC1, OC2 and OC3).

As I4.0 is digital production supported by CPSs, Inov4.0|F contemplated the reengineering of I4.0, to incorporate two innovative concepts of value co-creation supported by Service Science Theory: (i) the Fingerprint (FP-I4.0) – a vehicle to streamline the specifications of the customized product and make it available in a standardized way to the BIM operator and (ii) Cockpit – a humanized interface between the I4.0-OS-Provider and OS-Customer.

To map the service process, keeping the base matrix of the Shostack model (1982), a specific S-Bprint format was developed as part of Inov4.0|F, which mapped the activities and access to the resources of the service systems (S-Systems), in the three contexts of operation referred to (OC1, OC2 and OC3), the SO being determined through the ISPAR methodological tool.

Since each stakeholder is expected to make a different assessment of the value of the proposals, the concerns of the different stakeholders were defined in terms of Key Concern Indicators (KCI) with which it was possible to measure the concerns in a qualitative and quantitative way and their evolution in the shifting context, through qualitative and quantitative Innovation Outcomes (IO), as defined by Service Science.

Once the sample was clearly defined, the qualitative and quantitative data were collected on the four stakeholders' sites (Customers, Suppliers, Competitors and Authorities), as recommended by S-S, through the follow-up of ten orders, co-processed by the service systems in the three different Contexts of Operations as described above. From the data collected, the different concerns (KCI) of each of these stakeholders were determined and indexed to each other in "Indexes": (i) the OS-Customer Concerns indexed to the CSI; (ii) the OS-Provider Concerns indexed to the PPI; (iii) the OS-Competitor Concerns indexed to the SII and (iv) the Authority Concerns indexed to the CI.

By applying Inov4.0|F to a sample of CPMR-OS companies, it was found that in OC2 (CBP-Providing in BIM-Procurement), it was not possible for the sample CPMR-OS companies to provide any of the customized orders under BIM-Procurement, thus losing in BIM-Procurement mode one of their main current competitive advantages. From this discrepancy between the CPMR-OS companies' model of competitiveness and BIM-Procurement, it may be concluded that Threat 1 (standardization trend) is no longer potential but real, since in standard mode, the IC will tend to move purchase from natural stone to high homogeneity materials and in cases where BIM-Customers are interested in standard natural stone, the CPMR-OS companies will no longer be competitive against their Asian and Eastern European competitors.

Comparing OS-Customers' Concerns when operations evolved from OC1 (CBP & CAD) to OC3 (I4.0 & BIM), relief was found in Product Lead Time Concerns (58%), Product Labour Concerns (30%) and Product Quality Concerns (53%), thus confirming the average relief of 59% found in the qualitatively assessed concerns, and thus, from OS-Customers' perspective, the impact of I4.0 seems to be positive, in the sense that it favours the CPMR-OS companies' business.

By evaluating SII and CI through the evolution of OS-Competitor Concerns and Authority Concerns, average gains of 36% and 78% respectively were found in the BIM-Procurement context when operations evolved from CBP to I4.0 mode, and thus, for OS-Competitors and Authorities, the impact of I4.0 seems to favour CPMR-OS companies' business.

Non-parametric means comparison tests, based on the Wilconxon-Mann-Whitney statistic and t-Student, determined the significance of the effective reduction (relief in average terms) of stakeholder Concerns when operations evolved from OC1 to OC3, finding clear relief of the stakeholder concerns analysed and thus, in BIM-Procurement the impact of I4.0 seems to be positive, in the sense that it favours CPMR-OS companies' business. These results provided answers to the Research Questions (RQs), as stated in the chapter on Methodology.

Answer to RQ1 – In CBP-Providing in BIM-Procurement (OC2), Step 5 of the service process revealed a non-normative Step Outcome (SO = -S) for all monitored cases, thus stopping definitively the service process at this Step, since it was not possible for BIM-Customers to get customized products for their projects, from the BIM-WEB-Libraries. On the other hand, keeping BIM-Procurement but evolving the production operations to I4.0 (OC3) resulted in (SO = S) in all steps of the service process for all the monitored cases. Thus, in answer to RQ1 it may be concluded that in the BIM-Procurement context, OS-Providers can retain their main current competitive advantage of customizing their products.

Answer to RQ2 - Observing the PPI index when operations evolved from OC1 to OC3, it was concluded that the OS-Provider Quantified Concerns related to Threat 2 (faster delivery trend) diminished by 51%, confirming the mean relief of 69% in qualitatively assessed concerns. Thus, in answer to RQ2, it may be concluded that in BIM Procurement, Industry 4.0 operations can reduce the "delivery time" of CPMR-OS companies' products by 8.17 h per m2, when compared to delivery time in the current way of operating.

Answer to RQ3 - Observing the PPI index when operations evolved from OC1 to OC3, it was concluded that the OS-Provider Quantified Concerns related to Threat 3 (lower costs trend) diminished by 33%, confirming the trend found when assessing concerns qualitatively. Thus, in answer to RQ3, it may be concluded that in BIM Procurement, Industry 4.0 operations can reduce the "cost" of CPMR-OS companies' products by 13.35 € per m^2, when compared to the current way of operating.

Answer to RQ4 - Observing the PPI index when operations evolved from OC1 to OC3, it was concluded that the OS-Provider Quantified Concerns related to Threat 4 (lower emissions trend) fell by 32%, confirming the trend when assessing concerns qualitatively.

Thus, in answer to RQ4, it may be concluded that in BIM Procurement, Industry 4.0 operations can reduce the ecological footprint of CPMR-OS companies' products by 2,26 $KgCO_2$ per m^2, when compared to current operations.

Answer to RQ5 - Observing the PPI index when operations evolved from OC1 to OC3, it was concluded that the OS-Provider Quantified Concerns related to Threat 5 (lower non-quality tolerance) fell by 31%, confirming the trend in qualitatively assessed concerns. Thus, in answer to RQ5, it may be concluded that in BIM Procurement, Industry 4.0 operations can reduce the "non-quality" of CPMR-OS companies' products, compared to the current way of operating.

From these results, which did not consider the important investment component needed to become I4.0, it may be concluded that for CPMR-OS companies, BIM procurement may even become an opportunity if they have the capacity to invest and I4.0 technologies become available and mature, since the impact of this operation model on their response to the threats arising from BIM procurement is technically positive, letting us recommend I4.0 to these companies, especially when BIM becomes the globally adopted technology in the AECSC.

We can also conclude that the Inov4.0|F, conceptualized according to Service Science Theory was appropriate for the RP addressed in this thesis, allowing the combination of qualitative and quantitative data in a convergent way, and enabling robust conclusions to be drawn about the response of CPMR-OS companies in different operational contexts, resulting in the first contribution of this thesis to practice.

In describing and configuring stakeholder resources, and in accordance with the objectives of this research, determining the KCI and IO in the three different contexts (OC1, OC2 and OC3), it may be considered it has been found a possible solution to the RP as described in the chapter on Methodology. Since the objectives have been successfully achieved, it may be believed this thesis have contributed to the development of CPMR and to the Ornamental Stone sector in general, thus contributing to people's well-being and the Sustainability of the Planet.

From these conclusions, it maybe considered the suitability of Inov4.0|F as a possible practical tool for other ornamental stone types or other mineral resources, resulting in additional contributions to practice, but also with academic interest, since S-S theory proved to be able to support the innovation and understanding of value co-creation interactions among actors in the Ornamental Stone business, both in current operations (OC1) and in the future (OC3).

In addition to the empirical analysis that strengthens the scope of the objectives of this thesis, it must be emphasized the contribution to theory resulting from the development of a Conceptual Framework, supported by Service Science Theory. Guided by the Pragmatist paradigm and using the mixed methodology of parallel convergence, it was possible to evaluate the CPMR population, in two market contexts and in two different forms of production.

Contribuitons

This exploratory research was "an attempt" for pointing out an innovative way, by setting the scene and showing that the proposed approach is justified, desirable, feasible and, therefore, it is recommended to pursue it and, also, to fine tune it, later on. Consequently, without being fully comprehensive the following relevant contributions might be enumerated as examples:

To Theory - using the Theoretical Foundations of the Body of Knowledge of S-S to support design and development of the thesis model; proposing relevant ideas as a result of the maturation of the theoretical review, e.g. the development of the Body of Knowledge for S-S based on the perspective, propositions and vocabulary of S-D Logic; exploring and discussing the divergencies and gaps between S-S and S-D Logic; then, making a conclusive choice concerning the definitions to be followed in the thesis; operationalising stakeholders' concerns into KCI; developing the thesis conceptual model supported by S-S: Operationalization of concepts linked with Service Science, i.e. Step Outcomes (SO), Key Concern Indicators (KCI) and Innovation Outcomes (IO) and the definition of X-variables, Y-variables and intermediate variables.

To Research - using pragmatism as the research paradigm to include real world practices; using an evolutionary and interactive approach (i.e. abductive) to extract the knowledge from the expert, which is a major issue in Knowledge Based Systems; developing the INOVSTONE4.0 Framework to operationalize S-S; redesigning the use and developing of the technique Service Blueprinting; assessing multiple stakeholders' interest with the ISPAR tool, providing a solution for the requirements validation concern; enabling a seamless innovative approach to a common business process (order fulfilment) to describe both its product and service requirements altogether; operationalising stakeholders' concerns into KCI; appreciating and discussing (evaluate) the impact of I4.0.

To Practice - providing guidance in decision making as concerns BIM threats, BIM procurement, and I4.0; appreciating and discussing (evaluate) the impact of I4.0; implementing process steps with no distinction between tangible and intangible; identifying and evaluating the process steps and resources transactions in order fulfilment by stakeholders; pragmatic use of current performance indicators (multi-stakeholder view).

Limitations

Although the proposed objectives have been broadly achieved, there were several difficulties to overcome during this research, which led to some limitations.

The literature review revealed that the Service Science literature dealing with I4.0 is scarce and, even more so, the literature on I4.0 digital production applied to a traditional sector and studied from the perspective of this new scientific discipline, a situation that caused additional difficulty in the conceptualization of Inov4.0|F.

Since the framework is empirical, its implementation is a limitation of the research results; Natural patterns of the materials are data that might limit the results, specially when compared with industrial materials because of the difficulty to match them, later on, in case of reordering or even replacement; Differences in the orders considered in the empirical test may limit the results as well.

Monitoring the entire sequence of events from the discussion of orders to delivery of the products to customers was another difficulty found in this research, since a great amount of data occurred simultaneously and in different geographical locations. For this difficulty to have the least possible impact on the data collected, the assistance and collaboration of stakeholders' human resources was essential. This was provided by managing directors, section managers and operators, who not only registered the data at the researcher's request, but also allowed access to their records and databases. The difficulty in accessing data was greater in the orders executed in CBP production mode (OC1 and OC2), because in this mode of production, several operations, especially logistics, are (still) executed manually or semi-automatically. Therefore, in these situations, some data were collected by checking the manual records written by the operators, according to the practices of their respective companies.

The difficulty in identifying competitors who were "competing" for the same orders was perhaps the most difficult task during the data collection process, since directly asking potential competitors if they were competing for the orders monitored would mean passing on information from the providers with whom the researcher was committed to confidentiality. It has been overcame this difficulty via the customers, and through them, obtained the names of the different potential providers in competition, again adhering to ethical commitments and confidentiality. In some cases, it became necessary to prove this research had strictly academic purposes.

During application of Inov4.0|F to the sample companies, it has been found that the state-of-the-art BIM releases were still restrictive, especially in the dimensions related to Sustainability (6D-BIM), Maintenance (7D-BIM) and Security (8D-BIM), the different BIM releases in the market appearing to be far from maturity. To overcome these limitations the orders size in I4.0 were small m^2 / per order, able to be executed by the "prototype mini-factory I4.0". This resulted in limitations related to the information and data collected in OC3.

This research was focused on a single type of stone, the most representative in CPMR companies (moleanos[105]) and on one type of application (cladding) to create the minimum conditions for the results be comparable. Thus, despite all the limitations previously described, it may be believed the results found in this thesis can be generalized to other stone support systems used in building facades.

Recommendations for Future Work

This exploratory assignment has raised questions in order to create the right conditions to develop an explanatory research later on: In the context of this RP, it may be considered as possible future developments, dynamic analysis of the cost-benefit relationship and interpretation of the frontier conditions, related to the investment required to operate in I4.0 mode, aiming for better understanding and to provide investors with more solid and detailed information on which to base their investment decisions.

---

[105]Limestone white-brown, roughly calciclastic, slightly olytic, abundantly bioclastic.

Other possible future developments related to this Research Context may focus on evaluation of the I4.0 response in other stone types and applications other than cladding, applied to the Ornamental Stone sector in general without forgetting to identify the training requirements of new I4.0 professionals in the sector.

Finally, as the aim of this research was to conceptualize an empirical framework supported by Service Science Theory, to be applied to a sample of CPMR-OS companies, possible future developments may be carried out to adapt Inov4.0|F to other OS applications, to the OS sector in general or to another sector of activity.

APPENDIX A

INOVSTONE4.0 FRAMEWORK SERVICE BLUEPRINTING

The service blueprinting (S-Bprint) is a process mapping tool, first introduced by Shostack (1982), (Figure A.1) and later developed by Kingman-Brundage (1989). It is composed of five lanes - Customer Actions, Physical Evidence, Customer Actions, Frontstage, Backstage and Support Processes lanes, and separated by 3 lines – line of Interaction, Line of Visibility and Line of Internal Interaction (Bitner et al., 2008b).

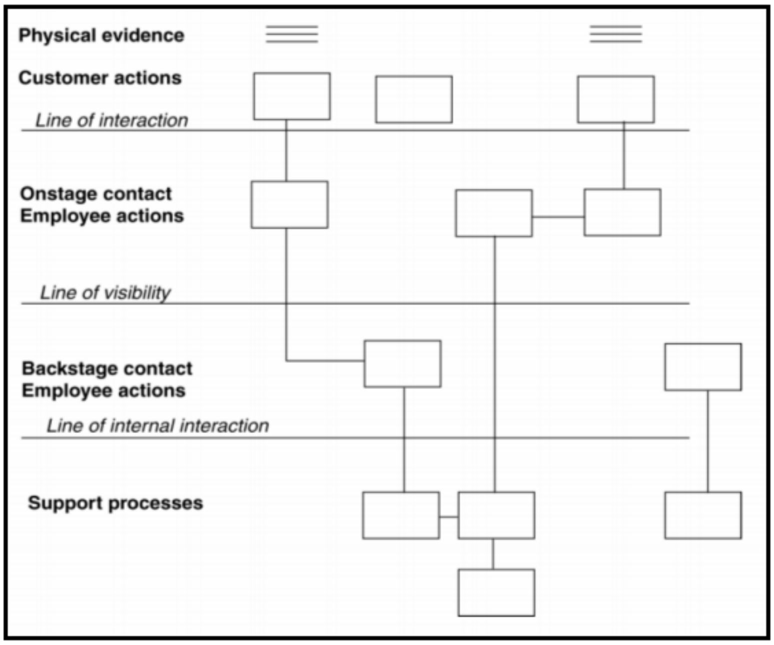


Figure A.1: Service Blueprinting Classic Layout (Shostack, 1982)

In its simplest form, the description of a service process by the S-Bprint is a linear representation composed of individual sequential steps, above the line of visibility, where all potential influences on the process, inputs and outputs must be represented (Boughnim & Yannou, 2005). Recommended by Service Science, the S-Bprint has proved to be a very powerful tool (Kwan et al., 2016), mainly because it is easily adapted to each case and is thus flexible and continuously improving. Although there is no standard symbology format, according to Suhardi, Doss and Yustianto (2015), actions must be represented by rectangles, transitions by arrows, start / end points by rounded rectangles and decisions or ramifications by diamond shapes (Figure A.2) (Seyring et al., 2009). For Suhardi, Doss and Yustianto (2015), the use of flow diagrams within the service blueprint is a good way to map the service process, proposing that actions be represented by rectangles, transitions by arrows, start/end points by rounded rectangles and the decisions or ramification by diamond-shaped figures (Figure A.1) (Seyring et al., 2009).

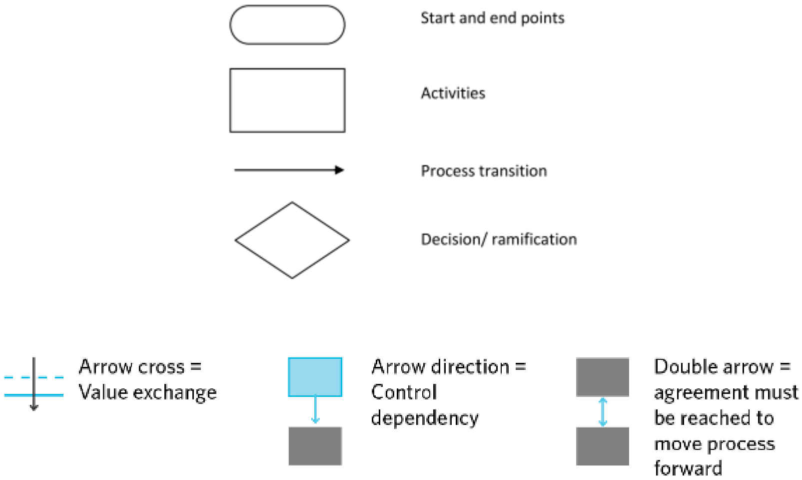


Figure A.2: Service Blueprinting Symbol System (Seyring et al., 2009)

The arrows have a very important symbolic meaning in S-Bprint because, in addition to the direction of the value exchange, they indicate on which resource the outcome depends more in each Step of the process (Suhardi et al., 2015). When an arrow crosses a lane, the value is being exchanged through the points of contact (Seyring et al., 2009). A single unidirectional arrow means that the source of the arrow has control of the value exchanged at that point, whereas a double arrow indicates it is necessary to agree between the two resources or entities for the process to move to the next Step (Boughnim & Yannou, 2005). The description of a service process by the S-Bprint tool entails placing the resources that make up each of the horizontal lanes as well as their activities, as much as possible supported by official documentation (Kingman-Brundage, 1989), from where the service process mapping begins in time (Seyring et al., 2009) and maintaining the rigor and constancy of the data collection methods recommended by S-S, such as observations, tracking and monitoring the Step transitions (Boughnim & Yannou, 2005). Thus, the S-Bprint tool maps the process steps in chronological order, so the description of the activities must be synchronized with the decomposition of the service process (N. Cardeal & António, 2012). During each Step of the process the resources will carry out activities whose results must be measured and used as data to calculate the concerns of each main stakeholders, as recommended by (Spohrer & Kwan, 2009). However, for some authors (Suhardi et al., 2015), S-Bprint loses its effectiveness if it is used to optimize the interest of multiple actors simultaneously (Suhardi et al., 2015), so this is one of the limitations of this methodological tool. Use of the S-Bprint tool in S-S is aimed at monitoring processes and designing innovative interactions that generate additional value for the actors involved (Spohrer & Kwan, 2009). This means that a S-Bprint map in S-S must be more than just a representative game (Kwan et al., 2016) where for each Step the contact points between resources are interpreted and the results measured. Whenever any result is not satisfactory, it means it is necessary to innovate in that Step in the form and content of the value interactions (S. L. Vargo & Lusch, 2010), in order to improve the output, that is, the value, for each of the S-Systems involved in the co-operative process (Fraunhofer, 2012).

Service Blueprinting For CBP-Providing In CAD-Procurement

For the Inov4.0|F, the service blueprinting must keep the traditional format as introduced by Kingman-Brundage (1989), (Bitner et al., 2008b; Kwan et al., 2016) separating the service in individualized steps and representing horizontally the individual components (resources and their activities), divided in lanes and ordered vertically. Phase 1 of the service process must be related to Design, Proposal Discussion and Order Processing involving 18 main steps: Step 1 corresponds to the CAD-Customer's connection to the Internet and Step 18, the order confirmation and down payment by the customer. Phase 2 is related to Order Execution and Phase 3 to Shipping, Using & Recycling.

In CAD-Customer and CBP-Providing operations mode (OC1), the S-Bprint format is not far from the classical Shostack format (Shostack, 1982) later improved by Kingman-Brundage (Kingman-Brundage, 1989), and thus, the Line of Interaction separates the activities of the CAD-Customer from those of the CBP-Provider (Seyring et al., 2009), which means there is close contact between the customer and the provider, often face-to-face or by phone or email (Figure A.3) (Fraunhofer, 2012). For the CAD-Customer the Line of Visibility separates the CBP-Provider's visible activities from the hidden activities (Seyring et al., 2009). As the name indicates, it is associated with how far the eye can see, or at the most, how far the customer can go with a phone-call or email (Boughnim & Yannou, 2005): OC1 CBP-Providing in CAD-Procurement Operations Context; OC2 CBP-Providing in BIM-Procurement Operations Context; OC3 I4.0-Providing in BIM-Procurement Operations Context.

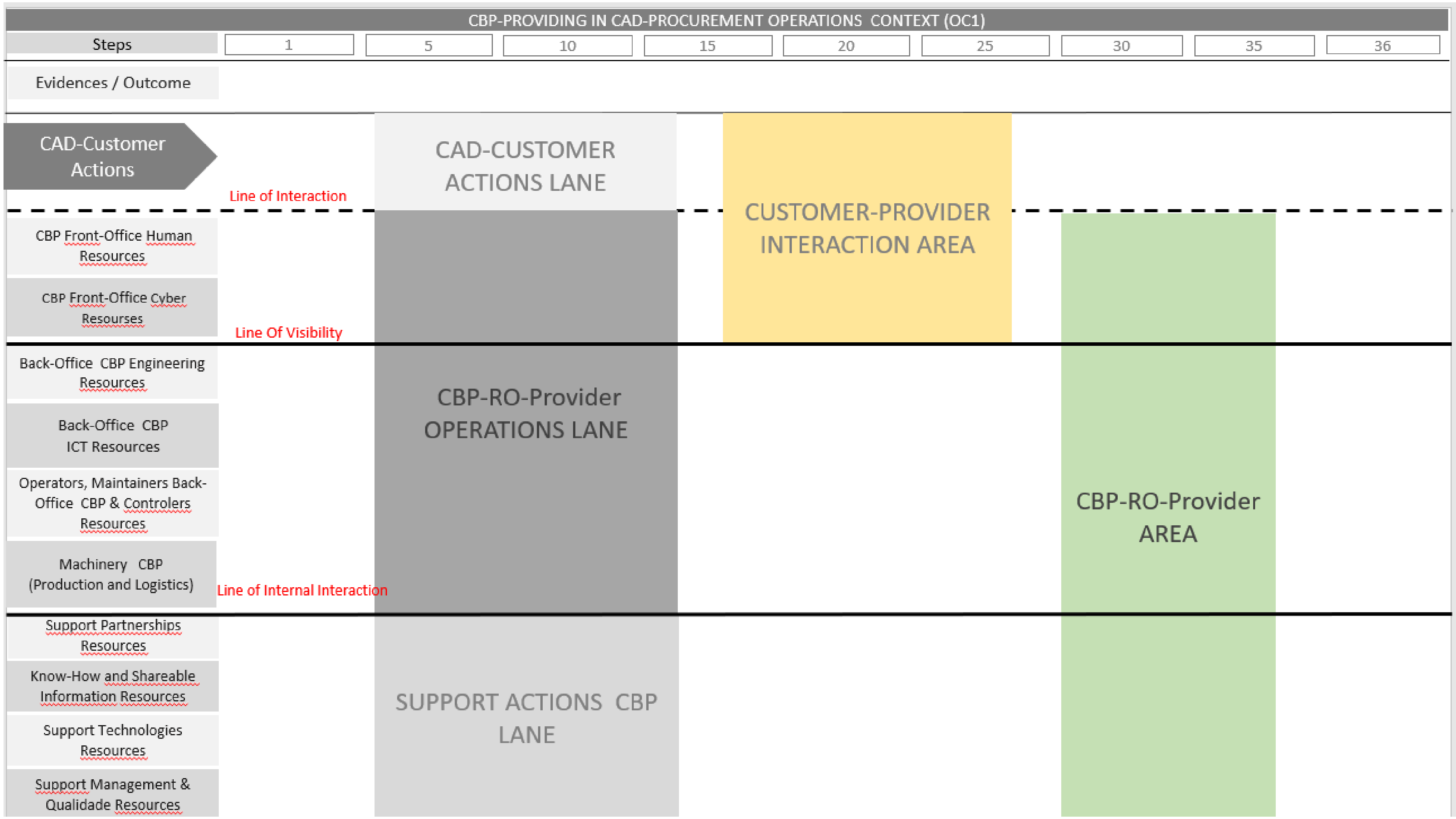


Figure A.3: Service Blueprinting Lanes Format for CBP-Providing in CAD-Procurement (OC1) Operation Context

For Inovstone4.0, the *Line of Internal Interaction* separates the CBP-Provider activities related to the value proposition or execution of the order, from the activities that support the value propositions or order execution as well as in the Kingman-Brundage model (Bitner et al., 2008b), with the understanding that beyond this line the CBP-Provider resources have no direct or indirect contact with the customer resources.

For ease of viewing, the *Evidence and Outcomes* Lane is usually placed at the top of the customers' actions, but in some S-Bprint applications such as the "six-layers" (Kwan et al., 2016), this designation is replaced by "Innovation Outcome", placed at the bottom of the S-Bprint map. Regardless of the designation, these are the physical proof of the co-creative actions and their outcomes, in the form of facts, places, formulas, products or signs used or seen by the customer (Bitner et al., 2008b) along the co-creative journey.

The *CAD-Customer Actions Lane* describes the CAD-Customer's interactions with the CBP-Provider throughout the service process as well as in the Shostack model (Hsu, 2016). If the customer does not interact, it simply ceases to be considered an S-System from the Service Science perspective (Spohrer, 2007) and there will be no more value co-creation (Seyring et al., 2009).

The classic *Frontstage Contact Actions Lane* (Kingman-Brundage, 1989) is delimited above by the *line of interaction* separating independent customer activities from provider activities (Seyring et al., 2009) and below by the *line of visibility*. The Frontstage Lane represents all the activity, people or physical evidence that the CAD-Customer can observe during the service process (Boughnim & Yannou, 2005), but in OC1 the Inovstone4.0 replaces this lane with the *Customer-Provider Interaction Area.*

The *Backstage Contact Actions Lane* is delimited in the traditional format (Shostack, 1982) by the *visibility line* above, which separates the visible activities from the hidden activities (Seyring et al., 2009) and the *line of internal interaction* that separates the activities of the provider related to the value proposition or order execution, from the activities that support these value propositions or order execution (Bitner et al., 2008b). The *Backstage* Lane contains all the activities and means required to produce the service the client expects to receive, and in some variants of the S-Bprint, this is designated *Execution* Lane (Kwan et al., 2016). Thus, for Inovstone4.0 when in OC1, only the *CBP-OS-Provider Area* must be considered as an area including both traditional lanes mentioned above (Figure A.3).

Support processes are all means and actions that support the service and the value co-creation from the provider side (Boughnim & Yannou, 2005), and therefore, in the OC1 operation context they must be designated *Support Actions CBP-Provider Lane* and delimited at the top by the *Line of Internal Interaction* (Fraunhofer, 2012).

Service Blueprinting For CBP-Providing In BIM-Procurement

In BIM-Customer and CBP-Providing operations mode (OC2), the S-Bprint format is similar to the one described for OC1, both in terms of lanes and lines (Figure A.4), replacing the *CAD-Customer Lane* with the *BIM-Customer Lane.*

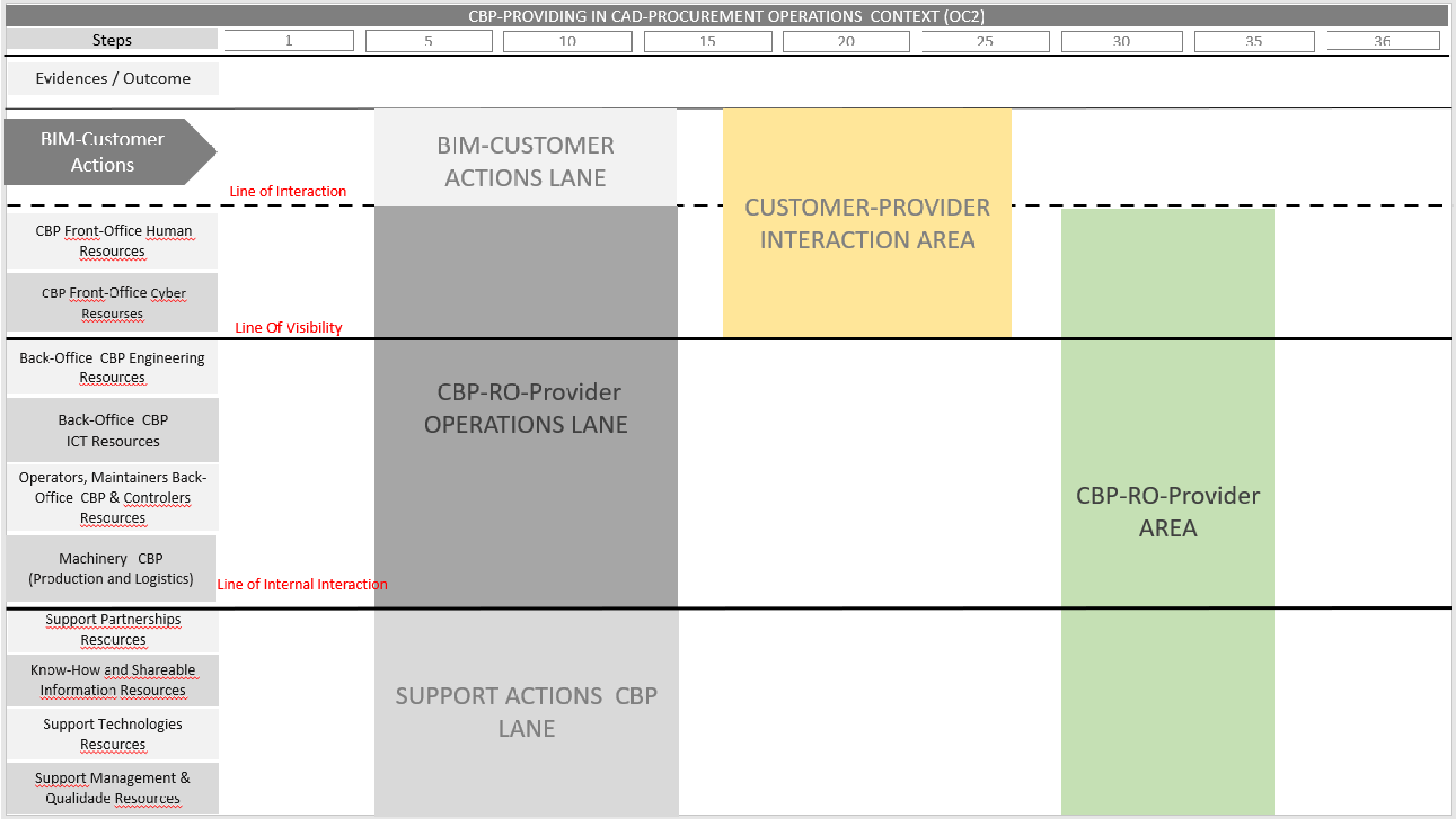


Figure A.4: Service Blueprinting Lanes Format for CBP-Providing in BIM-Procurement (OC2) Operation Context

For Inovstone4.0, in the OC2 Context, Phase 1 of the service process must also be related to *Design, Proposal Discussion and Order Processing,* Phase 2 related to *Order Execution* and Phase 3 related to the *Shipping, Using & Recycling*.

Service Blueprinting For I4.0-Providing In BIM-Procurement

Supported on the original format by Kingman-Brundage (Bitner et al., 2008a; Kingman-Brundage, 1989; Kwan et al., 2016), the S-Bprint to be used in Inovstone4.0 proposed in I4.0-Providing in BIM-Procurement (OC3) must be adapted to the digital economy, but must keep the classic separation of service in individualized processes by steps represented horizontally, the individual components (resources activity) divided in different lanes and ordered vertically (Shostack, 1982).

The classic *Customer Interaction Line* as introduced by Kingman-Brundage (1989) separates the customer's activities from the provider's activities, which matches perfectly with the traditional economy, in which customer-provider interactions normally involved close contact or a phone call or more recently email.

In contrast, in the IoT ecosystems (Matthies & D'Amato, 2016) in OC3, this line will be permanently crossed by the Internet, and thus, the Customer becomes a Cyber-Customer connected to the digital Provider, which could be a simple 3D printer or a I4.0 factory. The BIM-Customer and I4.0-Provider remotely enter into co-creative mode, interacting through value-propositions and the *Customer Interaction Line* is renamed *Line of Cyber Interaction* and represented by a dashed line (Figure A.5).

For the customer, the *Line of Visibility* separates the visible activities from the hidden activities (Shostack, 1982), a situation which, like other lines, is perfect to describe the traditional economy where as the name itself indicates "Visibility" is associated with how far can be seen, or at the most, as far as the customer can reach a provider resource by phone or by email. As detailed in Chapter 4, to describe a CPS architecture the Inov4.0|F proposes a new resource configuration, "the Cockpit", which as part of the CPS, operates as the dialogue and interaction frontend entity both upwards to the Customer from which the outcome is the FingerprintI4.0 product and downwards to the CPS Body whose outcome is the Smart Object.

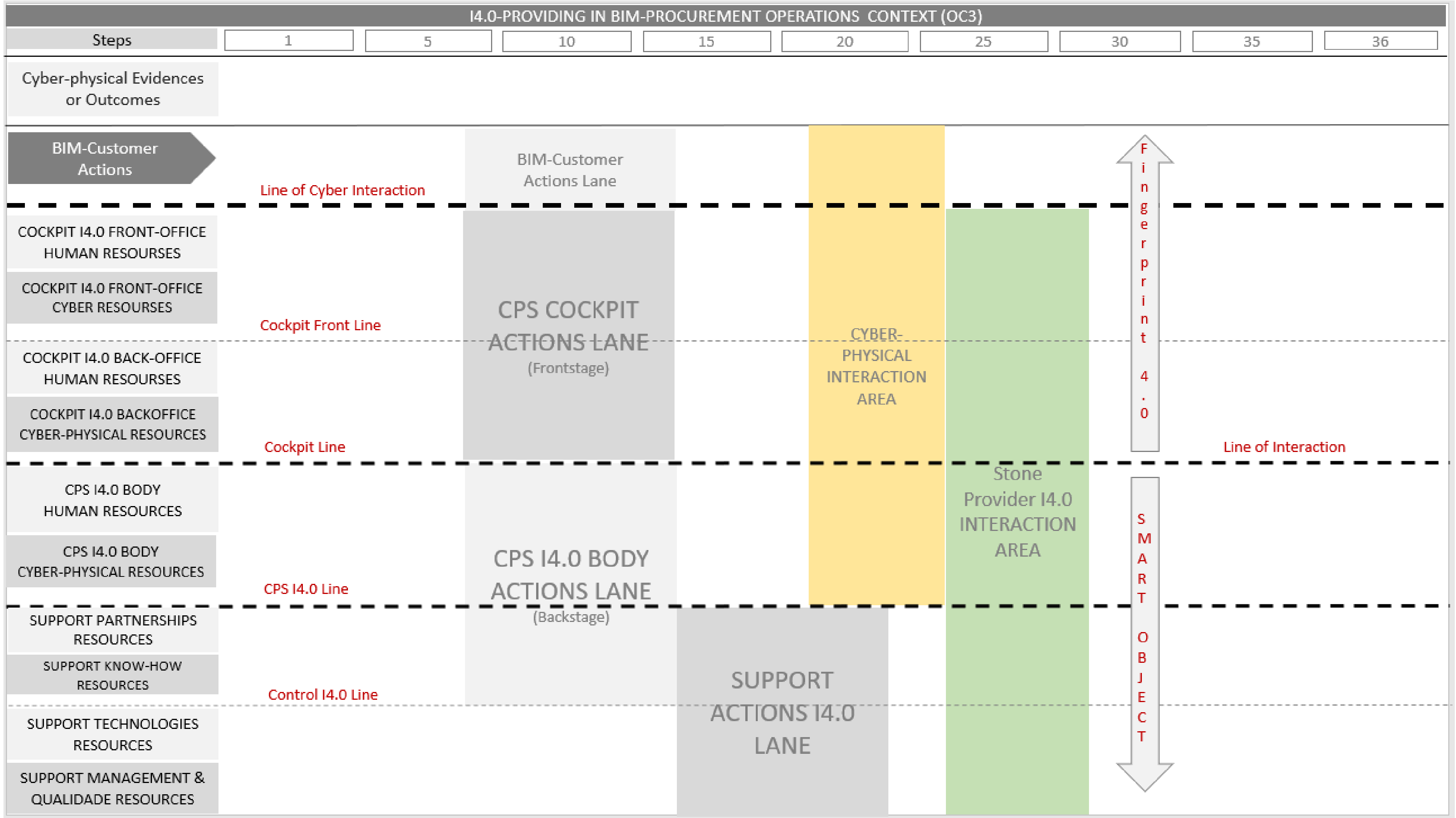


Figure A.5: Service Blueprinting Format for I4.0-Providing in BIM-Procurement (OC3) Operation Context

Thus, in OC3, the S-Bprint must have a new line type, replacing the traditional *Line of Visibility*, beyond which the BIM-Customer only has indirect access, via Cockpit, representing the limit of the remote co-creative interfaces and functioning as a separation between the Cockpit and the CPS-Body, designated *CPS Cockpit Line*, a dashed line since for I4.0, the Cyber-Customer can see beyond it (Figure A.5).

In the classic format (Shostack, 1982), the *Line of Internal Interaction* separates the activities in some way linked to the value proposition or execution order, from the activities that support those value propositions or order execution. To map OC3, where production must be supported by a CPS which shares a huge amount of information (big data) in real time (Lee et al., 2014) with all the other resources of productive equipment, customers, products themselves and human resources in real time, the *Line of Internal Interaction* represents the frontier of the CPS itself that supports I4.0 and thus must be renamed *CPS Line*, a dashed line since in I4.0 there are no “watertight compartments” for the Cyber-Customer as detailed in Chapter 2. For some authors (Kwan et al., 2016), it is common to use additional lines (secondary lines) to better visualize the activities of the Provider resources (Kwan et al., 2016). As detailed in Chapter 4, the Cockpit is composed of four groups of resources, distributed by the *Front-Office* and *Back-office* groups of resources. The Front-Office resources are the “front-line” of the Cockpit, available for the customer 24 hours a day, 365 days a year if possible and the Back-Office resources are those that support the Front-Office upwards and the CPS-Body downwards, from creation of the smart-objects to supervision of the productive process.

To separate these two resource groups as defined by the Inovstone4.0, the S-Bprint must have a secondary helpline to identify innovative possible paths to the process of value interactions (innovation outcomes), designated *Cockpit-Front-Office-Line*. Similarly, underneath the *Line of Internal Interaction* of the classic format (Kingman-Brundage, 1989), some authors add other secondary lines (Bitner et al., 2008b), delimiting activities inside the provider itself, to better detail the resources involved in the co-creative actions (Suhardi et al., 2015). Support Resources usually come from partnerships in the form of agreements, know-how, shareable information and from production technologies and the management-quality team. For this purpose, following the proposal of Seyring, Dornberger and Suvelza (2013), the S-Bprint in OC3 must have a Control Line (Seyring et al., 2009) dividing these two sub-groups of support resources designated *Control I4.0 Line* (Figure A.5).

For the Classic S-Bprint format, the *Physical Evidence Lane* represents the physical evidence of the co-creative outcomes, such as facts and places, but also formulas, products or signs used or seen by the customer along the co-creative journey (Kingman-Brundage, 1989). In OC3, besides this physical evidence there is new digital evidence such as that arising from the IoT, and thus, for the Inov4.0|F, the *Cyber Physical Evidence Lan*e must replace the classic (Shostack, 1982) S-Bprint *Physical Evidence Lane.*

The traditional *Customer Actions Lane* is used to describe the customer actions during the co-creative service process (Hsu, 2016). However, in OC3 there may also be “IoT customer actions” and thus for Inovstone4.0, the *Cyber Customer Actions Lane* must replace the traditional S-Bprint *Customer Actions Lane.*

In the S-Bprint format of Inovstone4.0, the *Frontstage Contact Actions Lane* is delimited at the top by the *Cyber Customer Interaction Line*, which separates the activities that the customer performs independently (Seyring et al., 2009), and below by the *Cockpit Line*. Since in OC3, the Cockpit operates as a dialogue and interaction resource in the interactive process, both upwards to the customer, resulting in the Fingerprint4.0 and downwards to the CPS-Body, resulting in the Smart Object, for Inovstone4.0 the S-Bprint *CPS Cockpit Actions Lane* must replace the *Frontstage Contact Actions Lane* (Figure A.5).

For Inovstone4.0, the *Backstage Contact Actions Lane* must be delimited upwards by the *Cockpit Line* and downwards by the *CPS I4.0 Line,* where all the activities and means necessary to produce must be placed, i.e., the activities of the CPS I4.0 Body, and therefore, the *CPS-I4.0 Body Actions Lane* must replace the *Backstage Contact Actions Lane*.

For the Inovstone4.0 S-Bprint, the *Support Processes Actions Lane* must be delimited by the *CPSI4.0Line*, where all activities related to supporting value creation must be represented, and thus, for the Inovstone4.0 S-Bprint, the *Support Processes I4.0 Actions Lane* must replace the classic *Support Processes Lane* (Figure A.5).

As mentioned above, in the traditional S-Bprint format of Shostack, the *Customer Visibility Area* is the horizontal lane between the *Line of Visibility* and the *Line of Customer Interaction*, the *Customer Actions Lane* being the level immediately above the *Line of Customer Interaction,* where the customer’s actions will take place, by steps. The first typical action of a *cyber customer* is likely to be connecting their digital BIM station to the Internet.

Based on the proposal of some authors (Seyring et al., 2009), for Inovstone4.0 the S-Bprint levels where the BIM-Customer actions take place, whether independent or co-creative actions, must be designated *Cyber Physical Interaction Area* (Figure A.5). The BIM-Customer resources carrying out activity at this level are the Frontstage group of resources which includes the human and cyber resources that interact directly with the Provider, and the resources of the I4.0-Provider are the Cockpit resources, which include both human and cyber-physical resources such as the main server, cognitive assistant systems, smart object generation systems and real-time smart object execution server, among other resources. The provider resource groups in the traditional S-Bprint format are placed in three lanes: the *Frontstage Lane*, *Backstage Lane*, and *Support Lane* and all together define the *Firm Area* (Kingman-Brundage, 1989), which is equivalent to the whole area underneath the *Line of Interaction* (Figure A.3). For Inovstone4.0, in OC3 the S-Bprint levels where the I4.0-Provider actions, either independent or in co-creation, take place must be designated as the *ProviderI4.0 Interaction Area (Figure A.5).*

As described above, for Inovstone4.0 in OC3 the BIM-Customer activities area must be designated the *Cyber Physical Interaction Area* and the I4.0-Provider area designated *I4.0-Provider Interaction Area*, meaning that the *CPS Cockpit Actions Lane* becomes common to the BIM-Customer and I4.0-Provider (Figure A.5). This transparency (cyber-visibility) that characterizes OC3 makes all the difference, since the BIM-Customer (Cyber-Customer) may cross all the lines, and so the continuous lines will no longer exist in this fully digital operations mode, being replaced by dashed lines. However, in OC3, the S-Bprint will keep the no-contact activities performed by the provider, which will remain as in the traditional model in the lower lanes throughout the process steps (Shostack, 1982).

In contrast to the Shostack model, for Inovstone4.0, in OC3, co-creative tasks can go beyond the lane delimited by the *"Cyber" Customer Interaction Line* as well as the *Cockpit Line*, both dashed lines. For instance, the information on the BIM-Customer's computer screen showing that payment was successfully made comes directly from an I4.0-Provider Support Resource such as the bank. As described above, for Inovstone4.0, in OC3, the S-Bprint must describe the I4.0-Provider resources in horizontal lanes on the left side of the map, describing the involvement of the same resource in each step, following Shostack's (1982) model, the resources of the I4.0 provider being composed of six groups (Chapter 4): (i) Cockpit, (ii) cyber physical system I4.0 Body, (iii) management and marketing I4.0 resources, (iv) support partnerships, (v) know-how and shareable information and (vi) support technology, and the data strictly related to each of the Key Concern Indicators (KCI), collected from observations and measurements in the field, among other methods accepted by S-S.

Once the directly perceivable activities are identified, the next Step must be to define in each Step the activities that are imperceptible to the Customer. In the horizontal S-Bprint Backstage and Support Processes, there are usually several simultaneous contact points, so some authors suggest subdividing these lanes (Seyring et al., 2009).

Thus, for Inovstone4.0, in OC3, the S-Bprint Phase 1 of the service process is still related to Design, Proposal Discussion and Order Processing, which in I4.0 production mode, means “to digitize” what the customer expects to receive FP-I4.0 (Figure A.6 and A.7). Phase 2 is related to *Order Execution*, which means that for Inovstone4.0 production can use the Smart Objects which are the Fingerprint outcome. This Phase of the process will comprise 9 main steps, starting in Step 19, beginning to prepare the raw materials and continuing to Step 27, corresponding to the finished product package (Figure A.8). Phase 3 is related to *Shipping, Using & Recycling*, which for Inovstone4.0 means the ability to deliver, install use and recycle at the end of useful life. This phase of the process will comprise 9 main steps, starting with Step 28 corresponding to transporting the product to the customer, until Step 36 corresponding to product recycling (Figure A.9).

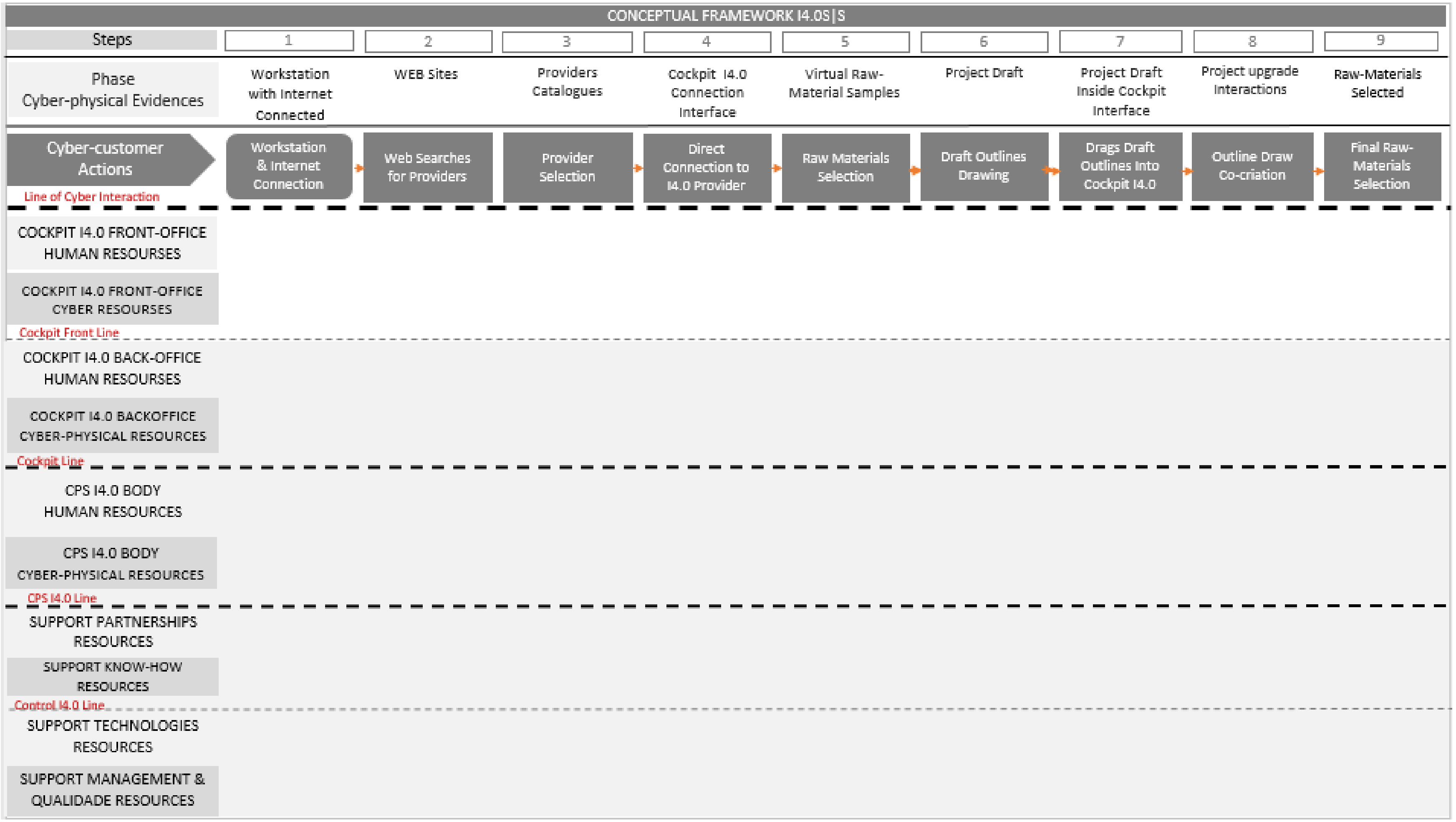


Figure A.6: Service Blueprinting Steps in OC3 | Phase 1 (Step 1 to 9)

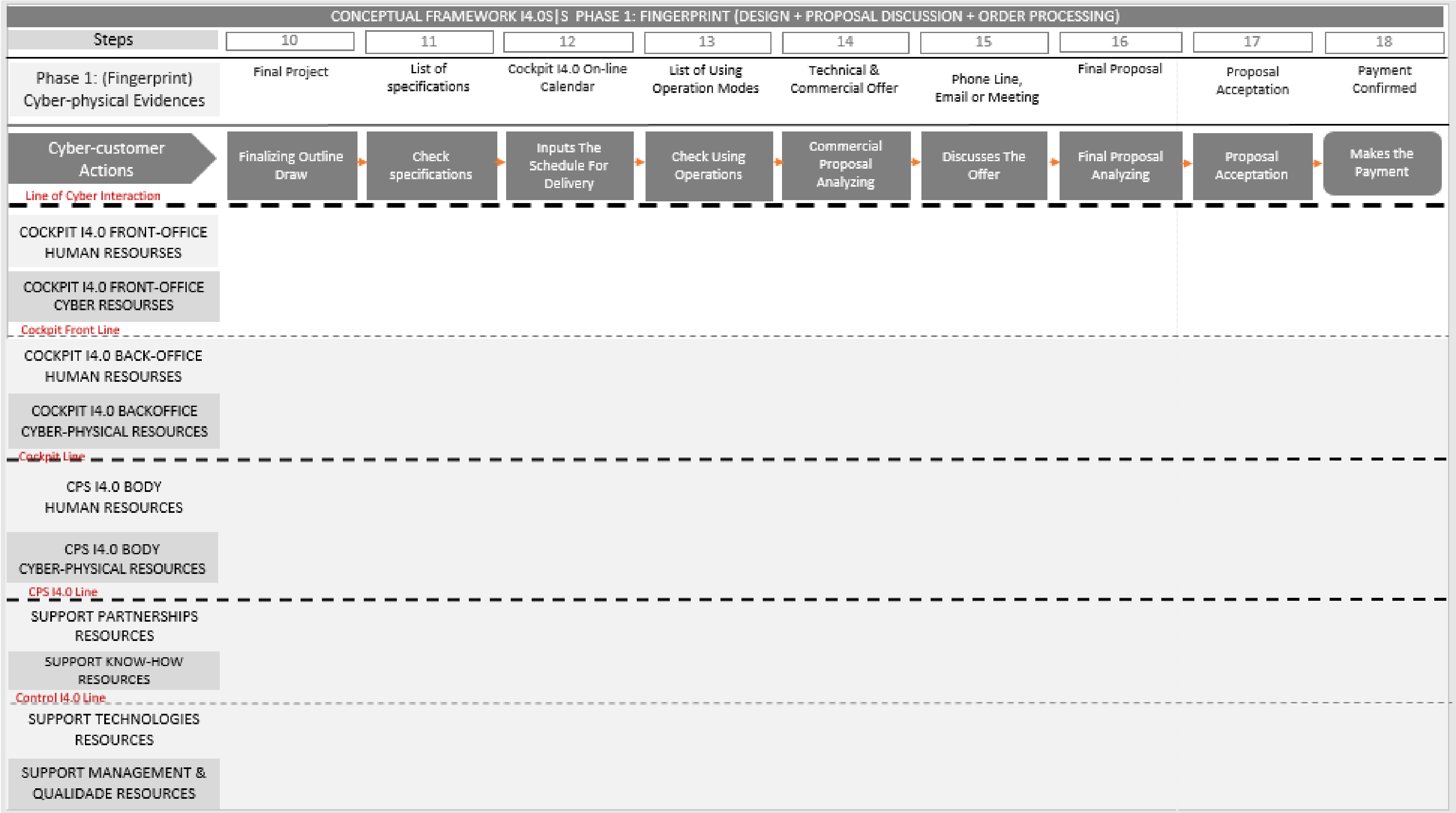


Figure A.7: Service Blueprinting Steps in OC3 | Phase 1 (Step 10 to 18)

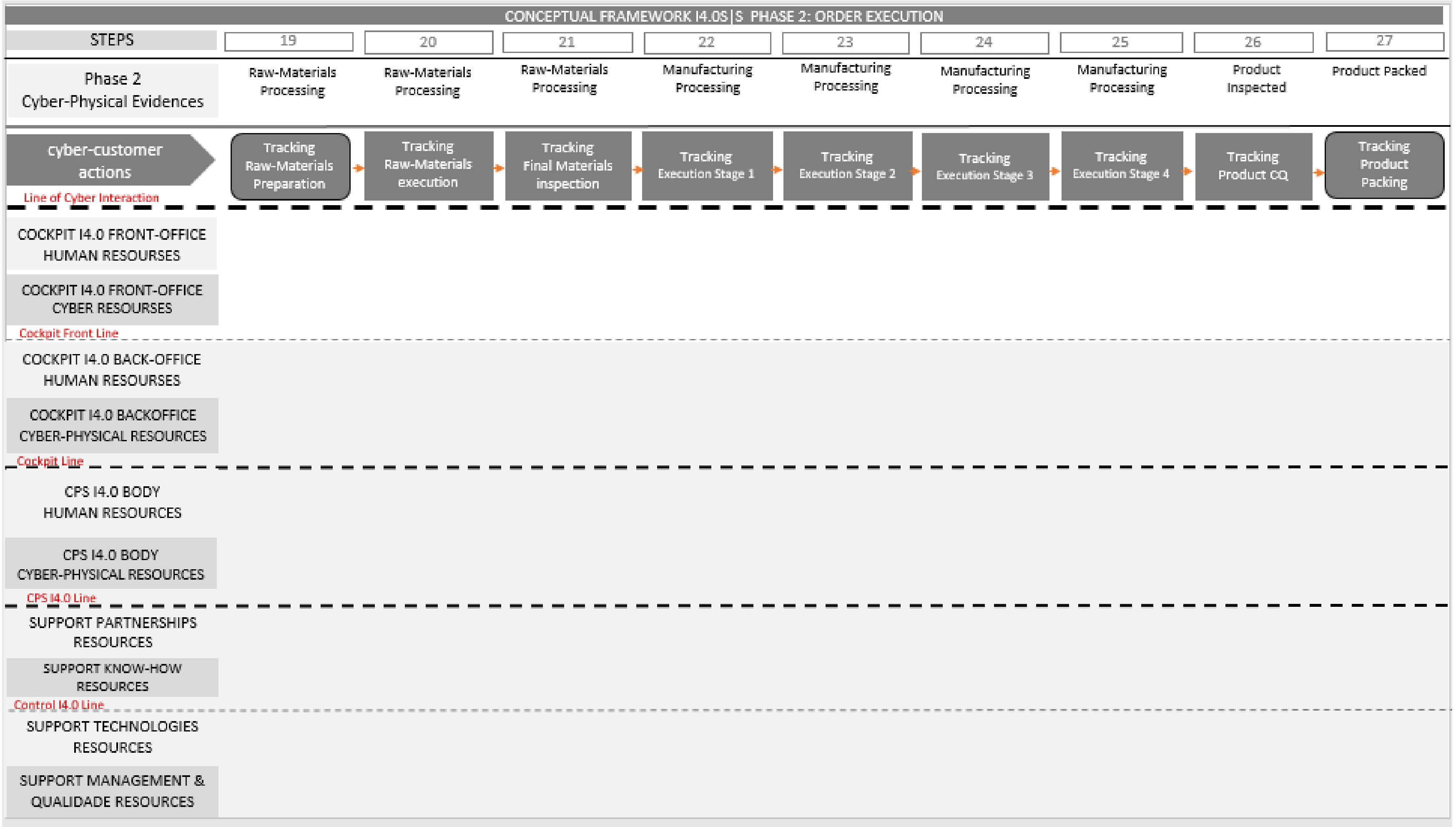


Figure A.8: Service Blueprinting Steps in OC3 | Phase 2 (Step 19 to 27)

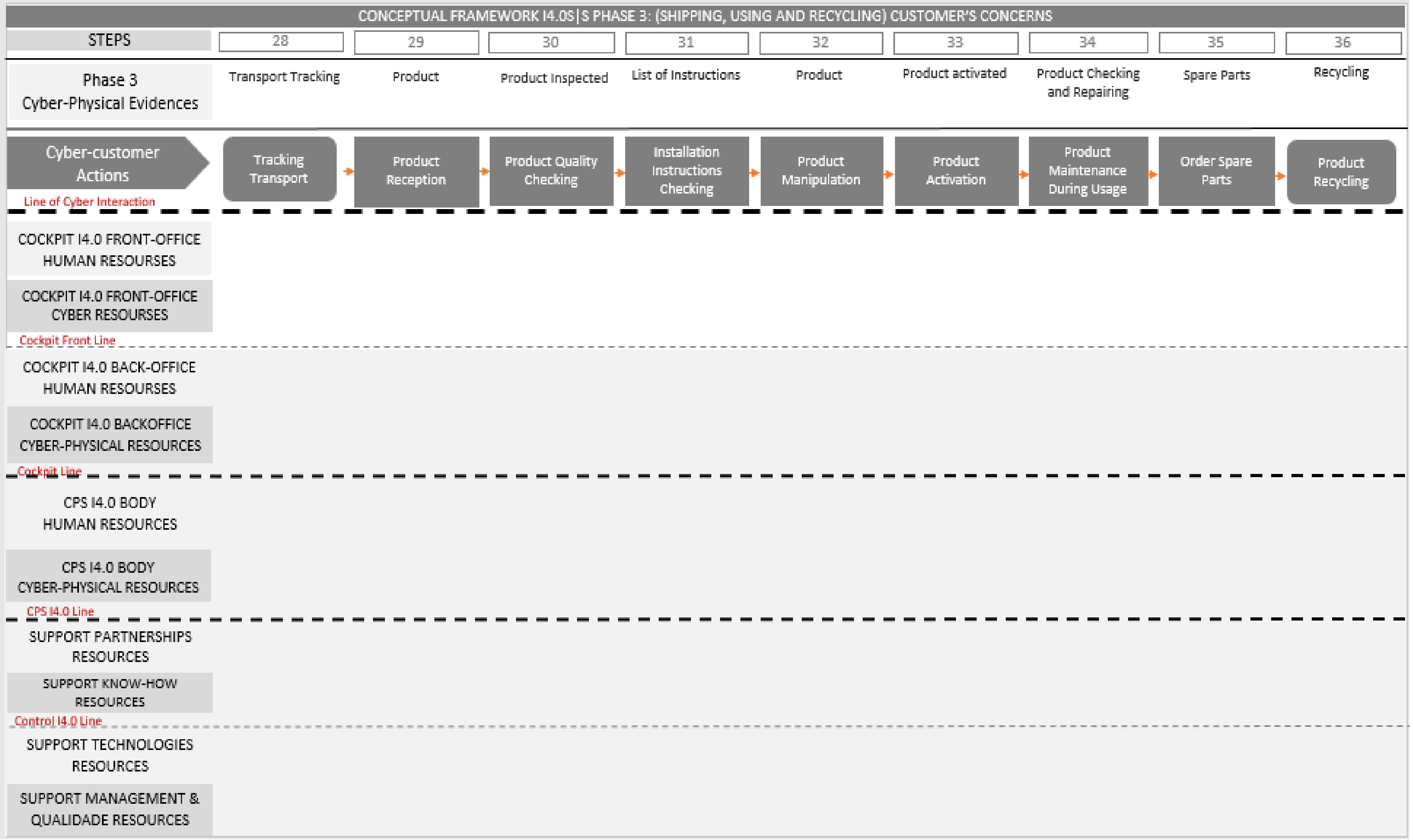


Figure A.9: Service Blueprinting Steps in OC3 | Phase 3 (Step 28 to 36)

APPENDIX B

INOVSTONE4.0 KEY CONCERN INDICATORS DEFINITION

Qualitative KCI

Time to receive the product KCI ($TRPC_{QUAL\_k}$) - from our own experience as consumers, the time between ordering and receiving a product may sometimes be as important in the decision as the quality or even the price. Designated *"Time to Receive the Product Concern",* $TRPC_{QUAL\_k}$, this KCI Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding the delivery time of a product.

$$TRPC_{QUAL\_k} = \frac{\sum(D\ .\ TRPC_{QUAL\_k})i}{\sum(U\ .\ TRPC_{QUAL\_k})i} \tag{b.1}$$

Product Sustainability KCI (PSC_{QUAL_k}) - for S-S Theory, ecosystem ecology should be a transversal concern in all value-creation interactions between S-Systems (Kwan et al., 2016; Maglio & Spohrer, 2008), thus making Planet Sustainability one of the aspects to be evaluated in the OS industry by the Inov4.0|F framework, where sustainability should be seen not only in environmental terms, but also as a symbolic value (J. Smith & Colgate, 2007) in the sense that stakeholders associate psychological meaning with products that are "environmentally friendly". Considering that industry outputs are physical products, the ecological footprint results basically from the energy consumed, transport and material wasted during the production process. Therefore, designated *"Product Sustainability Concern"*, PSC_{QUAL_k} evaluates qualitatively the stakeholder (k) concern about the ecological footprint associated with the design, production, delivery and installation of the product.

$$PSC_{QUAL\_k} = \frac{\sum(D\ .\ PSC_{QUAL\_k})i}{\sum(U\ .\ PSC_{QUAL\_k})i} \tag{b.2}$$

Product Quality KCI (PQC_{QUAL_k}) - assesses the stakeholder (k) concern about the relevant characteristics in terms of product functionality and adaptability to the needs for which it is provided (J. Smith & Colgate, 2007), thus for Inov4.0|F this is an indicator indexed to the characteristics required by the customer. Designated "*Product Quality*

Concern", the PQC_{QUAL_k} Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding product quality.

$$PQC_{QUAL\_K} = \frac{\sum(D \, . \, PQC_{QUAL\_K})i}{\sum(U \, . \, PQC_{QUAL\_K})i} \tag{b.3}$$

Contract Compliance KCI (CCC_{QUAL_k}) - Designated by Inov4.0|F as *"Contract Compliance Concern"*, the CCC_{QUAL_k} Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding contractual terms, thus being an indicator associated with the compliance and good faith of the stakeholders.

$$CCC_{QUAL\_k} = \frac{\sum(D \, . \, CCC_{QUAL\_K})i}{\sum(U \, . \, CCC_{QUAL\_K})i} \tag{b.4}$$

Brand Reputation KCI (BRC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding brand reputation, being therefore an indicator associated with the valuation or devaluation of image, of great interest for marketing (Prymon, 2016).

$$BRC_{QUAL\_k} = \frac{\sum(D \, . \, BRC_{QUAL\_k})i}{\sum(U \, . \, BRC_{QUAL\_k})i} \tag{b.5}$$

Product Flexibility KCI (PFC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding product manufacture flexibility necessary to produce as required by the customer, being therefore, an indicator associated with the production customization capacity (Stock & Seliger, 2016).

$$PFC_{QUAL\_k} = \frac{\sum(D \, . \, PFC_{QUAL\_k})i}{\sum(U \, . \, PFC_{QUAL\_k})i} \tag{b.6}$$

Purchasing Price KCI (PPC_{QUAL_k}) - In BIM procurement, price is one of the mandatory dimensions of the product (4D-BIM) (Han & Golparvar-Fard, 2015), available in IFC format in the BIM web libraries. The PPC_{QUAL_k} Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding the price to be paid for the product, which for SS is a qualitative concern shared equally by customers and providers.

$$PPC_{QUAL\_k} = \frac{\sum(D \ . \ PPC_{QUAL\_k})i}{\sum(U \ . \ PPC_{QUAL\_k})i} \qquad \text{(b.7)}$$

Product Total Cost KCI ($PTCC_{QUAL\_k}$) - The total cost of the product during the life-cycle extends beyond the purchase price. Aspects related to customer costs during the product co-ordination phase, transport, installation or maintenance have to be added to the purchase price, which may affect the acceptance of value propositions (Venâncio, 2015). In the case of costs whose components are attributable in the three phases of the process (from co-creation to the end of the life cycle), they must be compared with their experiential value, insofar as they can create experiences, feelings and emotions for the user, either positive or negative (J. Smith & Colgate, 2007), during the life-cycle. The PTC_{CQUAL_k} Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding product transport, installation and maintenance.

$$PTCC_{QUAL\_k} = \frac{\sum(D \ . \ PTCC_{QUAL\_k})i}{\sum(U \ . \ PTCC_{QUAL\_k})i} \qquad \text{(b.8)}$$

Product Warranty KCI (PWC_{QUAL_k}) - The warranty period and terms given by the provider may be understood as a symbolic value (J. Smith & Colgate, 2007) where customers associate a psychological meaning of trust with the product they acquire. The PWC_{QUAL_k} Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the period covered by warranty.

$$PWC_{QUAL\_k} = \frac{\sum(D \ . \ PWC_{QUAL\_k})i}{\sum(U \ . \ PWC_{QUAL\_k})i} \qquad \text{(b.9)}$$

Product After Sales KCI ($PASC_{QUAL\_k}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding efficiency, effectiveness and the cost of after-sales service.

$$PASC_{QUAL\_k} = \frac{\sum(D \ . \ PASC_{QUAL\_k})i}{\sum(U \ . \ PASC_{QUAL\_k})i} \qquad \text{(b.10)}$$

Product Reliability KCI (PRC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the reliability (non-failure) of products.

$$PRC_{QUAL\_k} = \frac{\sum(D \,.\, PRC_{QUAL\_k})i}{\sum(U \,.\, PRC_{QUAL\_k})i} \qquad \text{(b.11)}$$

Product Safety KCI (PSC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the security products represent for people and goods during production, transport, installation, use, maintenance and recycling.

$$PSC_{QUAL\_k} = \frac{\sum(D \,.\, PSC_{QUAL\_k})i}{\sum(U \,.\, PSC_{QUAL-k})i} \qquad \text{(b.12)}$$

Customer Satisfaction KCI (CSC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the satisfaction of the stakeholder who bought or uses the product.

$$CSC_{QUAL\_k} = \frac{\sum(D \,.\, CSC_{QUAL\_k})i}{\sum(U \,.\, CSC_{QUAL\_k})i} \qquad \text{(b.13)}$$

Product Maintenance Costs KCI ($PMCC_{QUAL\_k}$) - during the warranty period, maintenance costs are borne by the supplier, becoming a cost for the customer afterwards. The $PMCC_{QUAL\_k}$ Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding products’ maintenance costs.

$$PMCC_{QUAL\_k} = \frac{\sum(D \,.\, PMCC_{QUAL\_k})i}{\sum(U \,.\, PMCC_{QUAL\_k})i} \qquad \text{(b.14)}$$

Product Innovative KCI (PIC_{QUAL_k}) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the innovative character of products in relation to the state-of-the-art.

$$PIC_{QUAL\_k} = \frac{\sum(D \,.\, PIC_{QUAL\_k})i}{\sum(U \,.\, PIC_{QUAL\_k})i} \qquad \text{(b.15)}$$

Product Innovative Manufacturing Process ***KCI*** **($PIMPC_{QUAL\_K}$) -** evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data “Up” and the data “Down” regarding the innovative nature of the manufacturing process to produce the product, in relation to the state-of-the-art. In other words, it evaluates the "modernity" of the production model.

$$\text{PIMPC}_{QUAL\_k} = \frac{\sum(D\ .\ \text{PIMPC}_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PIMPC}_{\text{QUAL\_k}})i} \tag{b.16}$$

Product Recyclability KCI ($\text{PRECYC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding the product at the end of its life-cycle.

$$\text{PRECYC}_{QUAL\_k} = \frac{\sum(D\ .\ \text{PRECYC}_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PRECYC}_{\text{QUAL\_k}})i} \tag{b.17}$$

Product Handling & Application KCI ($\text{PH\&AC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding the applicability of legal rules to product handling and use.

$$\text{PH\&}AC_{QUAL\_k} = \frac{\sum(D\ .\ \text{PH\&}AC_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PH\&}AC_{\text{QUAL\_k}})i} \tag{b.18}$$

Product Manufacturing KCI ($\text{PMC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding the norms and legal rules about production of the product.

$$\text{PMC}_{QUAL\_k} = \frac{\sum(D\ .\ \text{PMC}_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PMC}_{\text{QUAL\_k}})i} \tag{b.19}$$

Product Transportation KCI ($\text{PTC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding compliance with the rules and legal rules for transporting the product.

$$\text{PTC}_{QUAL\_k} = \frac{\sum(D\ .\ \text{PTC}_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PTC}_{\text{QUAL\_k}})i} \tag{b.20}$$

Product Moral & Hazard KCI ($\text{PM\&HC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding compliance with legal rules and regulations for transporting the product.

$$\text{PM\&}HC_{QUAL\_k} = \frac{\sum(D\ .\ \text{PM\&}HC_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PM\&}HC_{\text{QUAL\_k}})i} \tag{b.21}$$

Product Legal KCI ($\text{PLC}_{\text{QUAL\_k}}$) - evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding product legality.

$$\text{PLC}_{QUAL\_\text{k}} = \frac{\sum(D\ .\ \text{PLC}_{\text{QUAL\_k}})i}{\sum(U\ .\ \text{PLC}_{\text{QUAL\_k}})i} \tag{b.22}$$

Taxes & Fines Concern ($T\&FC_{QUAL\_k}$) - Designated by Inov4.0|F as "Taxes & Fines Concern", the $T\&FC_{QUAL\_k}$ Concern Indicator evaluates qualitatively the stakeholder (k) Concern indexed to the relation between the data "Up" and the data "Down" regarding taxes, fees and fines.

$$T\&FC_{QUAL\_k} = \frac{\sum(D \, . \, T\&FC_{\mathrm{QUAL\_k}})i}{\sum(U \, . \, T\&FC_{\mathrm{QUAL\_k}})i} \tag{b.23}$$

Quantitative KCI

Product Lead Time KCI ($PLTC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the time from the start till the service process moves to the next step.

$$PLTC^{106}{}_{QUAL\_k} = \sum(\mathrm{STEP}_{Quant\_Global\_Time\_k})i \tag{b.24}$$

Product Labour Work Time KCI ($PLWTC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the workforce involved in each step, throughout the three phases of the process.

$$PLWTC^{107}{}_{QUAL\_k} = \sum(\mathrm{LABOR}_{Quant\_Work\_Time\_k})i \tag{b.25}$$

Product Quality KCI (PQC_{QUAN_k}) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between the number of units delivered and the number of units rejected.

$$PQC^{108}{}_{QUAN\_k} = \frac{\sum(\mathrm{REJECTED}_{\mathrm{Quant\_Units\_k}})i}{\sum(\mathrm{Total}_{\mathrm{Output\_Units\_k}})i} \tag{b.26}$$

Market Interfacing Time KCI ($MITC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the time of all operations, either productive or non-productive, plus the setup time at every step.

$$MITC^{109}{}_{QUAL\_k} = \sum(M\_E\_O\_Time\_k)i + \sum(M\_S\_Time\_k)i + \sum(L\_I\_Time\_k)i + \sum(I\_P\_Time\_k)i \tag{b.27}$$

[106] "$STEP_{QUAN\_GLOBAL\_TIME-K}$", The time required to complete Step (i), from the perspective of the stakeholder (k).
[107] "$LABOUR_{QUAN\_WORK\_TIME}$", The number of man / hour units, in each Step (i), in the stakeholder (k) perspective.
[108] "$Rejected_{QUAL\_UNITS-k}$", represents the number of units rejected after leaving the factory and "$Total_{QUAL\_UNITS-k}$", represents the number of units produced in each Step (i), from the stakeholder (k) perspective.
[109] (1) "M_E_O_Time" represents the time of production / machine; (2) M_S_Time represents the setup / machine time; (3) "L_I_Time" represents the time of occupation of the logistic means; (4) "I_P_Time" represents the downtime related to balancing, maintenance, or other reasons, at each stage of the service process.

Product Cycle Time KCI ($PCTC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the production, setup and logistics time in each Step (i) of the service process.

$$PCTC_{QUAL\_k} = \sum(M\_E\_O\_Time\_k)i + \sum(M\_S\_Time\_k)i + \sum(L\_I\_Time\_k)i \quad \text{(b.28)}$$

Production Occupation Time KCI ($POTC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the equipment occupancy rate. Being related to production balancing for Inov4.0|F, this indicator measures concerns indexed to the time in the various steps (i) use of productive machines and their setup time.

$$POTC_{QUAL\_k} = \sum(M\_E\_O\_Time\_k)i + \sum(M\_S\_Time\_k)i \quad \text{(b.29)}$$

Production Layout Balance KCI ($PLBC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the waiting times between two operations (balancing) (Lee et al., 2014).

$$PLBC_{QUAL\_k} = + \sum(I\_P\_Time\_k)i \quad \text{(b.30)}$$

Logistics Capability KCI (LCC_{QUAN_k}) - evaluates quantitatively the stakeholder (k) Concern indexed to the effectiveness of internal logistic means (Melton, 2005).

$$LCC_{QUAL\_k} = \sum(L\_I\_Time\_k)i \quad \text{(b.31)}$$

Labour Work Efficiency KCI ($LWEC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between the human resources needed to produce and the output units. It is a concept similar to "*Productivity*" (Lyons et al., 2013).

$$\mathrm{LWEC}_{QUAN\_k} = \frac{\sum(L_{\mathrm{\_Time\_k}})i}{\sum(\mathrm{O}_{\mathrm{\_Units\_k}})i} \quad \text{(b.32)}$$

Raw Material Efficiency KCI ($RMEC_{QUAN\_k}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between raw material consumption and output units, thus representing the inverse of wastage.

$$RMEC^{110}{}_{QUAN\_k} = \frac{\sum(P\_R\_M_{\mathrm{\_CONSUM\_k}})i}{\sum(\mathrm{O}_{\mathrm{\_UNITS\_k}})i} \quad \text{(b.33)}$$

Energy Efficiency KCI (EEC_{QUAN_k}) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between the energy consumed and output units, thus representing the inverse of energy wastage (Womack, Jones, & Daniel, 2003).

[110] "P_R_M$_{\text{Consum-k}}$", represents the units of raw material used in each Step (i) of the service process.

$$RMEC^{111}{}_{QUAN\_k} = \frac{\sum(P\_E_{\_\mathrm{CONSUM\_k}})i}{\sum(\mathrm{O}_{\_\mathrm{UNITS\_k}})i} \quad \text{(b.34)}$$

First Time Through Yield KCI (FFTC**QUAN_K**) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between the number of correctly produced units, without failures or reworking, and total output units (Womack et al., 2003).

$$FFTC^{112}{}_{QUAN\_k} = \frac{\sum(D_{\_UNITS\_k})i}{\sum(\mathrm{O}_{\_\mathrm{UNITS\_k}})i} \quad \text{(b.35)}$$

Rolled Throughput Yield **(RTYCQUAN_K) -** evaluates quantitatively the stakeholder (k) Concern indexed to the production units produced correctly, without failures or re-working.

$$RTYC^{113}{}_{QUAL\_k} = \sum[(1 - \mathrm{def}\_units\_k)i * (N\_Inspect\_k)]i * (N\_Operations\_k)i \quad \text{(b.36)}$$

Production Run Efficiency KCI (PREC$_{\mathrm{QUAN_k}}$) - evaluates quantitatively the stakeholder (k) Concern indexed to the relation between the cycle time and the total units produced.

$$PREC_{QUAL\_k} = \frac{\sum(M\_E\_O\_Time\_k)i + \sum(M\_S\_Time\_k)i + \sum(L\_I\_Time\_k)i + \sum(I\_P\_Time\_k)i}{\sum(O_{\_Units\_k})i} \quad \text{(b.37)}$$

[111] "P_E$_{\mathrm{_CONSUM\text{-}k}}$", represents the amount of energy units used in each Step (i) of the process.
[112] "P_R_M$_{\mathrm{_Consum\text{-}k}}$", represents the units of raw material used in each Step (i) of the service process.
[113] "P_R_M$_{\mathrm{_Consum\text{-}k}}$", represents the units of raw material used in each Step (i) of the service process.

APPENDIX C

INOVSTONE4.0 FRAMEWORK APPLICATION - RESOURCES ACTIVITY MAPPING

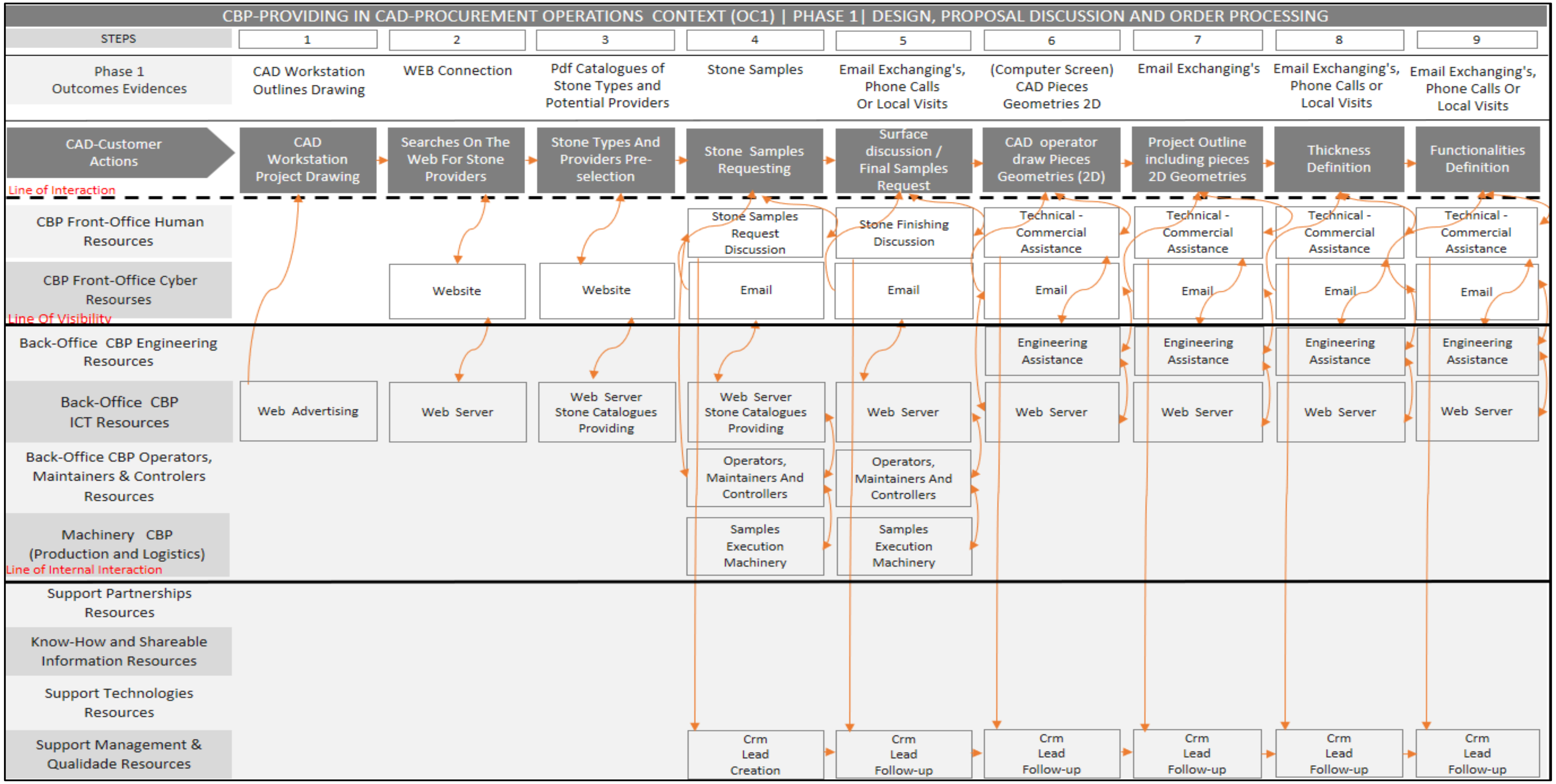


Figure C.1: OC1 (CBP-Providing in CAD-procurement) | Resources Activities, Access Rights and Interaction Outcomes Service-Blueprinting Mapping | Phase 1 (Steps 1-9)

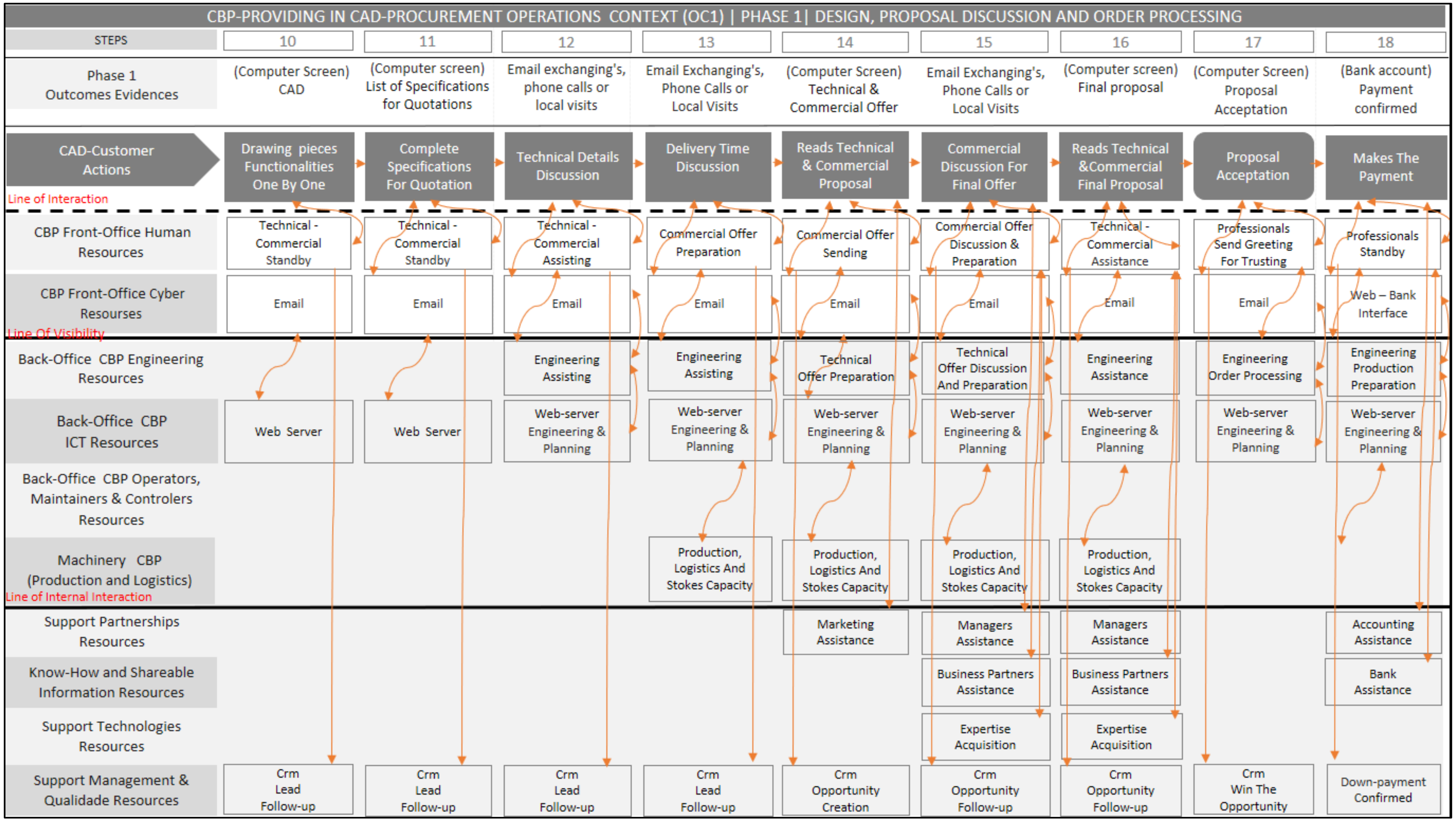


Figure C.2: OC1 (CBP-Providing in CAD-procurement) | Resources Activities, Access Rights and Interaction Outcomes Service-Blueprinting Mapping | Phase 1 (Steps 10-18)

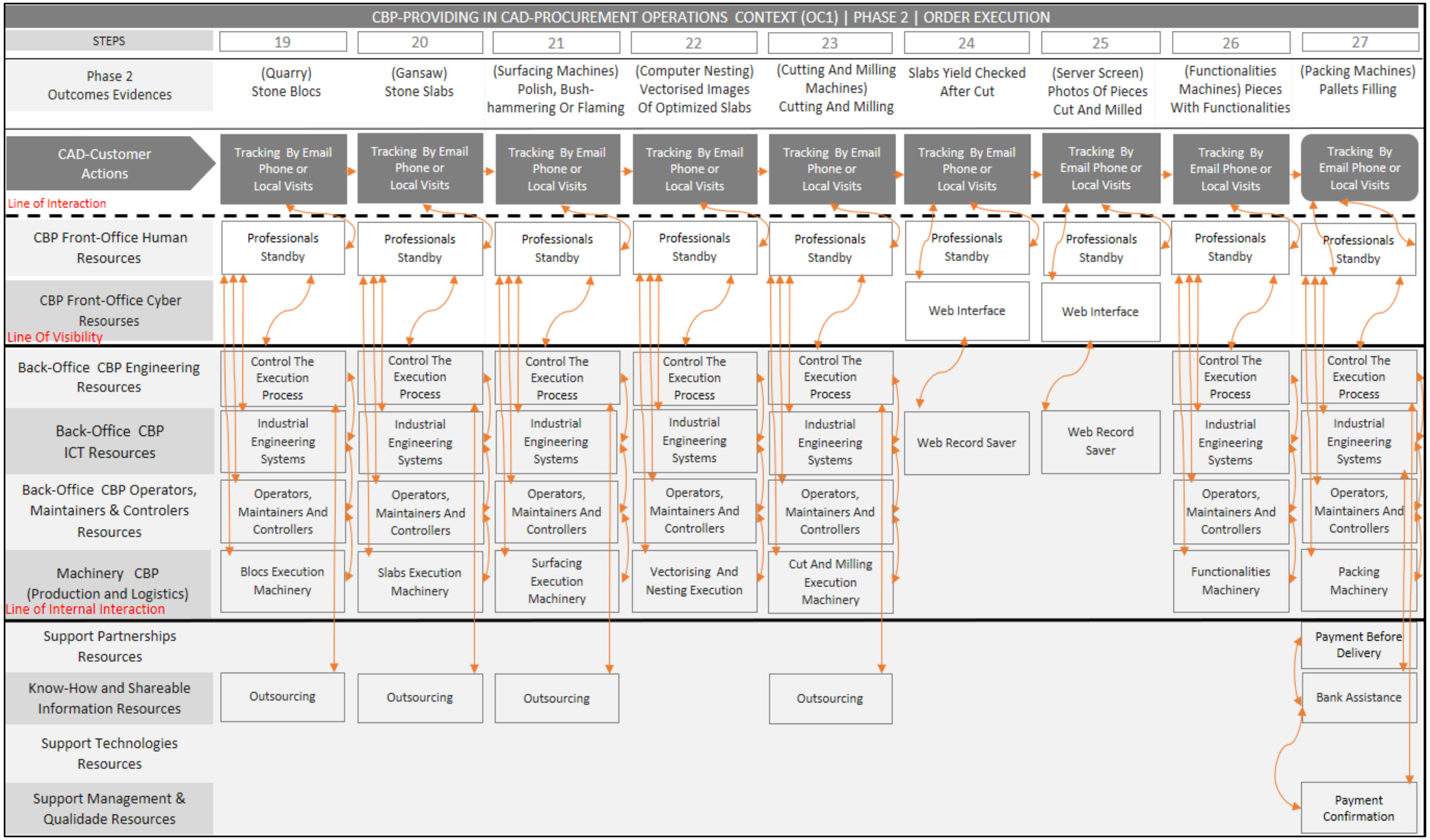


Figure C.3: OC1 (CBP-Providing in CAD-procurement) | Resources Activities, Access Rights and Interaction Outcomes Service-Blueprinting Mapping | Phase 2 (Steps 19-27)

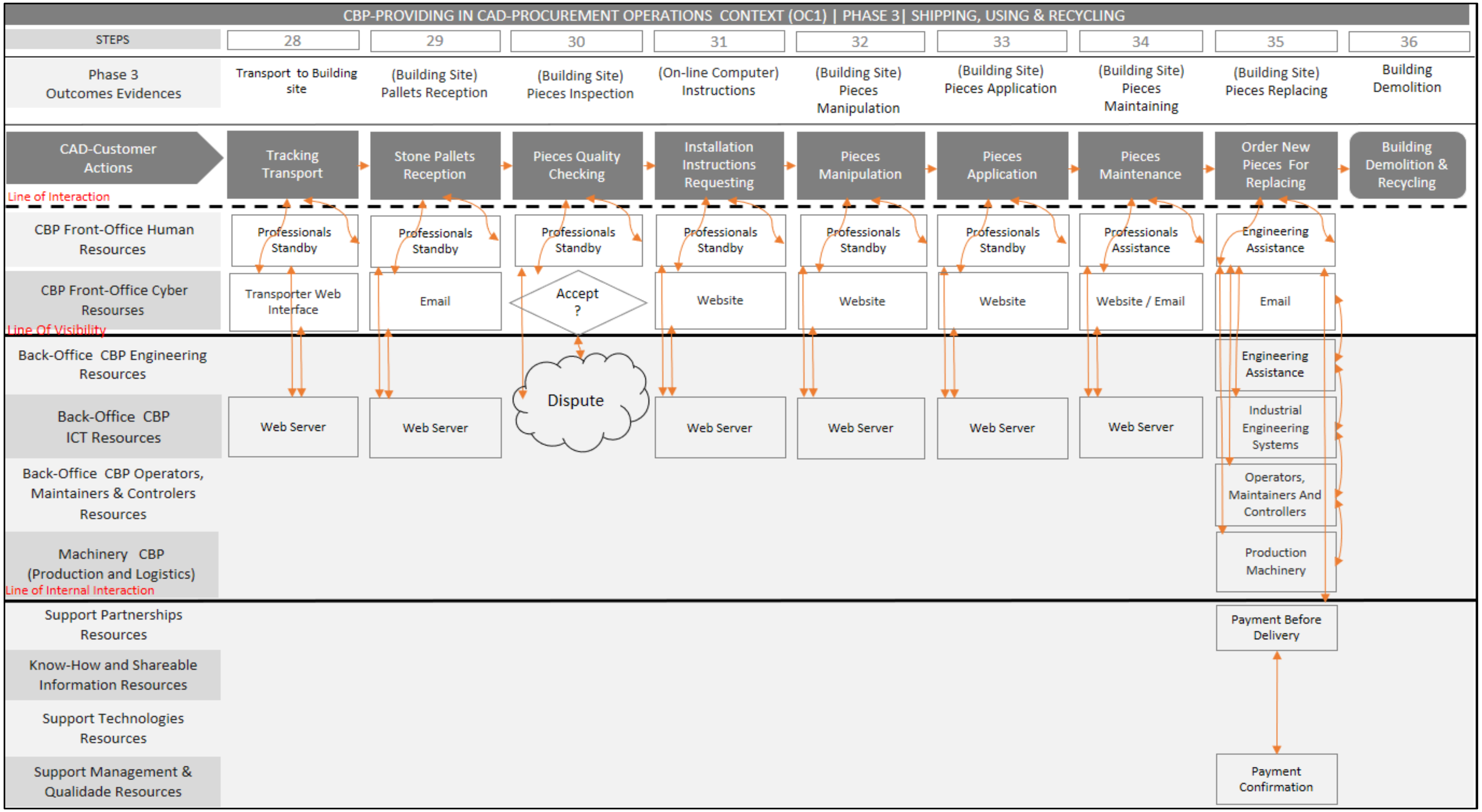


Figure C.4: OC1 (CBP-Providing in CAD-procurement) | Resources Activities, Access Rights and Interaction Outcomes Service-Blueprinting Mapping | Phase 2 (Steps 28-36)

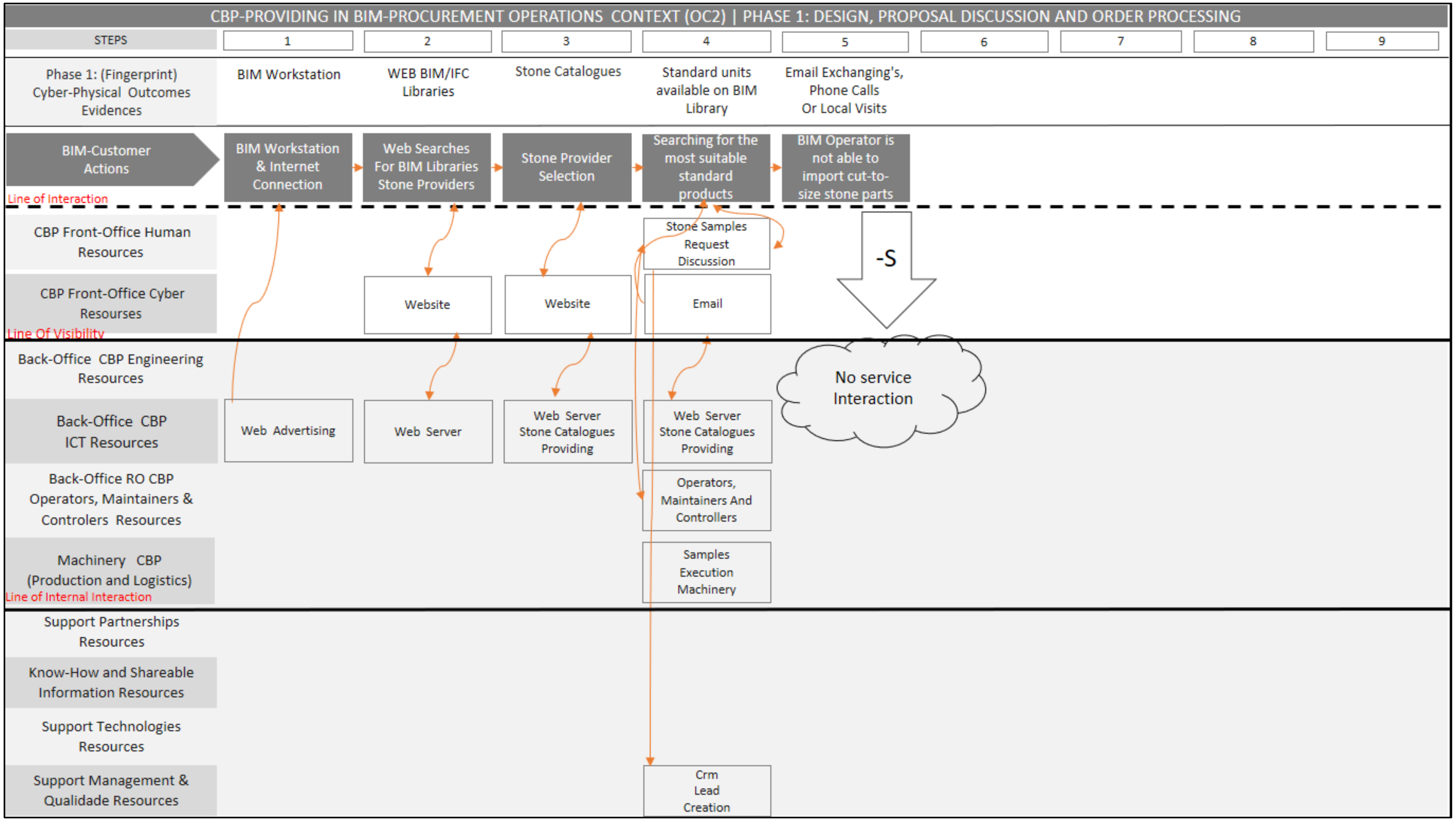


Figure C.5: OC2 (CBP-Providing in BIM-procurement) | Resources Activities, Access Rights and Interaction Outcomes Service-Blueprinting Mapping | Phase 1 (Steps 1-9)

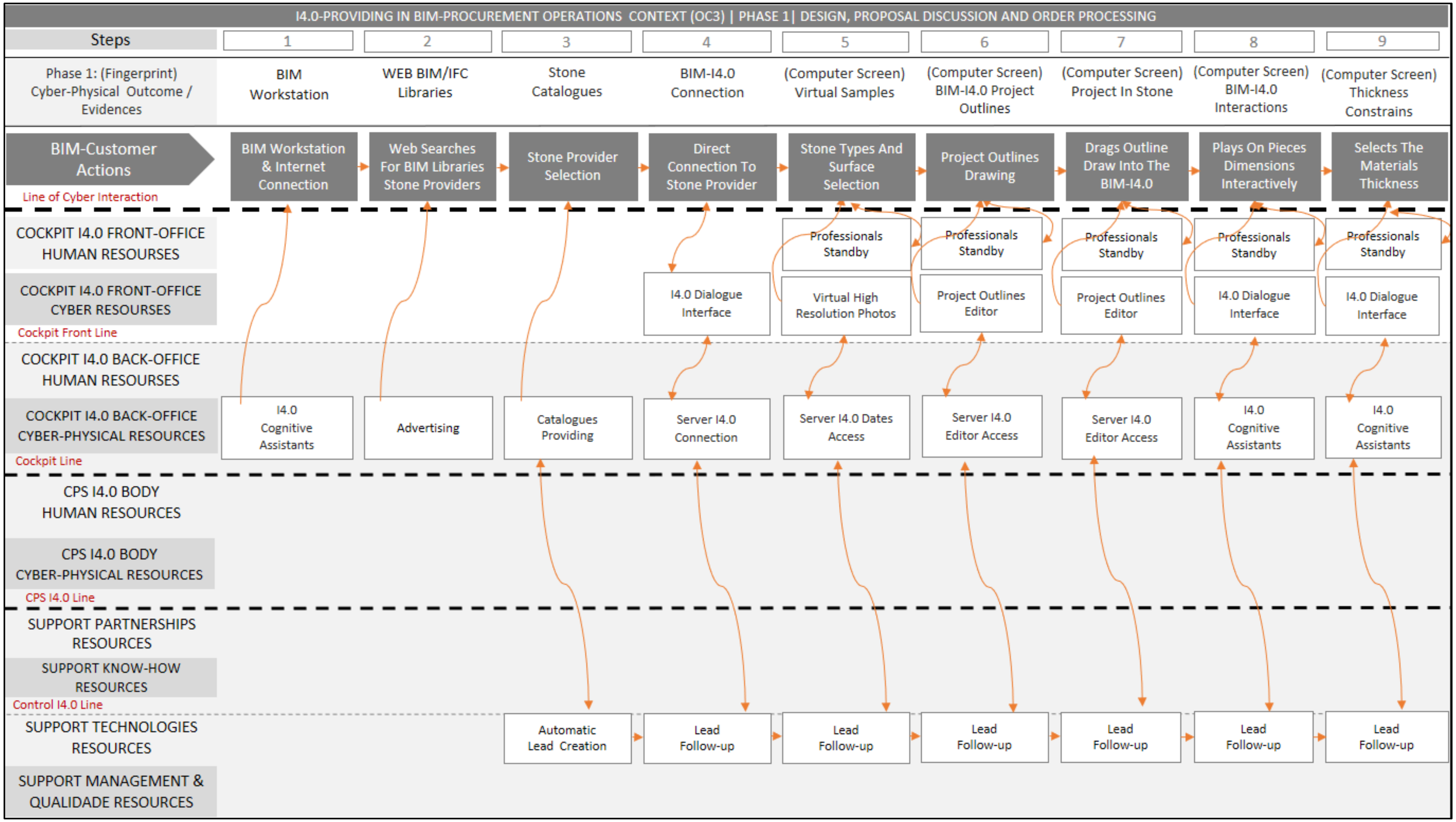


Figure C.6: OC3 (I4.0-Providing in BIM-procurement) | Resources Activities, Access Rights and interaction Outcomes and Mapping | Phase 1 (Steps 1-9)

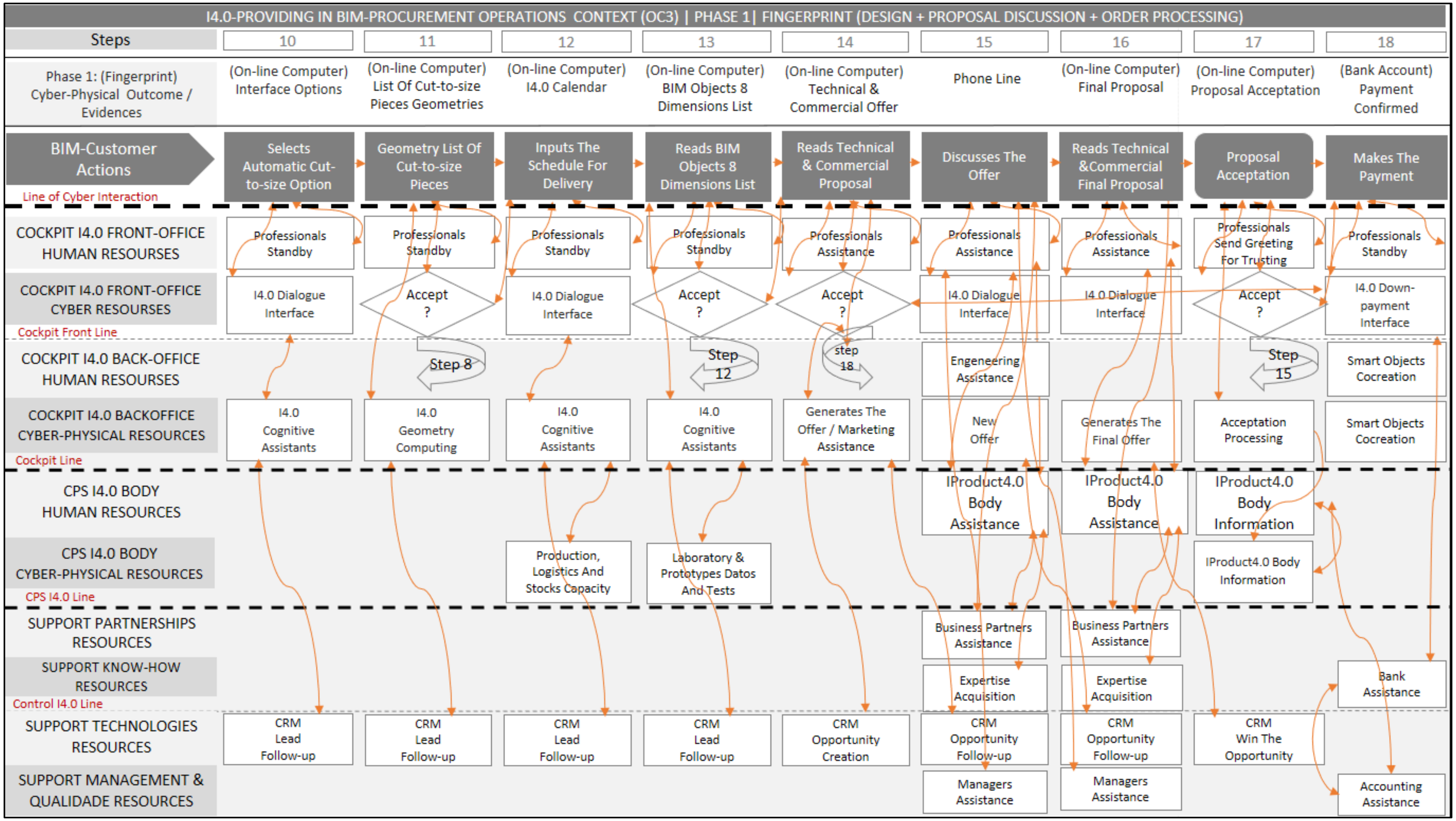


Figure C.7: OC3 (I4.0-Providing in BIM-procurement) | Resources Activities, Access Rights and Interaction Outcomes and Mapping | Phase 1 (Steps 10-18)

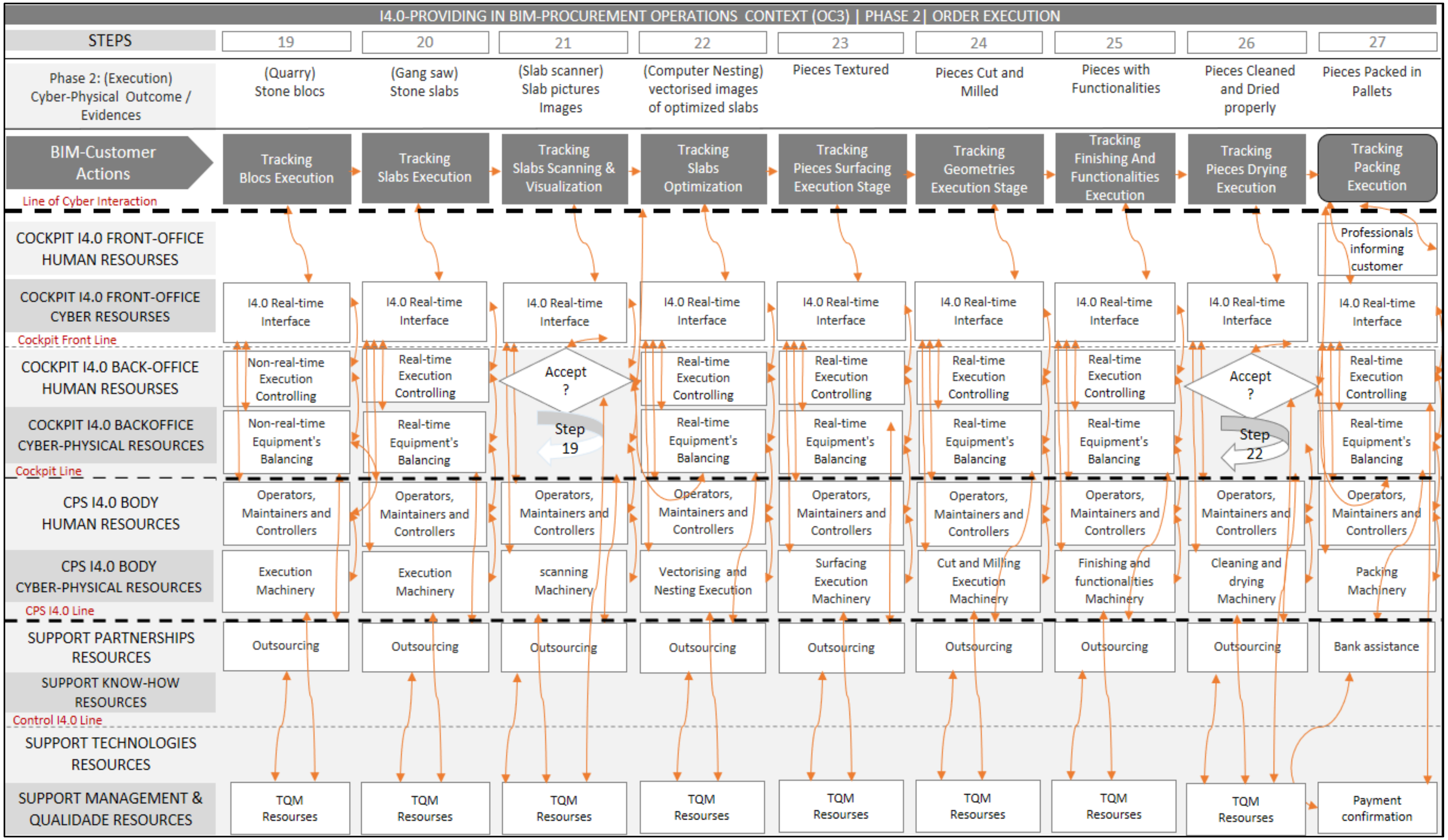


Figure C.8: OC3 (I4.0-Providing in BIM-procurement) | Resources Activities, Access Rights and Interaction Outcomes and Mapping | Phase 1 (Steps 19-27)

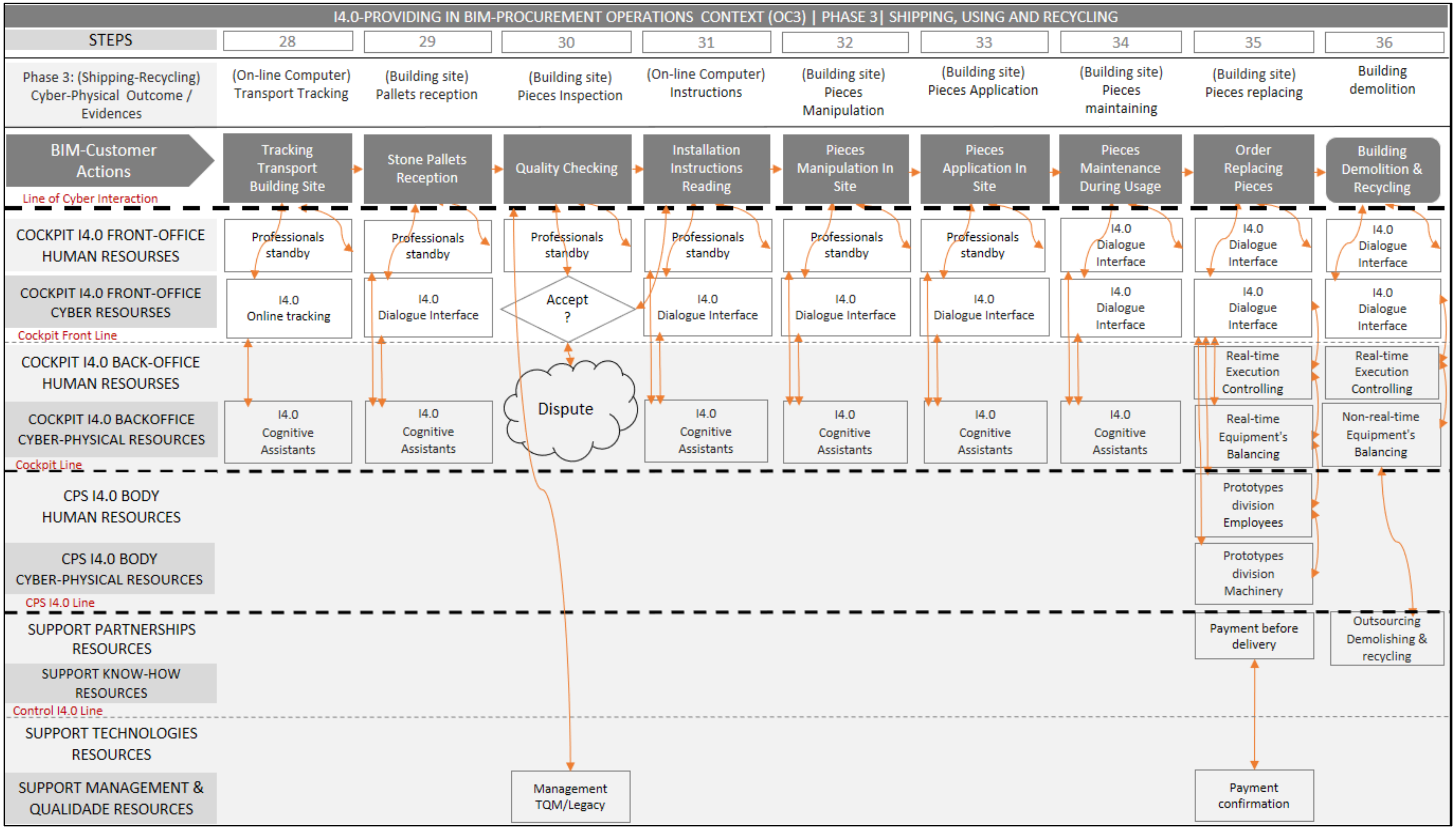


Figure C.9: OC3 (I4.0-Providing in BIM-procurement) | Resources Activities, Access Rights and Interaction Outcomes and Mapping | Phase 2 (Steps 28-36)

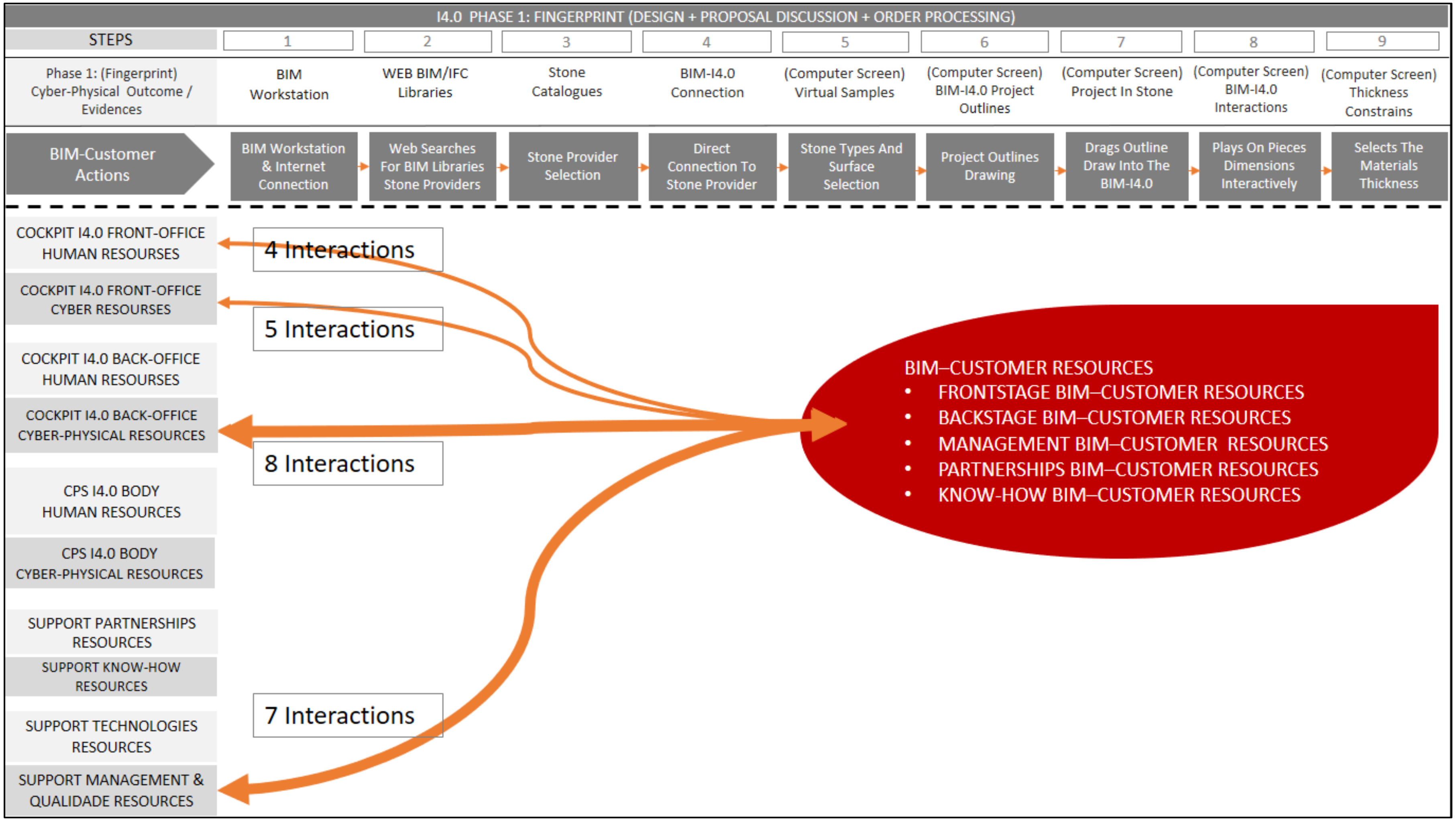


Figure C.10: Phase 1 (Steps 1-9) OC3 (I4.0-Providing in BIM-procurement) | Direct Interactions between BIM-Customer and I4.0-Provider

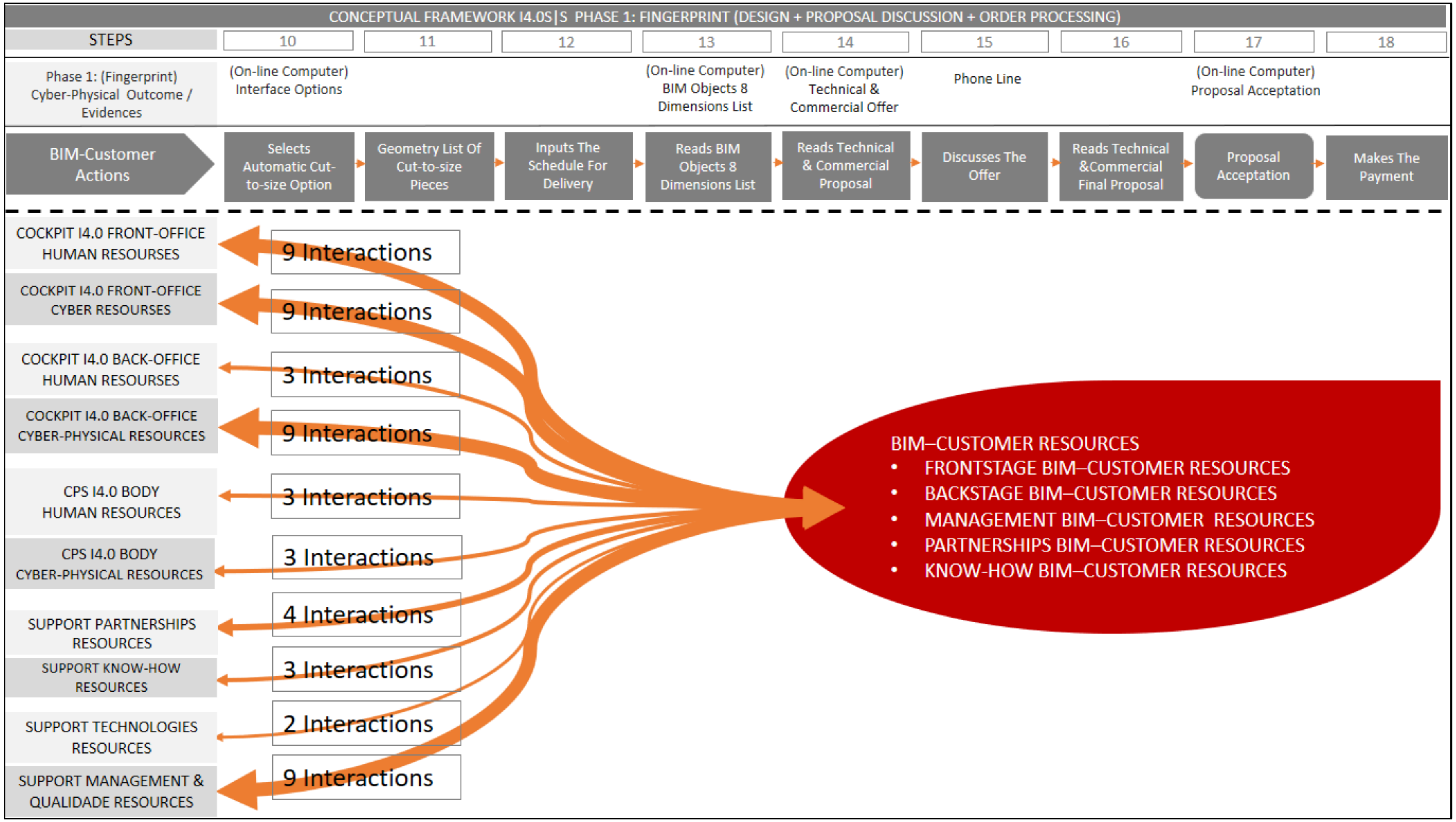


Figure C.11: Phase 1 (Steps 10-18) OC3 (I4.0-Providing in BIM-procurement) | Direct Interactions between BIM-Customer and I4.0-Provider

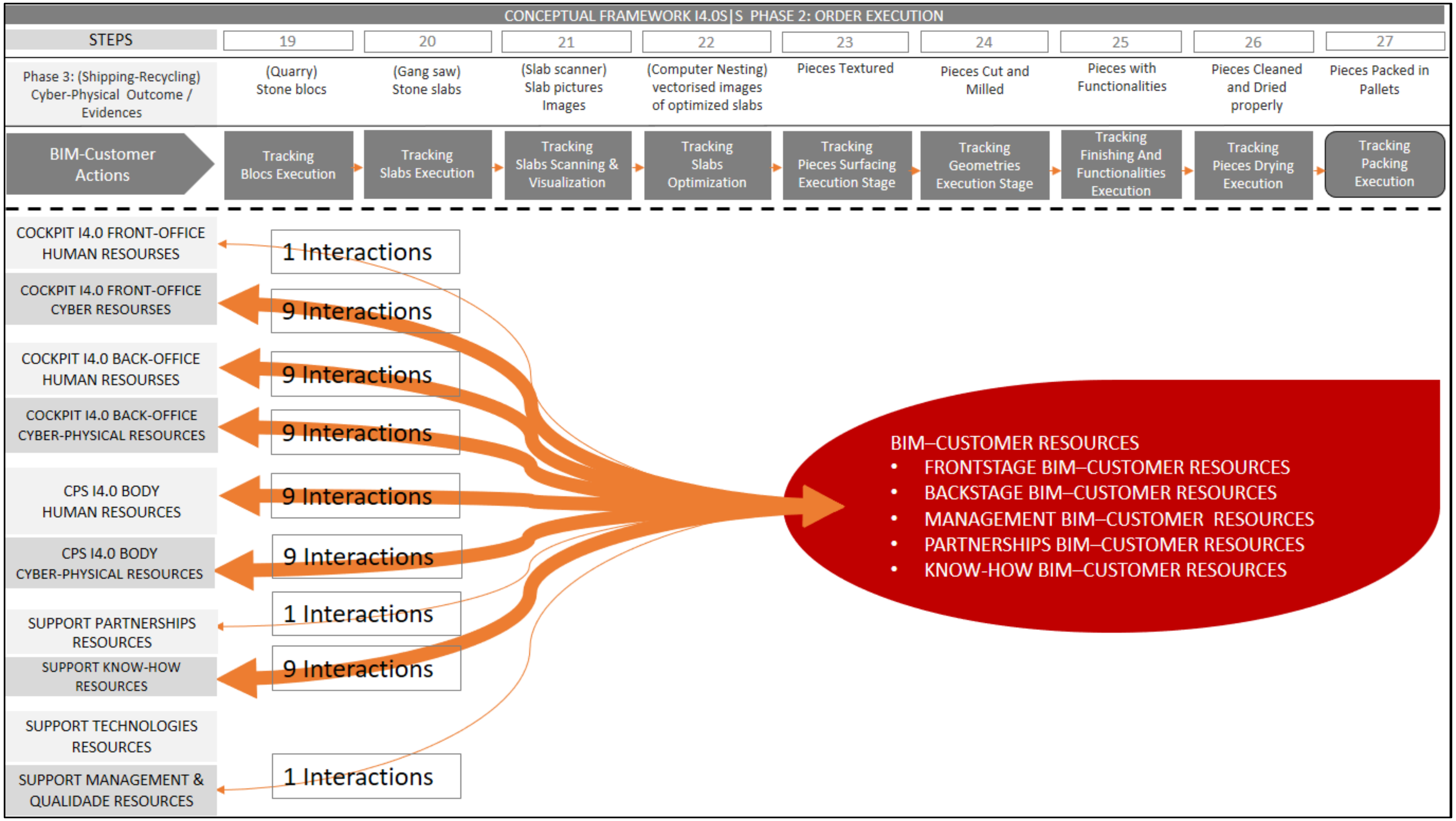


Figure C.12: Phase 2 (Steps 19-27) OC3 (I4.0-Providing in BIM-procurement) | Direct Interactions between BIM-Customer and I4.0-Provider

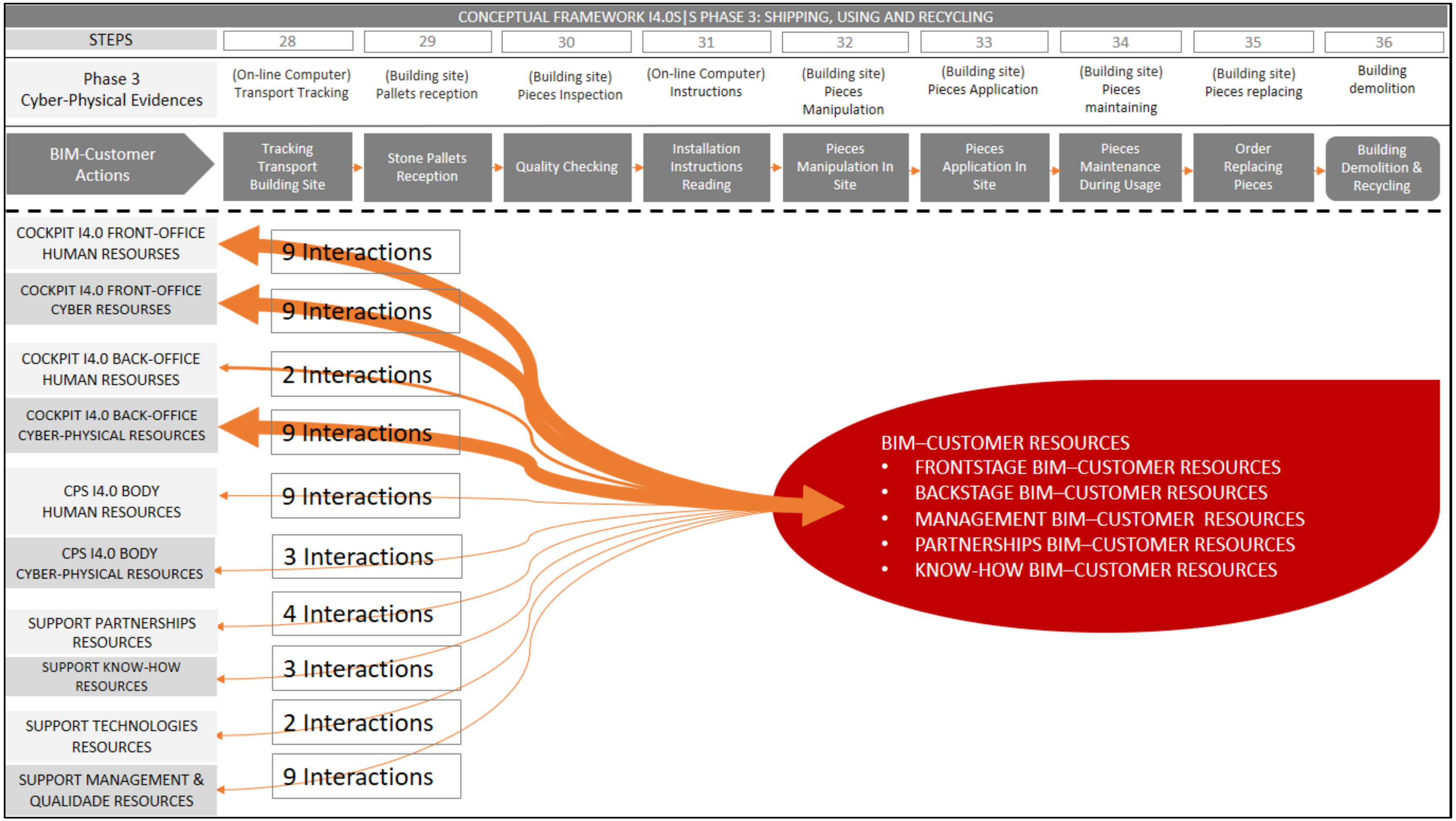


Figure C.13: Phase 3 (Steps 28-36) OC3 (I4.0-Providing in BIM-procurement) | Direct Interactions between BIM-Customer and I4.0-Provider

APPENDIX D

INOVSTONE4.0 FRAMEWORK APPLICATION - RESOURCES ACTIVITY DATA

OC1 | CAD-CUSTOMER CONCERNS	CAD Workstation Outlines Drawing		WEB Connection		Pdf Catalogues of Stone Types from Potential Provider		Stone Samples		Email Exchanging's Phone Calls Or Local Visits		(Computer Screen) CAD Units Geometries 2D		Email Exchanging's		Email Exchanging's Phone Calls or Local Visits		Email Exchanging's Phone Calls Or Local Visits	
CUSTOMER SATISFACTION INDEX (CSI)	1		2		3		4		5		6		7		8		9	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	CAD Workstation Project & Internet		Searches On The Web For Stone Providers		Stone Types And Providers Pre-selection		Stone Samples Requesting		Surface discussion Final Samples Request		CAD operator draw Units Geometries (2D)		Project Outline including Units 2D Geometries		Thickness Definition		Functionalities Definition	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?							1	1										
What is your concern with respect to Product Sustainability?																	1	1
What is your concern with respect to Product Quality?										1			1	1	1	1		1
What is your concern with respect to Contract Compliance?									1	1						1	1	1
What is your concern with respect to Brand Reputation?						1										1		1
What is your concern with respect to Flexibility?								1						1				
What is your concern with respect to Purchasing Price?																		1
What is your concern with respect to Total Product Cost?								1								1		1
What is your concern with respect to Warranty?																1	1	1
What is your concern with respect to After Sales Service?										1					1	1	1	1
What is your concern with respect to Product Reliability?																	1	1
What is your concern with respect to Product Safety?							1	1					1	1			1	1
What is your concern with respect to Product Recycling?															1	1	1	1
CUSTOMER QUANTITATIVE MEASUREMENTS	1		2		3		4		5		6		7		8		9	
Step Process Time (days)	0		0		0		7		5		2		3		1		16	
Customer Labor Time (hours)	2		2		2		1		5		2		2		8		30	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	

Table D.1: OC1 | CAD-Customer Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC1 | CBP-OS-PROVIDERS CONCERNS	CAD Workstation Outlines Drawing		WEB Connection		Pdf Catalogues of Stone Types from Potential Provider		Stone Samples		Email Exchanging's Phone Calls Or Local Visits		(Computer Screen) CAD Units Geometries 2D		Email Exchanging's		Email Exchanging's Phone Calls or Local Visits		Email Exchanging's Phone Calls Or Local Visits	
PROVIDER PERFORMANCE INDEX (PPI)	1		2		3		4		5		6		7		8		9	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	CAD Workstation Project & Internet		Searches On The Web For Stone Providers		Stone Types And Providers Pre-selection		Stone Samples Requesting		Surface discussion Final Samples Request		CAD operator draw Units Geometries (2D)		Project Outline including Units 2D Geometries		Thickness Definition		Functionalities Definition	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?								1	1	1								1
What is your concern with respect to Time to Receive the Product?							1	1										
What is your concern with respect to Product Sustainability ?															1	1		
What is your concern with respect to Procuct Maintenance Costs ?									1						1	1	1	
What is your concern with respect to Contract Compliance?									1	1			1	1				
What is your concern with respect to Brand Reputation?																		1
What is your concern with respect to Flexibility ?													1	1				
What is your concern with respect to Product Safety?							1	1					1	1				
What is your concern with respect to Product Recycling?															1	1	1	1
PROVIDER QUANTITATIVE MEASUREMENTS	1		2		3		4		5		6		7		8		9	
Machines Efective Operation Time (hours)	0		0		0		0		0		0		0		0		0	
Machines Setup Time (hours)	0		0		0		0		0		0		0		0		0	
Logistic Internal Time (hours)	0		0		0		0		0		0		0		0		0	
Idle Process Time (days)	0		0		0		7		5		2		3		1		16	
Labor Time (hours x man)	0		0		0		15		5		0		1		8		30	
Production Electricity Consumption (KWh)	0		0		0		0		0		0		0		0		0	
Production Propane Consumption (Nm3)	0		0		0		0		0		0		0		0		0	
Production Diesel Consumption (Lts)	0		0		0		0		0		0		0		0		0	
Production Raw Materials Consumption (m3)	0		0		0		0		0		0		0		0		0	
Production Raw Material waste (m3)	0		0		0		0		0		0		0		0		0	
Defective Units (defects during process+material defectes) (m2)	0		0		0		0		0		0		0		0		0	
Number of Operations (n)	0		0		0		17		0		0		0		0		0	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	
Total Output Units (n)	0		0		0		0		0		0		0		0		0	
Number of Inspections (n)	0		0		0		1		0		0		0		0		0	

Table D.2: OC1 | CBP-OS-Provider Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC1 | OS-COMPETITOR CONCERNS	CAD Workstation Outlines Drawing		WEB Connection		Pdf Catalogues of Stone Types from Potential Provider		Stone Samples		Email Exchanging's Phone Calls Or Local Visits		(Computer Screen) CAD Units Geometries 2D		Email Exchanging's		Email Exchanging's Phone Calls or Local Visits		Email Exchanging's Phone Calls Or Local Visits	
SUSTAINABLE INNOVATION INDEX (SII)	1		2		3		4		5		6		7		8		9	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	CAD Workstation Project & Internet		Searches On The Web For Stone Providers		Stone Types And Providers Pre-selection		Stone Samples Requesting		Surface discussion Final Samples Request		CAD operator draw Units Geometries (2D)		Project Outline including Units 2D Geometries		Thickness Definition		Functionalities Definition	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?							1	1	1	1					1	1		1
What is your concern with respect to Innovative Product ?																1		
What is your concern with respect to Innovative Manuf. Process ?																		1
What is your concern with respect to Total Product Cost?																		1
What is your concern with respect to Product Recyclable ?															1	1	1	1
What is your concern with respect to Contract Compliance ?																		1
What is your concern with respect to After Sales Response ?												1		1				1
What is your concern with respect to Product Reliability ?																		1

Table D.3: OC1 | OS-Competitor Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC1 | AUTHORITIES CONCERNS	CAD Workstation Outlines Drawing		WEB Connection		Pdf Catalogues of Stone Types from Potential Provider		Stone Samples		Email Exchanging's Phone Calls Or Local Visits		(Computer Screen) CAD Units Geometries 2D		Email Exchanging's		Email Exchanging's Phone Calls or Local Visits		Email Exchanging's Phone Calls Or Local Visits	
CONFORMITY INDEX (CI)	1		2		3		4		5		6		7		8		9	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	CAD Workstation Project & Internet		Searches On The Web For Stone Providers		Stone Types And Providers Pre-selection		Stone Samples Requesting		Surface discussion Final Samples Request		CAD operator draw Units Geometries (2D)		Project Outline including Units 2D Geometries		Thickness Definition		Functionalities Definition	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?								1										
What concern with respect to Product Manufacturing Compliance?																		
What concern with respect to Product Transport Compliance?								1										
What is your concern with respect to Product Recyclable Compliance?																		
What concern with respect to Product Moral Hazard Compliance?								1										
What concern with respect to Product Legal Compliance?								1										
What concern with respect to Taxes & Fines application and execution?								1										

Table D.4 OC1 | Authority Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC1 | CAD-CUSTOMER CONCERNS	(CAD -Computer Screen)		(Computer screen) List of Specifications for Quotations		Email exchanging's phone calls or local visits		Email Exchanging's Phone Calls or local visits		(Computer Screen) Technical & Commercial Offer		Email Exchanging's Phone Calls or local visits		(Computer screen) Final proposal		(Computer Screen) Proposal Acceptation		(Bank account) Payment confirmed	
CUSTOMER SATISFACTION INDEX (CSI)	10		11		12		13		14		15		16		17		18	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	Drawing pieces Functionalities One By One		Complete Specifications For Quotation		Technical Details Discussion		Delivery Time Discussion		Reads Technical & Commercial Proposal		Commercial Discussion For Final Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Payment	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?	1		1	1	1	1	1	1							1	1	1	1
What is your concern with respect to Product Sustainability?			1	1		1									1	1	1	1
What is your concern with respect to Product Quality?			1	1				1		1					1	1	1	1
What is your concern with respect to Contract Compliance?			1	1				1		1					1	1	1	1
What is your concern with respect to Brand Reputation?										1				1				
What is your concern with respect to Flexibility?										1		1		1				
What is your concern with respect to Purchasing Price?									1			1			1	1	1	1
What is your concern with respect to Total Product Cost?									1						1	1	1	1
What is your concern with respect to Warranty?																1		1
What is your concern with respect to After Sales Service?																1		1
What is your concern with respect to Product Reliability?																1		1
What is your concern with respect to Product Safety?												1						
What is your concern with respect to Product Recycling?											1	1						
CUSTOMER QUANTITATIVE MEASUREMENTS	10		11		12		13		14		15		16		17		18	
Step Process Time (days)	3		1		2		4		3		8		1		11		9	
Customer Labor Time (hours)	18		8		3		15		8		10		8		12		1	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	

Table D.5: OC1 | CAD-Customer Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC 1 | CBP-OS-PROVIDERS CONCERNS	(CAD -Computer Screen)		(Computer screen) List of Specifications for Quotations		Email exchanging's phone calls or local visits		Email Exchanging's Phone Calls or local visits		(Computer Screen) Technical & Commercial Offer		Email Exchanging's Phone Calls or local visits		(Computer screen) Final proposal		(Computer Screen) Proposal Acceptation		(Bank account) Payment confirmed	
PROVIDER PERFORMANCE INDEX (PPI)	10		11		12		13		14		15		16		17		18	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	Drawing pieces Functionalities One By One		Complete Specifications For Quotation		Technical Details Discussion		Delivery Time Discussion		Reads Technical & Commercial Proposal		Commercial Discussion For Final Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Payment	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?					1		1		1	1	1	1	1	1				1
What is your concern with respect to Time to Receive the Product?									1	1	1	1	1	1			1	1
What is your concern with respect to Product Sustainability ?												1			1	1		
What is your concern with respect to Procuct Maintenance Costs ?			1		1	1			1	1	1	1	1	1	1		1	
What is your concern with respect to Contract Compliance?			1		1								1	1				
What is your concern with respect to Brand Reputation?	1		1		1		1										1	1
What is your concern with respect to Flexibility ?			1		1				1	1	1	1					1	
What is your concern with respect to Product Safety?			1		1													1
What is your concern with respect to Product Recycling?			1		1													1

PROVIDER QUANTITATIVE MEASUREMENTS	10	11	12	13	14	15	16	17	18
Machines Efective Operation Time (hours)	0	0	0	0	0	0	0	0	0
Machines Setup Time (hours)	0	0	0	0	0	0	0	0	0
Logistic Internal Time (hours)	0	0	0	0	0	0	0	0	0
Idle Process Time (days)	3	1	2	4	3	8	1	11	9
Labor Time (hours x man)	1	7	6	19	9	6	8	6	1
Production Electricity Consumption (KWh)	0	0	0	0	0	0	0	0	0
Production Propane Consumption (Nm3)	0	0	0	0	0	0	0	0	0
Production Diesel Consumption (Lts)	0	0	0	0	0	0	0	0	0
Production Raw Materials Consumption (m3)	0	0	0	0	0	0	0	0	0
Production Raw Material waste (m3)	0	0	0	0	0	0	0	0	0
Defective Units (defects during process+material defectes) (m2)	0	0	0	0	0	0	0	0	0
Number of Operations (n)	0	4	6	0	7	0	0	8	9
Rejected Units by Costumer (m2)	0	0	0	0	0	0	0	0	0
Total Output Units (n)	0	0	0	0	0	0	0	0	0
Number of Inspections (n)	0	0	0	0	0	0	0	0	0

Table D.6: OC1 | CBP-OS-Provider Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC1 | OS-COMPETITOR CONCERNS	(CAD -Computer Screen)		(Computer screen) List of Specifications for Quotations		Email exchanging's phone calls or local visits		Email Exchanging's Phone Calls or local visits		(Computer Screen) Technical & Commercial Offer		Email Exchanging's Phone Calls or local visits		(Computer screen) Final proposal		(Computer Screen) Proposal Acceptation		(Bank account) Payment confirmed	
SUSTAINABLE INNOVATION INDEX (SII)	10		11		12		13		14		15		16		17		18	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	Drawing pieces Functionalities One By One		Complete Specifications For Quotation		Technical Details Discussion		Delivery Time Discussion		Reads Technical & Commercial Proposal		Commercial Discussion For Final Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Payment	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?	1						1	1	1	1	1	1	1	1	1	1	1	
What is your concern with respect to Innovative Product ?												1		1		1		
What is your concern with respect to Innovative Manuf. Process ?												1		1		1		
What is your concern with respect to Total Product Cost?																1		
What is your concern with respect to Product Recyclable ?															1	1		
What is your concern with respect to Contract Compliance ?			1		1		1	1		1	1	1				1		
What is your concern with respect to After Sales Response ?										1		1			1	1		1
What is your concern with respect to Product Reliability ?																	1	1

Table D.7: OC1 | OS-Competitor Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC1 | AUTHORITIES CONCERNS	(CAD -Computer Screen)		(Computer screen) List of Specifications for Quotations		Email exchanging's phone calls or local visits		Email Exchanging's Phone Calls or local visits		(Computer Screen) Technical & Commercial Offer		Email Exchanging's Phone Calls or local visits		(Computer screen) Final proposal		(Computer Screen) Proposal Acceptation		(Bank account) Payment confirmed	
CONFORMITY INDEX (CI)	10		11		12		13		14		15		16		17		18	
PHASE 1: DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING	Drawing pieces Functionalities One By One		Complete Specifications For Quotation		Technical Details Discussion		Delivery Time Discussion		Reads Technical & Commercial Proposal		Commercial Discussion For Final Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Payment	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?																		1
What concern with respect to Product Manufacturing Compliance?																		1
What concern with respect to Product Transport Compliance?																		1
What is your concern with respect to Product Recyclable Compliance?																		1
What concern with respect to Product Moral Hazard Compliance?																		1
What concern with respect to Product Legal Compliance?																		1
What concern with respect to Taxes & Fines application and execution?																		1

Table D.8: OC1 | Authority Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC1 | CAD-CUSTOMER CONCERNS	(Quarry) Stone Blocs		(Gansaw) Stone Slabs		(Surfacing Machines) Flaming		(Computer Nesting) Vectorised Images Of Optimized Slabs		(Cutting And Milling Machines) Cutting And Milling		Slabs Yield Checked After Cut		(Server Screen) Photos Of Pieces Cut And Milled		(Functionalities Machines) Pieces With Functionalities		(QC & Packing Machines) Pallets Filling and dry lay	
CUSTOMER SATISFACTION INDEX (CSI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?	1		1		1		1	1	1	1	1	1	1	1	1		1	1
What is your concern with respect to Product Sustainability?							1								1		1	1
What is your concern with respect to Product Quality?																	1	1
What is your concern with respect to Contract Compliance?																	1	1
What is your concern with respect to Brand Reputation?															1		1	1
What is your concern with respect to Flexibility?																	1	1
What is your concern with respect to Purchasing Price?																	1	1
What is your concern with respect to Total Product Cost?																	1	1
What is your concern with respect to Warranty?																	1	1
What is your concern with respect to After Sales Service?																	1	1
What is your concern with respect to Product Reliability?																	1	1
What is your concern with respect to Product Safety?																	1	1
What is your concern with respect to Product Recycling?																	1	1
CUSTOMER QUANTITATIVE MEASUREMENTS	19		20		21		22		23		24		25		26		27	
Step Process Time (days)	15		7		18		0		7		0		0		5		9	
Customer Labor Time (hours)	0		0		0		0		0		0		0		0		0	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	

Table D.9 OC1 | CAD-Customer Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC1 | CBP-OS-PROVIDERS CONCERNS	(Quarry) Stone Blocs		(Gansaw) Stone Slabs		(Surfacing Machines) Flaming		(Computer Nesting) Vectorised Images Of Optimized Slabs		(Cutting And Milling Machines) Cutting And Milling		Slabs Yield Checked After Cut		(Server Screen) Photos Of Pieces Cut And Milled		(Functionalities Machines) Pieces With Functionalities		(QC & Packing Machines) Pallets Filling and dry lay	
PROVIDER PERFORMANCE INDEX (PPI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?		1		1		1	1		1		1				1		1	1
What is your concern with respect to Time to Receive the Product?	1		1		1		1		1		1				1		1	1
What is your concern with respect to Product Sustainability ?															1	1	1	1
What is your concern with respect to Procuct Maintenance Costs ?																	1	1
What is your concern with respect to Contract Compliance?															1		1	1
What is your concern with respect to Brand Reputation?							1		1		1						1	1
What is your concern with respect to Flexibility ?																	1	1
What is your concern with respect to Product Safety?																	1	1
What is your concern with respect to Product Recycling?																	1	1
PROVIDER QUANTITATIVE MEASUREMENTS	19		20		21		22		23		24		25		26		27	
Machines Efective Operation Time (hours)	0,00		19,88		62,59		0,00		36,51		0,00		0,00		36,38		66,24	
Machines Setup Time (hours)	0,00		5,97		21,90		0,00		3,65		0,00		0,00		10,91		26,50	
Logistic Internal Time (hours)	0,00		5,97		18,78		0,00		7,30		0,00		0,00		14,55		19,87	
Idle Process Time (days)	15,00		6,00		14,00		0,00		5,00		0,00		0,00		2,58		4,69	
Labor Time (hours x man)	0,00		10,00		103,27		0,00		47,46		0,00		0,00		61,84		112,61	
Production Electricity Consumption (KWh)	0,00		2187,29		688,44		0,00		730,16		0,00		0,00		400,13		496,80	
Production Propane Consumption (Nm3)	0,00		0,00		87,62		0,00		0,00		0,00		0,00		0,00		0,00	
Production Diesel Consumption (Lts)	128,18		0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00	
Production Raw Materials Consumption (m3)	16,35		16,35		13,51		12,44		12,44		9,30		9,30		9,30		8,94	
Production Raw Material waste (m3)	0,00		3,55		0,54		0,00		3,13		0,00		0,00		0,00		0,00	
Defective Units (defects during process+material defectes) (m2)	0,00		0,00		17,88		0,00		0,20		0,00		0,00		15,00		12,00	
Number of Operations (n)	0,00		4,00		6,00		0,00		7,00		0,00		0,00		8,00		9,00	
Rejected Units by Costumer (m2)	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00	
Total Output Units (n)	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00		276,00	
Number of Inspections (n)	0,00		1,00		1,00		1,00		1,00		0,00		0,00		1,00		1,00	

Table D.10: OC1 | CBP-OS-Provider Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC1 | OS-COMPETITOR CONCERNS	(Quarry) Stone Blocs		(Gansaw) Stone Slabs		(Surfacing Machines) Flaming		(Computer Nesting) Vectorised Images Of Optimized Slabs		(Cutting And Milling Machines) Cutting And Milling		Slabs Yield Checked After Cut		(Server Screen) Photos Of Pieces Cut And Milled		(Functionalities Machines) Pieces With Functionalities		(QC & Packing Machines) Pallets Filling and dry lay	
SUSTAINABLE INNOVATION INDEX (SII)	19		20		21		22		23		24		25		26		27	
PHASE 2 : ORDER EXECUTION	Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?							1	1	1	1					1	1	1	1
What is your concern with respect to Innovative Product ?																	1	1
What is your concern with respect to Innovative Manuf. Process ?																	1	1
What is your concern with respect to Total Product Cost?																	1	1
What is your concern with respect to Product Recyclable ?															1	1	1	1
What is your concern with respect to Contract Compliance ?							1		1							1	1	1
What is your concern with respect to After Sales Response ?												1		1	1		1	1
What is your concern with respect to Product Reliability ?																	1	1

Table D.11: OC1 | OS-Competitor Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC1 | AUTHORITIES CONCERNS	(Quarry) Stone Blocs		(Gansaw) Stone Slabs		(Surfacing Machines) Flaming		(Computer Nesting) Vectorised Images Of Optimized Slabs		(Cutting And Milling Machines) Cutting And Milling		Slabs Yield Checked After Cut		(Server Screen) Photos Of Pieces Cut And Milled		(Functionalities Machines) Pieces With Functionalities		(QC & Packing Machines) Pallets Filling and dry lay	
CONFORMITY INDEX (CI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits		Tracking By Email Phone or Local Visits	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?																		1
What concern with respect to Product Manufacturing Compliance?																		1
What concern with respect to Product Transport Compliance?																	1	1
What is your concern with respect to Product Recyclable Compliance?																	1	1
What concern with respect to Product Moral Hazard Compliance?																	1	1
What concern with respect to Product Legal Compliance?																		1
What concern with respect to Taxes & Fines application and execution?																	1	1

Table D.12: OC1 | Authority Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC1 | CAD-CUSTOMER CONCERNS	Transport to Building site		(Building Site) Pallets Reception		(Building Site) Pieces Inspection		(On-line Computer) Instructions		(Building Site) Pieces Manipulation		(Building Site) Pieces Application		(Building Site) Pieces Maintaining		(Building Site) Pieces Replacing		Building Demolition	
CUSTOMER SATISFACTION INDEX (CSI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport		Stone Pallets Reception		Pieces Quality Checking		Installation Instructions Requesting		Pieces Manipulation / Dry Laying		Pieces Application		Pieces Maintenance		Order New Pieces For Replacing		Building Demolition & Recycling	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?	1	1	1		1		1	1										
What is your concern with respect to Product Sustainability?								1										
What is your concern with respect to Product Quality?					1	1		1										
What is your concern with respect to Contract Compliance?					1	1		1										
What is your concern with respect to Brand Reputation?					1	1												
What is your concern with respect to Flexibility?					1	1												
What is your concern with respect to Purchasing Price?																		
What is your concern with respect to Total Product Cost?																		
What is your concern with respect to Warranty?																		
What is your concern with respect to After Sales Service?																		
What is your concern with respect to Product Reliability?																		
What is your concern with respect to Product Safety?																		
What is your concern with respect to Product Recycling?																		
CUSTOMER QUANTITATIVE MEASUREMENTS	10		11		12		13		14		15		16		17		18	
Step Process Time (days)	3		1		5		1											
Customer Labor Time (hours)	0		8		12		1											
Rejected Units by Costumer (m2)	0		0		22		0											

Table D.13: OC1 | CAD-Customer Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC1 | CBP-OS-PROVIDERS CONCERNS	Transport to Building site		(Building Site) Pallets Reception		(Building Site) Pieces Inspection		(On-line Computer) Instructions		(Building Site) Pieces Manipulation		(Building Site) Pieces Application		(Building Site) Pieces Maintaining		(Building Site) Pieces Replacing		Building Demolition	
PROVIDER PERFORMANCE INDEX (PPI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport		Stone Pallets Reception		Pieces Quality Checking		Installation Instructions Requesting		Pieces Manipulation		Pieces Application		Pieces Maintenance		Order New Pieces For Replacing		Building Demolition & Recycling	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?	1				1		1		1		1	1						
What is your concern with respect to Time to Receive the Product?	1										1	1						
What is your concern with respect to Product Sustainability ?												1						
What is your concern with respect to Procuct Maintenance Costs ?			1		1	1			1			1						
What is your concern with respect to Contract Compliance?			1		1							1						
What is your concern with respect to Brand Reputation?			1		1		1		1			1						
What is your concern with respect to Flexibility ?			1		1				1			1						
What is your concern with respect to Product Safety?			1		1							1						
What is your concern with respect to Product Recycling?												1						

PROVIDER QUANTITATIVE MEASUREMENTS	28	29	30	31	32	33	34	35	36
Machines Efective Operation Time (hours)	0,00	0,00	0,00	0,00					
Machines Setup Time (hours)	0,00	0,00	0,00	0,00					
Logistic Internal Time (hours)	0,00	0,00	0,00	0,00					
Idle Process Time (days)	3,00	1,00	5,00	1,00					
Labor Time (hours x man)	0,00	0,00	0,00	0,00					
Production Electricity Consumption (KWh)	0,00	0,00	0,00	0,00					
Production Propane Consumption (Nm3)	0,00	0,00	0,00	0,00					
Production Diesel Consumption (Lts)	0,00	0,00	0,00	0,00					
Production Raw Materials Consumption (m3)	8,94	8,94	8,28	8,28					
Production Raw Material waste (m3)	0,00	0,00	0,00	0,00					
Defective Units (defects during process+material defectes) (m2)	0,00	0,00	0,00	0,00					
Number of Operations (n)	0,00	0,00	0,00	0,00					
Rejected Units by Costumer (m2)	0,00	0,00	22,00	0,00					
Total Output Units (n)	0,00	0,00	0,00	0,00					
Number of Inspections (n)	0,00	0,00	0,00	0,00					

Table D.14: OC1 | CBP-OS-Provider Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC1 | OS-COMPETITOR CONCERNS	Transport to Building site		(Building Site) Pallets Reception		(Building Site) Pieces Inspection		(On-line Computer) Instructions		(Building Site) Pieces Manipulation		(Building Site) Pieces Application		(Building Site) Pieces Maintaining		(Building Site) Pieces Replacing		Building Demolition	
SUSTAINABLE INNOVATION INDEX (SII)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport		Stone Pallets Reception		Pieces Quality Checking		Installation Instructions Requesting		Pieces Manipulation		Pieces Application		Pieces Maintenance		Order New Pieces For Replacing		Building Demolition & Recycling	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?					1	1	1	1	1	1	1	1						
What is your concern with respect to Innovative Product ?												1						
What is your concern with respect to Innovative Manuf. Process ?												1						
What is your concern with respect to Total Product Cost?												1						
What is your concern with respect to Product Recyclable ?												1						
What is your concern with respect to Contract Compliance ?								1		1	1	1						
What is your concern with respect to After Sales Response ?										1	1	1						
What is your concern with respect to Product Reliability ?											1	1						

Table D.15: OC1 | OS-Competitor Concerns |Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC1 | AUTHORITIES CONCERNS	Transport to Building site		(Building Site) Pallets Reception		(Building Site) Pieces Inspection		(On-line Computer) Instructions		(Building Site) Pieces Manipulation		(Building Site) Pieces Application		(Building Site) Pieces Maintaining		(Building Site) Pieces Replacing		Building Demolition	
CONFORMITY INDEX (CI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport		Stone Pallets Reception		Pieces Quality Checking		Installation Instructions Requesting		Pieces Manipulation		Pieces Application		Pieces Maintenance		Order New Pieces For Replacing		Building Demolition & Recycling	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?	1	1				1		1	1	1		1						
What concern with respect to Product Manufacturing Compliance?	1	1				1		1	1	1		1						
What concern with respect to Product Transport Compliance?	1	1				1		1	1	1		1						
What is your concern with respect to Product Recyclable Compliance?	1	1				1		1	1	1		1						
What concern with respect to Product Moral Hazard Compliance?	1	1				1		1	1	1		1						
What concern with respect to Product Legal Compliance?	1	1				1		1	1	1		1						
What concern with respect to Taxes & Fines application and execution?	1	1				1		1	1	1		1						

Table D.16: OC1 | Authority Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC3 | BIM-CUSTOMER CONCERNS	BIM Workstation		WEB BIM/IFC Libraries		Stone Catalogues		BIM-Istone4.0 Connection		(Computer Screen) Virtual Samples		(Computer Screen) BIM-Istone4.0 Project Outlines		(Computer Screen) Project In Stone		(Computer Screen) BIM-Istone4.0 Interactions		(Computer Screen) Thickness Constrains	
CUSTOMER SATISFACTION INDEX (CSI)	1		2		3		4		5		6		7		8		9	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	BIM Workstation & Internet Connection		Web Searches For BIM Libraries Stone Providers		Stone Provider Selection		Direct Connection To Stone Provider		Stone Types And Surface Selection		Project Outlines Drawing		Drags Outline Draw Into The BIM-Istone4.0		Playing on Pieces Dimensions Interactively		Selects The Materials Thickness	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?								1										
What is your concern with respect to Product Sustainability?																		1
What is your concern with respect to Product Quality?										1				1	1	1		1
What is your concern with respect to Contract Compliance?										1						1		1
What is your concern with respect to Brand Reputation?						1										1		1
What is your concern with respect to Flexibility?								1						1				
What is your concern with respect to Purchasing Price?																		1
What is your concern with respect to Total Product Cost?								1								1		1
What is your concern with respect to Warranty?																1		1
What is your concern with respect to After Sales Service?										1					1	1		1
What is your concern with respect to Product Reliability?																		1
What is your concern with respect to Product Safety?								1						1				1
What is your concern with respect to Product Recycling?							1	1						1				1
CUSTOMER QUANTITATIVE MEASUREMENTS	1		2		3		4		5		6		7		8		9	
Step Process Time (days)	0,0		0,0		0,0		0,0		1,0		3,0		0,0		1,0		0,0	
Customer Labor Time (hours)	2		2		2		1		5		0		2		8		1	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	

Table D.17: OC3 | BIM-Customer Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC 3 | I4.0-OS-PROVIDERS CONCERNS	BIM Workstation		WEB BIM/IFC Libraries		Stone Catalogues		SBIM-I4.0 Connection		(Computer Screen) Virtual Samples		(Computer Screen) BIM-I4.0 Project Outlines		(Computer Screen) Project In Stone		(Computer Screen) BIM-I4.0 Interactions		(Computer Screen) Thickness Constrains	
PROVIDER PERFORMANCE INDEX (PPI)	1		2		3		4		5		6		7		8		9	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	BIM Workstation & Internet Connection		Web Searches For BIM Libraries Stone Providers		Stone Provider Selection		Direct Connection To Stone Provider		Stone Types And Surface Selection		Project Outlines Drawing		Drags Outline Draw Into The BIM-I4.0		Plays On Pieces Dimensions Interactively		Selects The Materials Thickness	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?								1		1		1		1				1
What is your concern with respect to Time to Receive the Product?												1						
What is your concern with respect to Product Sustainability ?																1		
What is your concern with respect to Procuct Maintenance Costs ?																1		1
What is your concern with respect to Contract Compliance?														1				
What is your concern with respect to Brand Reputation?																		1
What is your concern with respect to Flexibility ?														1				
What is your concern with respect to Product Safety?														1				
What is your concern with respect to Product Recycling?														1				1
PROVIDER QUANTITATIVE MEASUREMENTS	1		2		3		4		5		6		7		8		9	
Machines Efective Operation Time (hours)	0		0		0		0		0				0		0		0	
Machines Setup Time (hours)	0		0		0		0		0		0		0		0		0	
Logistic Internal Time (hours)	0		0		0		0		0		0		0		0		0	
Idle Process Time (days)	0		0		0		0		1		3		0		1		0	
Labor Time (hours x man)	0		0		0		0		5		4		0		8		1	
Production Electricity Consumption (KWh)	0		0		0		0		0		0		0		0		0	
Production Propane Consumption (Nm3)	0		0		0		0		0		0		0		0		0	
Production Diesel Consumption (Lts)	0		0		0		0		0		0		0		0		0	
Production Raw Materials Consumption (m3)	0		0		0		0		0		0		0		0		0	
Production Raw Material waste (m3)	0		0		0		0		0		0		0		0		0	
Defective Units (defects during process+material defectes) (m2)	0		0		0		0		0		0		0		0		0	
Number of Operations (n)	0		0		0		0		0		9		0		0		0	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	
Total Output Units (n)	0		0		0		0		0		0		0		0		0	
Number of Inspections (n)	0		0		0		0		0		1		0		0		0	

Table D.18: OC3 | I4.0-OS-Provider Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC3 | OS-COMPETITOR CONCERNS	BIM Workstation		WEB BIM/IFC Libraries		Stone Catalogues		SBIM-I4.0 Connection		(Computer Screen) Virtual Samples		(Computer Screen) BIM-I4.0 Project Outlines		(Computer Screen) Project In Stone		(Computer Screen) BIM-I4.0 Interactions		(Computer Screen) Thickness Constrains	
SUSTAINABLE INNOVATION INDEX (SII)	1		2		3		4		5		6		7		8		9	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	BIM Workstation & Internet Connection		Web Searches For BIM Libraries Stone Providers		Stone Provider Selection		Direct Connection To Stone Provider		Stone Types And Surface Selection		Project Outlines Drawing		Drags Outline Draw Into The BIM-I4.0		Plays On Pieces Dimensions Interactively		Selects The Materials Thickness	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?									1	1					1	1		1
What is your concern with respect to Innovative Product ?																1		
What is your concern with respect to Innovative Manuf. Process ?																		1
What is your concern with respect to Total Product Cost?																		1
What is your concern with respect to Product Recyclable ?															1	1	1	1
What is your concern with respect to Contract Compliance ?																		1
What is your concern with respect to After Sales Response ?												1		1				1
What is your concern with respect to Product Reliability ?												1						1

Table D.19: OC3 | OS-Competitor Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC3 | AUTHORITIES CONCERNS	BIM Workstation		WEB BIM/IFC Libraries		Stone Catalogues		SBIM-I4.0 Connection		(Computer Screen) Virtual Samples		(Computer Screen) BIM-I4.0 Project Outlines		(Computer Screen) Project In Stone		(Computer Screen) BIM-I4.0 Interactions		(Computer Screen) Thickness Constrains	
CONFORMITY INDEX (CI)	1		2		3		4		5		6		7		8		9	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	BIM Workstation & Internet Connection		Web Searches For BIM Libraries Stone Providers		Stone Provider Selection		Direct Connection To Stone Provider		Stone Types And Surface Selection		Project Outlines Drawing		Drags Outline Draw Into The BIM-I4.0		Plays On Pieces Dimensions Interactively		Selects The Materials Thickness	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?								1										
What concern with respect to Product Manufacturing Compliance?																		
What concern with respect to Product Transport Compliance?								1										
What is your concern with respect to Product Recyclable Compliance?																		
What concern with respect to Product Moral Hazard Compliance?								1										
What concern with respect to Product Legal Compliance?								1										
What concern with respect to Taxes & Fines application and execution?								1										

Table D.20: OC3 | Authority Concerns | Data Collection | Phase1 Steps 1-9 | Data collected from January 2016 to May 2017

OC3 | BIM-CUSTOMER CONCERNS	(On-line Computer) Interface Options		(On-line Computer) List Of Cut-to-size Pieces Geometries		(On-line Computer) I4.0 Calendar		(On-line Computer) BIM Objects 8 Dimensions List		(On-line Computer) Technical & Commercial Offer		Phone Line		(On-line Computer) Final Proposal		(On-line Computer) Proposal Acceptation		(Bank Account) Payment Confirmed	
CUSTOMER SATISFACTION INDEX (CSI)	10		11		12		13		14		15		16		17		18	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	Selects Automatic Cut-to-size Option		Geometry List Of Cut-to-size Pieces		Inputs The Schedule For Delivery		Reads BIM Objects 8 Dimensions List		Reads Technical & Commercial Proposal		Discusses The Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Makes The Payment	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	10		11		12		13		14		15		16		17		18	
What is your concern with respect to Time to Receive the Product?				1		1		1								1		1
What is your concern with respect to Product Sustainability?				1		1										1		1
What is your concern with respect to Product Quality?				1				1		1						1		1
What is your concern with respect to Contract Compliance?				1				1		1						1		1
What is your concern with respect to Brand Reputation?										1				1				
What is your concern with respect to Flexibility?										1		1		1				
What is your concern with respect to Purchasing Price?												1				1		1
What is your concern with respect to Total Product Cost?																1		1
What is your concern with respect to Warranty?																1		1
What is your concern with respect to After Sales Service?																1		1
What is your concern with respect to Product Reliability?																1		1
What is your concern with respect to Product Safety?												1						
What is your concern with respect to Product Recycling?												1				1		
CUSTOMER QUANTITATIVE MEASUREMENTS	10		11		12		13		14		15		16		17		18	
Step Process Time (days)	0		0		0		2		3		8		1		11		9	
Customer Labor Time (hours)	18		1		3		5		8		10		8		12		1	
Rejected Units by Costumer (m2)	0		0		0		0		0		0		0		0		0	

Table D.21: OC3 | BIM-Customer Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC 3 | I4.0-OS-PROVIDERS CONCERNS	(On-line Computer) Interface Options		(On-line Computer) List Of Cut-to-size Pieces Geometries		(On-line Computer) I4.0 Calendar		(On-line Computer) BIM Objects 8 Dimensions List		(On-line Computer) Technical & Commercial Offer		Phone Line		(On-line Computer) Final Proposal		(On-line Computer) Proposal Acceptation		(Bank Account) Payment Confirmed	
PROVIDER PERFORMANCE INDEX (PPI)	10		11		12		13		14		15		16		17		18	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	Selects Automatic Cut-to-size Option		Geometry List Of Cut-to-size Pieces		Inputs The Schedule For Delivery		Reads BIM Objects 8 Dimensions List		Reads Technical & Commercial Proposal		Discusses The Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Makes The Payment	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?					1		1	1	1	1	1	1	1	1				1
What is your concern with respect to Time to Receive the Product?									1	1	1	1	1	1			1	1
What is your concern with respect to Product Sustainability ?												1			1	1		
What is your concern with respect to Procuct Maintenance Costs ?				1	1	1			1	1	1	1	1	1	1		1	
What is your concern with respect to Contract Compliance?				1	1								1	1				
What is your concern with respect to Brand Reputation?		1		1	1		1	1									1	
What is your concern with respect to Flexibility ?				1	1				1	1	1	1					1	
What is your concern with respect to Product Safety?				1	1													
What is your concern with respect to Product Recycling?				1	1													

PROVIDER QUANTITATIVE MEASUREMENTS	10	11	12	13	14	15	16	17	18
Machines Efective Operation Time (hours)	0	0	0	0	0	0	0	0	0
Machines Setup Time (hours)	0	0	0	0	0	0	0	0	0
Logistic Internal Time (hours)	0	0	0	0	0	0	0	0	0
Idle Process Time (days)	0	0	0	2	3	8	1	11	9
Labor Time (hours x man)	1	1	2	3	9	6	8	6	1
Production Electricity Consumption (KWh)	0	0	0	0	0	0	0	0	0
Production Propane Consumption (Nm3)	0	0	0	0	0	0	0	0	0
Production Diesel Consumption (Lts)	0	0	0	0	0	0	0	0	0
Production Raw Materials Consumption (m3)	0	0	0	0	0	0	0	0	0
Production Raw Material waste (m3)	0	0	0	0	0	0	0	0	0
Defective Units (defects during process+material defectes) (m2)	0	0	0	0	0	0	0	0	0
Number of Operations (n)	0	0	0	0	0	0	0	0	0
Rejected Units by Costumer (m2)	0	0	0	0	0	0	0	0	0
Total Output Units (n)	0	0	0	0	0	0	0	0	0
Number of Inspections (n)	0	0	0	0	0	0	0	0	0

Table D.22: OC3 | I4.0-OS-Provider Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC3 | OS-COMPETITOR CONCERNS	(On-line Computer) Interface Options		(On-line Computer) List Of Cut-to-size Pieces Geometries		(On-line Computer) I4.0 Calendar		(On-line Computer) BIM Objects 8 Dimensions List		(On-line Computer) Technical & Commercial Offer		Phone Line		(On-line Computer) Final Proposal		(On-line Computer) Proposal Acceptation		(Bank Account) Payment Confirmed	
SUSTAINABLE INNOVATION INDEX (SII)	10		11		12		13		14		15		16		17		18	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	Selects Automatic Cut-to-size Option		Geometry List Of Cut-to-size Pieces		Inputs The Schedule For Delivery		Reads BIM Objects 8 Dimensions List		Reads Technical & Commercial Proposal		Discusses The Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Makes The Payment	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?		1					1	1	1	1	1	1		1		1		1
What is your concern with respect to Innovative Product ?												1		1		1		
What is your concern with respect to Innovative Manuf. Process ?												1		1		1		
What is your concern with respect to Total Product Cost?																1		
What is your concern with respect to Product Recyclable ?															1	1		
What is your concern with respect to Contract Compliance ?				1		1	1	1		1	1	1				1		
What is your concern with respect to After Sales Response ?										1		1			1	1		1
What is your concern with respect to Product Reliability ?																		1

Table D.23: OC3 | OS-Competitor Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC3 | AUTHORITIES CONCERNS	(On-line Computer) Interface Options		(On-line Computer) List Of Cut-to-size Pieces Geometries		(On-line Computer) Istone4.0 Calendar		(On-line Computer) BIM Objects 8 Dimensions List		(On-line Computer) Technical & Commercial Offer		Phone Line		(On-line Computer) Final Proposal		(On-line Computer) Proposal Acceptation		(Bank Account) Payment Confirmed	
CONFORMITY INDEX (CI)	10		11		12		13		14		15		16		17		18	
PHASE 1: FINGERPRINT (DESIGN + PROPOSAL DISCUSSION + ORDER PROCESSING)	Selects Automatic Cut-to-size Option		Geometry List Of Cut-to-size Pieces		Inputs The Schedule For Delivery		Reads BIM Objects 8 Dimensions List		Reads Technical & Commercial Proposal		Discusses The Offer		Reads Technical &Commercial Final Proposal		Proposal Acceptation		Makes The Payment	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?																		1
What concern with respect to Product Manufacturing Compliance?																		1
What concern with respect to Product Transport Compliance?																		1
What is your concern with respect to Product Recyclable Compliance?																		1
What concern with respect to Product Moral Hazard Compliance?																		1
What concern with respect to Product Legal Compliance?																		1
What concern with respect to Taxes & Fines application and execution?																		1

Table D.24: OC3 | Authority Concerns | Data Collection | Phase1 Steps 10-18 | Data collected from January 2016 to May 2017

OC3 | BIM-CUSTOMER CONCERNS	(Quarry) Stone blocs		(Gang saw) Stone slabs		(Slab scanner) Slab pictures Images		(Computer Nesting) vectorised images of optimized slabs		Pieces Textured		Pieces Cut and Milled		Pieces with Functionalities		Pieces Cleaned and Dried properly		Pieces Packed in Pallets	
CUSTOMER SATISFACTION INDEX (CSI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking Blocs Execution		Tracking Slabs Execution		Tracking Slabs Scanning & Visualization		Tracking Slabs Optimization		Tracking Pieces Surfacing Execution Stage		Tracking Geometries Execution Stage		Tracking Finishing & Functionalities Execution		Tracking Pieces Drying Execution		Tracking Packing Execution	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?		1		1		1		1		1		1		1		1	1	1
What is your concern with respect to Product Sustainability?																	1	1
What is your concern with respect to Product Quality?																	1	1
What is your concern with respect to Contract Compliance?																	1	1
What is your concern with respect to Brand Reputation?																1	1	1
What is your concern with respect to Flexibility?																	1	1
What is your concern with respect to Purchasing Price?																	1	1
What is your concern with respect to Total Product Cost?																	1	1
What is your concern with respect to Warranty?																	1	1
What is your concern with respect to After Sales Service?																	1	1
What is your concern with respect to Product Reliability?																	1	1
What is your concern with respect to Product Safety?																	1	1
What is your concern with respect to Product Recycling?																		
CUSTOMER QUANTITATIVE MEASUREMENTS	19		20		21		22		23		24		25		26		27	
Step Process Time (days)	8		1		0		0		1		1		1		0		1	
Customer Labor Time (hours)	0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0	
Rejected Units by Costumer (m2)	0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0	

Table D.25: OC3 | BIM-Customer Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC 3 | I4.0-OS-PROVIDERS CONCERNS	(Quarry) Stone blocs		(Gang saw) Stone slabs		(Slab scanner) Slab pictures Images		(Computer Nesting) vectorised images of optimized slabs		Pieces Textured		Pieces Cut and Milled		Pieces with Functionalities		Pieces Cleaned and Dried properly		Pieces Packed in Pallets	
PROVIDER PERFORMANCE INDEX (PPI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking Blocs Execution		Tracking Slabs Execution		Tracking Slabs Scanning & Visualization		Tracking Slabs Optimization		Tracking Pieces Surfacing Execution Stage		Tracking Geometries Execution Stage		Tracking Finishing And Functionalities Execution		Tracking Pieces Drying Execution		Tracking Packing Execution	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?		1		1		1		1		1		1		1		1	1	1
What is your concern with respect to Time to Receive the Product?		1		1		1		1		1		1		1		1	1	1
What is your concern with respect to Product Sustainability ?																1	1	1
What is your concern with respect to Procuct Maintenance Costs ?																	1	1
What is your concern with respect to Contract Compliance?																1	1	1
What is your concern with respect to Brand Reputation?								1		1		1		1			1	1
What is your concern with respect to Flexibility ?																	1	1
What is your concern with respect to Product Safety?																	1	1
What is your concern with respect to Product Recycling?																	1	1
PROVIDER QUANTITATIVE MEASUREMENTS	19		20		21		22		23		24		25		26		27	
Machines Efective Operation Time (hours)	0,00		2,00		0,00		0,00		3,70		3,65		3,86		4,00		1,00	
Machines Setup Time (hours)	0,00		0,62		0,00		0,00		0,00		0,37		0,00		0,00		0,00	
Logistic Internal Time (hours)	0,00		0,62		0,10		0,00		0,00		0,73		0,00		1,50		1,55	
Idle Process Time (days)	1,50		0,60		0,00		0,00		0,50		0,40		0,50		0,20		0,50	
Labor Time (hours x man)	0,00		1,00		3,00		1,00		1,00		7,00		2,00		2,00		5,00	
Production Electricity Consumption (KWh)	0,00		226,78		0,00		0,00		41,00		73,02		33,00		32,00		22,00	
Production Propane Consumption (Nm3)	0,00		0,00		0,00		0,00		5,30		0,00		0,00		0,00		0,00	
Production Diesel Consumption (Lts)	11,22		0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00	
Production Raw Materials Consumption (m3)	1,42		1,42		1,19		1,19		1,19		1,15		0,85		0,85		0,83	
Production Raw Material waste (m3)	0,00		0,00		0,00		0,00		0,05		0,29		0,00		0,00		0,00	
Defective Units (defects during process+material defectes) (m2)	0,00		0,00		0,00		0,00		0,00		0,30		1,30		0,20		0,60	
Number of Operations (n)	0,00		0,40		3,00		0,00		3,00		3,00		2,00		1,00		2,00	
Rejected Units by Costumer (m2)	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00	
Total Output Units (n)	0,00		0,00		0,00		0,00		0,00		0,00		0,00		0,00		26,50	
Number of Inspections (n)	1,00		1,00		1,00		2,00		1,00		2,00		1,00		2,00		2,00	

Table D.26: OC3 | I4.0-OS-Provider Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC3 | OS-COMPETITOR CONCERNS	(Quarry) Stone blocs		(Gang saw) Stone slabs		(Slab scanner) Slab pictures Images		(Computer Nesting) vectorised images of optimized slabs		Pieces Textured		Pieces Cut and Milled		Pieces with Functionalities		Pieces Cleaned and Dried properly		Pieces Packed in Pallets	
SUSTAINABLE INNOVATION INDEX (SII)	19		20		21		22		23		24		25		26		27	
PHASE 2 : ORDER EXECUTION	Tracking Blocs Execution		Tracking Slabs Execution		Tracking Slabs Scanning & Visualization		Tracking Slabs Optimization		Tracking Pieces Surfacing Execution Stage		Tracking Geometries Execution Stage		Tracking Finishing And Functionalities Execution		Tracking Pieces Drying Execution		Tracking Packing Execution	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?								1		1						1	1	1
What is your concern with respect to Innovative Product ?																	1	1
What is your concern with respect to Innovative Manuf. Process ?																	1	1
What is your concern with respect to Total Product Cost?																	1	1
What is your concern with respect to Product Recyclable ?																1	1	1
What is your concern with respect to Contract Compliance ?								1		1						1	1	1
What is your concern with respect to After Sales Response ?												1		1		1	1	1
What is your concern with respect to Product Reliability ?																	1	1

Table D.27: OC3 | OS-Competitor Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC3 | AUTHORITIES CONVERNS	(Quarry) Stone blocs		(Gang saw) Stone slabs		(Slab scanner) Slab pictures Images		(Computer Nesting) vectorised images of optimized slabs		Pieces Textured		Pieces Cut and Milled		Pieces with Functionalities		Pieces Cleaned and Dried properly		Pieces Packed in Pallets	
CONFORMITY INDEX (CI)	19		20		21		22		23		24		25		26		27	
PHASE 2: ORDER EXECUTION	Tracking Blocs Execution		Tracking Slabs Execution		Tracking Slabs Scanning & Visualization		Tracking Slabs Optimization		Tracking Pieces Surfacing Execution Stage		Tracking Geometries Execution Stage		Tracking Finishing And Functionalities Execution		Tracking Pieces Drying Execution		Tracking Packing Execution	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?																		1
What concern with respect to Product Manufacturing Compliance?																		1
What concern with respect to Product Transport Compliance?																	1	1
What is your concern with respect to Product Recyclable Compliance?																	1	1
What concern with respect to Product Moral Hazard Compliance?																	1	1
What concern with respect to Product Legal Compliance?																		1
What concern with respect to Taxes & Fines application and execution?																	1	1

Table D.28: OC3 | Authority Concerns | Data Collection | Phase2 Steps 19-27 | Data collected from January 2016 to May 2017

OC3 | BIM-CUSTOMER CONCERNS	(On-line Computer) Transport Tracking		(Building site) Pallets reception		(Building site) Pieces Inspection		(On-line Computer) Instructions		(Building site) Pieces Manipulation		(Building site) Pieces Application		(Building site) Pieces maintaining		(Building site) Pieces replacing		Building demolition	
CUSTOMER SATISFACTION INDEX (CSI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport Building Site		Stone Pallets Reception		Quality Checking		Installation Instructions Reading		Pieces Manipulation In Site		Pieces Application In Site		Pieces Maintenance During Usage		Order Replacing Pieces		Building Demolition & Recycling	
CUSTOMER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Time to Receive the Product?		1		1	1	1	1	1										
What is your concern with respect to Product Sustainability?								1										
What is your concern with respect to Product Quality?					1	1		1										
What is your concern with respect to Contract Compliance?					1	1		1										
What is your concern with respect to Brand Reputation?					1	1												
What is your concern with respect to Flexibility?					1	1												
What is your concern with respect to Purchasing Price?																		
What is your concern with respect to Total Product Cost?																		
What is your concern with respect to Warranty?																		
What is your concern with respect to After Sales Service?																		
What is your concern with respect to Product Reliability?																		
What is your concern with respect to Product Safety?																		
What is your concern with respect to Product Recycling?																		
CUSTOMER QUANTITATIVE MEASUREMENTS	10		11		12		13		14		15		16		17		18	
Step Process Time (days)	3		1		5		1											
Customer Labor Time (hours)	0		8		12		1											
Rejected Units by Costumer (m2)	0		0		1		0											

Table D.29: OC3 | BIM-Customer Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC 3 | I4.0-OS-PROVIDERS CONCERNS	(On-line Computer) Transport Tracking		(Building site) Pallets reception		(Building site) Pieces Inspection		(On-line Computer) Instructions		(Building site) Pieces Manipulation		(Building site) Pieces Application		(Building site) Pieces maintaining		(Building site) Pieces replacing		Building demolition	
PROVIDER PERFORMANCE INDEX (PPI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport Building Site		Stone Pallets Reception		Quality Checking		Installation Instructions Reading		Pieces Manipulation In Site		Pieces Application In Site		Pieces Maintenance During Usage		Order Replacing Pieces		Building Demolition & Recycling	
PROVIDER QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction?		1			1	1		1		1	1	1						
What is your concern with respect to Time to Receive the Product?		1									1							
What is your concern with respect to Product Sustainability ?												1						
What is your concern with respect to Procuct Maintenance Costs ?				1	1	1				1		1						
What is your concern with respect to Contract Compliance?				1	1	1						1						
What is your concern with respect to Brand Reputation?				1	1	1		1		1		1						
What is your concern with respect to Flexibility ?				1	1	1				1		1						
What is your concern with respect to Product Safety?				1	1	1						1						
What is your concern with respect to Product Recycling?				1	1	1						1						
PROVIDER QUANTITATIVE MEASUREMENTS	28		29		30		31		32		33		34		35		36	
Machines Efective Operation Time (hours)	0,00		0,00		0,00		0,00											
Machines Setup Time (hours)	0,00		0,00		0,00		0,00											
Logistic Internal Time (hours)	0,00		0,00		0,00		0,00											
Idle Process Time (days)	3,00		1,00		5,00		1,00											
Labor Time (hours x man)	0,00		0,00		0,00		0,00											
Production Electricity Consumption (KWh)	0,00		0,00		0,00		0,00											
Production Propane Consumption (Nm3)	0,00		0,00		0,00		0,00											
Production Diesel Consumption (Lts)	0,00		0,00		0,00		0,00											
Production Raw Materials Consumption (m3)	0,83		0,83		0,80		0,80											
Production Raw Material waste (m3)	0,00		0,00		0,00		0,00											
Defective Units (defects during process+material defectes) (m2)	0,00		0,00		0,00		0,00											
Number of Operations (n)	0,00		0,00		0,00		0,00											
Rejected Units by Costumer (m2)	0,00		0,00		1,17		0,00											
Total Output Units (n)	0,00		0,00		0,00		0,00											
Number of Inspections (n)	0,00		0,00		0,00		0,00											

Table D.30: OC3 | I4.0-OS-Provider Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC3 | OS-COMPETITOR CONCERNS	(On-line Computer) Transport Tracking		(Building site) Pallets reception		(Building site) Pieces Inspection		(On-line Computer) Instructions		(Building site) Pieces Manipulation		(Building site) Pieces Application		(Building site) Pieces maintaining		(Building site) Pieces replacing		Building demolition	
SUSTAINABLE INNOVATION INDEX (SII)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport Building Site		Stone Pallets Reception		Quality Checking		Installation Instructions Reading		Pieces Manipulation In Site		Pieces Application In Site		Pieces Maintenance During Usage		Order Replacing Pieces		Building Demolition & Recycling	
COMPETITOR QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What is your concern with respect to Customer Satisfaction ?						1		1		1		1						
What is your concern with respect to Innovative Product ?												1						
What is your concern with respect to Innovative Manuf. Process ?												1						
What is your concern with respect to Total Product Cost?												1						
What is your concern with respect to Product Recyclable ?												1						
What is your concern with respect to Contract Compliance ?								1		1		1						
What is your concern with respect to After Sales Response ?										1		1						
What is your concern with respect to Product Reliability ?												1						

Table D.31: OC3 | OS-Competitor Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

OC3 | AUTHORITIES CONCERNS	(On-line Computer) Transport Tracking		(Building site) Pallets reception		(Building site) Pieces Inspection		(On-line Computer) Instructions		(Building site) Pieces Manipulation		(Building site) Pieces Application		(Building site) Pieces maintaining		(Building site) Pieces replacing		Building demolition	
CONFORMITY INDEX (CI)	28		29		30		31		32		33		34		35		36	
PHASE 3: SHIPPING, USING AND RECYCLING	Tracking Transport Building Site		Stone Pallets Reception		Quality Checking		Installation Instructions Reading		Pieces Manipulation In Site		Pieces Application In Site		Pieces Maintenance During Usage		Order Replacing Pieces		Building Demolition & Recycling	
AUTHORITY QUALITATIVE CONCERNS (QUESTIONNAIRE-GUIDELINES)	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U	D	U
What concern with respect to Handling &Application Compliance?						1		1		1		1						
What concern with respect to Product Manufacturing Compliance?						1		1		1		1						
What concern with respect to Product Transport Compliance?						1		1		1		1						
What is your concern with respect to Product Recyclable Compliance?						1		1		1		1						
What concern with respect to Product Moral Hazard Compliance?						1		1		1		1						
What concern with respect to Product Legal Compliance?						1		1		1		1						
What concern with respect to Taxes & Fines application and execution?						1		1		1		1						

Table D.32: OC3 | Authority Concerns | Data Collection | Phase3 Steps 28-36 | Data collected from January 2016 to May 2017

LIST OF REFERENCES

Akaka, M. A., Corsaro, D., Kelleher, C., Maglio, P. P., Seo, Y., Lusch, R. F., & Vargo, S. L. (2014). The role of symbols in value cocreation. *Marketing Theory*, *14*(3), 311–326. http://doi.org/10.1177/1470593114534344

Akwei, A. C., Peppard, J., & Hughes, P. (2010). The Process of Creating Dynamic Capabilities. *British Journal of Management*, *44*(0), 1–45. Retrieved from https://dspace.lboro.ac.uk/2134/7869

Albert, M. (2015). Seven Things to Know about the Internet of Things and Industry 4.0. *Modern Machine Shop*, *88*(4), 74–81. Retrieved from http://www.mmsonline.com/articles/7-things-to-know-about-the-internet-of-things-and-industry-40

Álvarez-Fernández, M. I., González-Nicieza, C., Álvarez-Vigil, A. E., & Alejano, L. R. (2012). Geometrical design of ornamental stone slabs cutting using the neutral region concept. *International Journal of Rock Mechanics & Mining Sciences*, *52*, 31–39. http://doi.org/10.1016/j.ijrmms.2012.01.012

Amaral, L. M. (2014). Construir As Vantagens Competitivas De Portugal 20 Anos Depois Do "Relatório Porter." In *Instituto Superior Técnico - Lisboa* (pp. 1–46). Retrieved from http://forumcompetitividade.org/wp-content/uploads/2014/04/O-projecto-Porter-e-o-Impasse-Português-ISEG-2-Abril-2014.pdf

Antony, J., Setijono, D., & Dahlgaard, J. J. (2014). Lean Six Sigma and Innovation – an exploratory study among UK organisations. *Total Quality Management & Business Excellence*, (April), 1–17. http://doi.org/10.1080/14783363.2014.959255

Anya, O., Moore, B., Kieliszewski, C., Maglio, P., & Anderson, L. (2015). Understanding the Practice of Discovery in Enterprise Big Data Science: An Agent-based Approach. *Procedia Manufacturing*, *3*(Ahfe), 882–889. http://doi.org/10.1016/j.promfg.2015.07.345

Ariu, A. (2016). Services versus goods trade: a firm-level comparison. *Review of World Economics*, *152*(1), 19–41. http://doi.org/10.1007/s10290-015-0230-0

B&R. (2015). Industry 4.0 at B&R. *B&R Industrial Automation Ltd - UK*. Retrieved from https://www.brautomation.com/smc/b4f9ffd2a1f42eb67a796e860fb32f6dab7e7bbf.pdf

Babič, N. Č., Podbreznik, P., & Rebolj, D. (2010). Integrating resource production and construction using BIM. *Automation in Construction*, *19*(5), 539–543. http://doi.org/10.1016/j.autcon.2009.11.005

Baraúna, L. J. (1996). *An Inquiry into the Nature and Causes of the Wealth of Nations*. *Editora Nova Cultural Ltda*.

Barazzetti, L., Banfi, F., Brumana, R., Gusmeroli, G., Previtali, M., & Schiantarelli, G. (2015). Cloud-to-BIM-to-FEM: Structural simulation with accurate historic BIM from laser scans. *Simulation Modelling Practice and Theory*, *57*, 71–87. http://doi.org/10.1016/j.simpat.2015.06.004

Bardhan, I., Demirkan, H., Kannan, P. K., Kauffman, R. J., & Sougstad, R. (2010). An Interdisciplinary Perspective on IT Services Management and Service Science. *Journal of Management Information Systems / Spring*, *26*(4), 13. http://doi.org/10.2753/MIS0742-1222260402

Behera, P., Mohanty, R., & Prakash, A. (2015). Understanding Construction Supply Chain Management. *Production Planning & Control*, *2616*(March), 1332–1350. http://doi.org/10.1080/09537287.2015.1045953

Bento, V. (2011). *Economia, Moral e Política*. *Fundação Francisco Manuel dos Santos*. Retrieved from https://ffms.pt/FileDownload/cd230319-1863-44a9-a2ce-ea4708073896/economia-moral-e-politica

Beske, P. (2012). Dynamic capabilities and sustainable supply chain management. *International Journal of Physical Distribution&Logistics Management*, *Vol. 42*(4), 372–387. http://doi.org/10.1108/09600031211231344

Bharti, K., Agrawal, R., & Sharma, V. (2015). Value co-creation Literature review and proposed conceptual framework. *International Journal of Market Research*, *57*(4), 571–603. http://doi.org/10.2501/IJMR-2015-012

Biesta, J., & Burbules, N. (2000). *Pragmatism and educational research*. *Lanham, MD: Rowman & Littlefield.*

Binner, H. F. (2014). Industrie 4.0 bestimmt die Arbeitswelt der Zukunft. *Elektrotechnik & Informationstechnik*, *131*(7), 230–236. http://doi.org/10.1007/s00502-014-0216-y

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008a). Service Blueprinting: A PRACTICAL TECHNIQUE FOR SERVICE INNOVATION. *CALIFORNIA MANAGEMENT REVIEW VOL. 50,NO. 3 SPRING 2008 CMR.BERKELEY.EDU*, *50*(3), 66–94. http://doi.org/10.2307/41166446

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008b). *Service Blueprinting: A Practical Technique For Service Innovation*. *Center for Services Leadership, Arizona State University* (Vol. 50). Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=32129010&site=ehost-live

Blanco, F. G. B., & Chen, H. (2014). The Implementation of Building Information Modelling in the United Kingdom by the Transport Industry. *Procedia - Social and Behavioral Sciences*, *138*(0), 510–520. http://doi.org/10.1016/j.sbspro.2014.07.232

Bolton, R. N., Grewal, D., & Levy, M. (2007). Six strategies for competing through service: An agenda for future research. *Journal of Retailing*, *83*(1), 1–4. http://doi.org/10.1016/j.jretai.2006.11.001

Boughnim, N., & Yannou, B. (2005). Using blueprinting method for developing product-service systems. *International Conference of Engineering Design (ICED)*, 1–16. Retrieved from http://hal.archives-ouvertes.fr/hal-00108215/

Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand Experience: What Is It? How Is It Measures? Does It Affect Loyalty? *Journal of Marketing*, *73*(May), 52–68. http://doi.org/10.1509/jmkg.73.3.52

Brasco, A., Found, P., & Moura, A. (2014). A Lean & Green Model for a production cell. *Journal of Cleaner Production*, *85*, 19–30. http://doi.org/10.1016/j.jclepro.2013.06.014

Bravo, M. P. C., & Eisman, L. B. (1998). *Investigación Educativa*. *Sevilla - Ediciones Alfar*.

Breidbach, C. F., & Maglio, P. P. (2016). Technology-enabled value co-creation: An empirical analysis of actors, resources, and practices. *Industrial Marketing Management*, *56*, 73–85. http://doi.org/10.1016/j.indmarman.2016.03.011

Breznik, L., & Lahovnik, M. (2014). Renewing the resource base in line with the dynamic capabilities view : a key to sustained competitive advantage in the IT industry.

Journal of East European Management Studies, *19*(4), 453–485. http://doi.org/10.1688/JEEMS-2014-04

Caggiano, A., Caiazzo, F., & Teti, R. (2015). Digital Factory Approach for Flexible and Efficient Manufacturing Systems in the Aerospace Industry. *Procedia CIRP*, *37*, 122–127. http://doi.org/10.1016/j.procir.2015.08.015

Camarinha-Matos, L. M., & Afsarmanesh, H. (2007). A framework for virtual organization creation in a breeding environment. *Annual Reviews in Control*, *31*(1), 119–135. http://doi.org/10.1016/j.arcontrol.2007.03.006

Cardeal, J. G. (2010). *PME's em " clusters ": Desenvolvimento de vantagens competitivas em indústrias maduras, em mudança lenta . O caso da indústria portuguesa de calçado*. *PhD Thesis, ISCTE*.

Cardeal, N., & António, N. (2012). Valuable , rare , inimitable resources and organization (VRIO) resources or valuable , rare , inimitable resources (VRI) capabilities : What leads to competitive advantage ? *African Journal of Business Management*, *6*(37), 10159–10170. http://doi.org/10.5897/AJBM12.295

Cemesova, A., Hopfe, C. J., & Mcleod, R. S. (2015). PassivBIM: Enhancing interoperability between BIM and low energy design software. *Automation in Construction*, *57*, 17–32. http://doi.org/10.1016/j.autcon.2015.04.014

Chavez, R., Yu, W., Jacobs, M., Fynes, B., Wiengarten, F., & Lecuna, A. (2015). Internal lean practices and performance: The role of technological turbulence. *Int. J. Production Economics*, *160*, 157–171. http://doi.org/10.1016/j.ijpe.2014.10.005

Chen, K., Lu, W., Peng, Y., Rowlinson, S., & Huang, G. Q. (2015). Bridging BIM and building: From a literature review to an integrated conceptual framework. *International Journal of Project Management*, *33*(6), 1405–1416. http://doi.org/10.1016/j.ijproman.2015.03.006

Cheng, J. C. P., & Ma, L. Y. H. (2013). A BIM-based system for demolition and renovation waste estimation and planning. *Waste Management*, *33*(6), 1539–51. http://doi.org/10.1016/j.wasman.2013.01.001

Chesbrough, H., & Spohrer, J. (2006). A research manifesto for services science. *Communications of the ACM*, *49*(7), 35. http://doi.org/10.1145/1139922.1139945

Cheung, F. K. T., Rihan, J., Tah, J., Duce, D., & Kurul, E. (2012). Early stage multi-level cost estimation for schematic BIM models. *Automation in Construction*, *27*, 67–77. http://doi.org/10.1016/j.autcon.2012.05.008

Cho, Y. S. (2013). The Effect of Business Diversification on a Firm's Performance , Depending on Its Dynamic Capabilities and Market Dynamism. *Journal of Management and Strategy*, *4*(3), 1–9. http://doi.org/10.5430/jms.v4n3p1

Ciancimino, E., Cannella, S., Bruccoleri, M., & Framinan, J. M. (2012). On the Bullwhip Avoidance Phase: The Synchronised Supply Chain. *European Journal of Operational Research*, *221*(1), 49–63. http://doi.org/10.1016/j.ejor.2012.02.039

Constantinescu, C. L., Francalanza, E., Matarazzo, D., & Balkan, O. (2014). Information support and interactive planning in the digital factory: Approach and industry-driven evaluation. *Procedia CIRP*, *25*(C), 269–275. http://doi.org/10.1016/j.procir.2014.10.038

Corry, E., Pauwels, P., Hu, S., Keane, M., & O'Donnell, J. (2015). A performance assessment ontology for the environmental and energy management of buildings. *Automation in Construction*, *57*, 249–259. http://doi.org/10.1016/j.autcon.2015.05.002

Costa, G., & Madrazo, L. (2015). Connecting building component catalogues with BIM models using semantic technologies: an application for precast concrete components. *Automation in Construction*, *57*, 239–248. http://doi.org/10.1016/j.autcon.2015.05.007

Cox, A., & Chicksand, D. (2005). The limits of lean management thinking: Multiple retailers and food and farming supply chains. *European Management Journal*, *23*(6), 648–662. http://doi.org/10.1016/j.emj.2005.10.010

CPMR. (2017). *INOVSTONE 4.0 – Tecnologias Avançadas e Software para a Pedra*. *Agencia Nacional de Inovação-Lisboa*. Retrieved from https://www.clustermineralresources.pt/projetos

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. *SAGE Publications, Inc*. http://doi.org/10.1007/s13398-014-0173-7.2

Dankers, M., van Geel, F., & Segers, N. M. (2014). A Web-platform for Linking IFC to External Information during the Entire Lifecycle of a Building. *Procedia Environmental Sciences*, *22*, 138–147. http://doi.org/10.1016/j.proenv.2014.11.014

DeCanio, S. J., & Fremstad, A. (2013). Game theory and climate diplomacy. *Ecological Economics*, *85*, 177–187. http://doi.org/10.1016/j.ecolecon.2011.04.016

Demirkan, H., & Spohrer, J. (2015). T-Shaped Innovators: Identifying the Right Talent to Support Service Innovation. *Research-Technology Management*, *1*(6), 12–15. http://doi.org/10.5437/08956308X5805007

Demirkan, H., & Spohrer, J. C. (2016). Emerging service orientations and transformations (SOT). *Information Systems Frontiers*, *18*(3), 407–411. http://doi.org/10.1007/s10796-016-9656-8

Denzin, N., & Yvonna, L. (1994). *Handbook of Qualitative Research*. *Sage Publications*.

Diniz, F., Vaz, R., & Duarte, N. (2015). Innovation Strategies in the Portuguese Footwear Industry. *International Journal of Contemporary Management*, *14*(1), 37–50.

Domegan, C., & Bringle, R. (2010). *Charting social marketing's implications for service learning*. *Journal of Nonprofit & Public Sector Marketing* (Vol. 22). http://doi.org/10.1080/10495142.2010.483272

Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or hype? *IEEE Industrial Electronics Magazine*, *8*(2), 56–58. http://doi.org/10.1109/MIE.2014.2312079

E.Weisberg David. (2008). *The Engineering Design Revolution: The People, Companies and Computer Systems That Changed Forever the Practice of Engineering*. *© 2008 David E. Weisberg*.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. http://doi.org/10.1016/j.autcon.2013.09.001

Edvardsson, B., & Tronvoll, B. (2013). A new conceptualization of service innovation grounded in S-D logic and service systems. *International Journal of Quality & Service Sciences*, *5*(1), 19–31. http://doi.org/10.1108/17566691311316220

Elmualim, A., & Gilder, J. (2014). BIM: innovation in design management, influence and challenges of implementation. *Architectural Engineering and Design Management*, *10*(3/4). http://doi.org/10.1080/17452007.2013.821399

European Commission. Diretiva 2014/24/UE do Parlamento Europeu e do Conselho, Jornal Oficial da União Europeia (2014). Jornal Oficial da União Europeia.

European Parliament. Industry 4.0. Digitalisation for productivity and growth, European Parliament - Briefing September (2015). Retrieved from http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI(2015)568337_EN.pdf

Fair, H., Russwurm, S., & Sector, S. I. (2012). Industry prepares for the next industrial revolution: Automation companies share views on the fourth industrial revolution, Industry 4.0, according to Control Engineering Europe. *Control Engineering International*, 10–11. Retrieved from www.controlengeurope.com

Faller, C., & Feldmüller, D. (2015). Industry 4.0 Learning Factory for regional SMEs. *Procedia CIRP*, *32*(Clf), 88–91. http://doi.org/10.1016/j.procir.2015.02.117

Feller, J., Parhankangas, A., Smeds, R., & Jaatinen, M. (2013). How companies learn to collaborate: Emergence of improved inter-organizational processes in R&D alliances. *Sage - Organization Studies*, *34*(3), 313–343. http://doi.org/10.1177/0170840612464758

Fernandes, J. M. (2014). *Caminhos do Exportador: Estratégias de Internacionalização. Ed. Almedina, Lisboa*.

Ferreira, V. M., Dias, A. B., Afonso, A. S., & Brito, J. de. (2012). Inovação na Construção Sustentável. In *ed. Plataforma centro Habitat*. Retrieved from http://www.centrohabitat.net/pt/evento/congresso-de-inovacao-na-construcao-sustentavel-cincos12

Ford, M. (2015). Industry 4.0: Who Benefits? *SMT Magazine*, (7), 52–55. Retrieved from http://www.magazines007.com/pdf/SMT-July2015.pdf

Fraunhofer. (2012). *Methods in Service Innovation: Current trends and future perspectives*. (F. Verlag, Ed.). Fraunhofer Verlag. Retrieved from https://www.ksri.kit.edu/downloads/Ganz_Satzger_Schultz_2012_Methods_in_Service_Innovation.pdf

Frazao, I. (2016). *Evolução do Cluster da Pedra*. *Master's thesis - Instituto Superior de Gestão*. ISG.

Frazao, J. (2016). *Evolução do Colaborador no Setor da Pedra*. *Master's thesis - Instituto Superior de Gestão*. ISG.

Fullerton, R. R., Kennedy, F. a., & Widener, S. K. (2013). Management accounting and control practices in a lean manufacturing environment. *Accounting, Organizations and Society, 38*(1), 50–71. http://doi.org/10.1016/j.aos.2012.10.001

Galetakis, M., & Soultana, A. (2016). A review on the utilisation of quarry and ornamental stone industry fine by-products in the construction sector. *Construction and Building Materials*, *102*, 769–781. http://doi.org/10.1016/j.conbuildmat.2015.10.204

Gao, G., Liu, Y.-S., Wang, M., Gu, M., & Yong, J.-H. (2015). A query expansion method for retrieving online BIM resources based on Industry Foundation Classes. *Automation in Construction*, *56*, 14–25. http://doi.org/10.1016/j.autcon.2015.04.006

Ghauri, P., Kjell, G., & Ivar, K. (2010). *Research Methods in Business Studies. A Practical Guide (4th edition). Prentice-Hall, Hemel Hempstead*.

Ghosh, S., Negahban, S., Kwak, Y. H., & Skibniewski, M. J. (2011). Impact of sustainability on integration and interoperability between BIM and ERP - A governance framework. *IEEE Industrial Electronics Magazine*, *1*, 187–193. http://doi.org/10.1109/ITMC.2011.5995975

Global Construction Perspectives and Oxford Economics. (2015). Global Forecast for the Construction Industry 2030 (Vol. 53, p. 160). http://doi.org/10.1017/CBO9781107415324.004

Gollan, P. J., Kalfa, S., Agarwal, R., Green, R., & Randhawa, K. (2014). Lean manufacturing as a high-performance work system: the case of Cochlear. *International Journal of Production Research*, *52*(21), 6434–6447. http://doi.org/10.1080/00207543.2014.940430

Grilo, A., & Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction*, *19*(5), 522–530. http://doi.org/10.1016/j.autcon.2009.11.003

Grilo, A., & Jardim-Goncalves, R. (2011). Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective. *Automation in Construction*, *20*(2), 107–114. http://doi.org/10.1016/j.autcon.2010.09.008

Gronroos, C. (2011). Value co-creation in service logic: A critical analysis. *Sage - Marketing Theory*, *11*(3), 279–301. http://doi.org/10.1177/1470593111408177

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999. http://doi.org/10.1016/j.autcon.2010.09.002

Gunasekaran, A., & Ngai, E. V. T. (2004). Information systems in supply chain integration and management. *European Journal of Operational Research*, *159*(2 SPEC. ISS.), 269–295. http://doi.org/10.1016/j.ejor.2003.08.016

Gupta, M., & Andersen, S. (2012). Revisiting local TOC measures in an internal supply chain: a note. *International Journal of Production Research*, *50*(19), 5363–5371. http://doi.org/10.1080/00207543.2011.627389

Hammersley, M. (2010). *Deconstructing the Qualitative-Quantitative Divide*. *Julia Brannen (ed.)*. Retrieved from http://oro.open.ac.uk/id/eprint/20445

Han, K. K., & Golparvar-Fard, M. (2015). Appearance-based material classification for monitoring of operation-level construction progress using 4D BIM and site photologs. *Automation in Construction*, *53*, 44–57. http://doi.org/10.1016/j.autcon.2015.02.007

Heidari, M., Allameh, E., De Vries, B., Timmermans, H., Jessurun, J., & Mozaffar, F. (2014). Smart-BIM virtual prototype implementation. *Automation in Construction*, *39*, 134–144. http://doi.org/10.1016/j.autcon.2013.07.004

Hjelseth, E. (2010). Exchange of Relevant Information in BIM Objects Defined by the Role- and Life-Cycle Information Model. *AEDM - Architectural Engineering and Design Management*, *6*(4), 279–287. http://doi.org/10.3763/aedm.2010.IDDS5

HM Government. Government Construction Strategy, 96 Cabinet Office 1–43 (2011). http://doi.org/Vol 19

HM Government. (2013). Construction 2025. Industrial Strategy: Government and industry in partnership. *Cabinet Office*, (July), 1–78. http://doi.org/HM Government.

HM Government. Digital Built Britain Level 3 Building Information Modelling - Strategic Plan, Cabinet Office 1–47 (2015). Retrieved from http://digital-built-britain.com/DigitalBuiltBritainLevel3BuildingInformationModellingStrategicPlan.pdf

Hoske, T. (2015). Industrial internet of things, industry 4.0. *Control Engineering*, *62*(6), 26–35. Retrieved from www.controleng.com

Howard, R., & Björk, B. C. (2008). Building information modelling - Experts' views on standardisation and industry deployment. *Advanced Engineering Informatics*, *22*(2), 271–280. http://doi.org/10.1016/j.aei.2007.03.001

Hsu, Y. (2016). Integrating Service Science and Information System Technology : A Case Study. *The International Journal of Organizational Innovation*, *9*(1), 158–173. http://doi.org/10.4236/ti.2011.22015

Hunt, S. D. (2000). Shelby D. Hunt (2000) A General Theory of Competition: Resources, Competences, Pro- ductivity, Economic Growth. *Thousand Oaks - Sage Publications*, *16:4*(2000), 385–393.

Hüttinger, L., Schiele, H., & Veldman, J. (2012). The drivers of customer attractiveness , supplier satisfaction and preferred customer status : A literature review. *Industrial Marketing Management*, *41*(8), 1194–1205. http://doi.org/10.1016/j.indmarman.2012.10.004

Iansiti, M., & Levien, R. (2004). *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. *Harvard Business School Press*. Retrieved from http://www.antitrustinstitute.org/files/356.pdf

Ibem, E. O., & Laryea, S. (2014). Survey of digital technologies in procurement of construction projects. *Automation in Construction*, *46*, 11–21. http://doi.org/10.1016/j.autcon.2014.07.003

Ismail, A. R. (2011). Experience Marketing: An Empirical Investigation. *Journal of Relationship Marketing*, *10*(3), 167–201. http://doi.org/10.1080/15332667.2011.599703

Ivanov, D., Dolgui, A., Sokolov, B., Werner, F., & Ivanova, M. (2016). A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0. *International Journal of Production Research*, *54*(2), 386–402. http://doi.org/10.1080/00207543.2014.999958

Jaca, C., Santos, J., Errasti, A., & Viles, E. (2012). Lean thinking with improvement teams in retail distribution: a case study. *Total Quality Management*, *23*(3–4), 449–465. http://doi.org/10.1080/14783363.2011.593907

Jalaei, F., & Jrade, A. (2015). Integrating building information modeling (BIM) and

LEED system at the conceptual design stage of sustainable buildings. *Sustainable Cities and Society*, *18*, 95–107. http://doi.org/10.1016/j.scs.2015.06.007

Jardim-Gonçalves, R., & Grilo, A. (2010). SOA4BIM: Putting the building and construction industry in the Single European Information Space. *Automation in Construction*, *19*(4), 388–397. http://doi.org/10.1016/j.autcon.2009.11.009

Johansson, M., Roupé, M., & Bosch-Sijtsema, P. (2015). Real-time visualization of building information models (BIM). *Automation in Construction*, *54*, 69–82. http://doi.org/10.1016/j.autcon.2015.03.018

Johnson, B., & Onwuegbuzie, A. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *American Educational Research Association*, *33*, 14–26. http://doi.org/10.3102/0013189X033007014

Jones, R., & Serafeim, G. (2013). The Big Idea: The Performance Frontier: Innovating for a Sustainable Strategy. *Harvard Business Review May*, *12*(1), 50–60. http://doi.org/10.1057/palgrave.crr.1540128

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, *20*(2), 126–133. http://doi.org/10.1016/j.autcon.2010.09.010

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative Industrie 4.0*. *ACATEC-National Academy of Science and Engineering*.

Kahkonen, A.-K., & Lintukangas, K. (2012). The underlying potential of supply management in value creation. *Journal of Purchasing & Supply Management*, *18*, 68–75. http://doi.org/10.1016/j.pursup.2012.04.006

Kang, T.-W., & Choi, H.-S. (2015). BIM perspective definition metadata for interworking facility management data. *Advanced Engineering Informatics*, *29*(4), 958–970. http://doi.org/10.1016/j.aei.2015.09.004

Kang, T. W., & Hong, C. H. (2015). A study on software architecture for effective BIM/GIS-based facility management data integration. *Automation in Construction*, *54*, 25–38. http://doi.org/10.1016/j.autcon.2015.03.019

Karan, E. P., & Irizarry, J. (2015). Extending BIM interoperability to preconstruction operations using geospatial analyses and semantic web services. *Automation in*

Construction, *53*, 1–12. http://doi.org/10.1016/j.autcon.2015.02.012

Karimi, J., & Walter, Z. (2015). The role of Dynamic Capabilities in responding to digital disruption: A factor-based study of the newspaper industry. *Journal of Management Information Systems*, *32*(1), 39–81. http://doi.org/10.1080/07421222.2015.1029380

Karimi, M. H., & Asemani, D. (2013). Surface defect detection in tiling Industries using digital image processing methods: Analysis and evaluation. *ISA Transactions*, *53*(3), 834–844. http://doi.org/10.1016/j.isatra.2013.11.015

Keith, M., Demirkan, H., & Goul, M. (2013). Service-Oriented Methodology for Systems Development. *Journal of Management Information Systems*, *30*(1), 227–260. http://doi.org/10.2753/MIS0742-1222300107

Kim, J. B., Jeong, W., Clayton, M. J., Haberl, J. S., & Yan, W. (2015). Developing a physical BIM library for building thermal energy simulation. *Automation in Construction*, *50*, 16–28. http://doi.org/10.1016/j.autcon.2014.10.011

Kindström, D., Kowalkowski, C., & Erik, S. (2013). Enabling service innovation – A dynamic capabilities approach. *Journal of Business Research*, *66*(8), 1063–1073. http://doi.org/0.1016/j.jbusres.2012.03.003

Kingman-Brundage, J. (1989). The ABC’s of service system Blueprinting: Designing a winning service strategy. In *7th annual Services Marketing Conference Proceedings- Chicago*.

Kjellberg, H., & Helgesson, C. (2006). Multiple versions of markets: multiplicity and performativity inmarket practice. *Industrial Marketing Management*, *35*(7), 839–855. http://doi.org/10.1016/j.indmarman.2006.05.011

Kropotkin, P. (1902). *Mutual Aid, a Factor of Evolution (PDF version by Stephen DeMeulenaere 1972). New York University Press* (Vol. 67). http://doi.org/10.1038/067196a0

Kuo, D. C. L., Lin, C. C., & Wu, Y. K. (2011). The Connection Between Customer Value Creation and Innovation Strategy : A Proposed Framework and Its Implication in Fashion Products. *Industrial Engineering and Engineering Management (IEEM)*, *978*(1), 1175–1179. Retrieved from http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6103492

Kwan, S., Spohrer, J., & Sawatani, Y. (2016). *Global Perspectives on Service Science :*

Japan. Springer Science+Business Media.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business and Information Systems Engineering*, *6*(4), 239–242. http://doi.org/10.1007/s12599-014-0334-4

Lee, J., Bagheri, B., & Kao, H. A. (2015). A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters*, *3*, 18–23. http://doi.org/10.1016/j.mfglet.2014.12.001

Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for Industry 4.0 and big data environment. *Procedia CIRP*, *16*, 3–8. http://doi.org/10.1016/j.procir.2014.02.001

Leite, F., Akcamete, A., Ackinci, B., Atasoy, G., & Kizitas, S. (2011). Analysis of modeling effort and impact of different levels of detail in building information models. *Automation in Construction*, *20*(5), 601–609. http://doi.org/10.1016/j.autcon.2010.11.027

Liu, Z., Osmani, M., Demian, P., & Baldwin, A. (2015). A BIM-aided construction waste minimisation framework. *Automation in Construction*, *59*(2015), 1–23. http://doi.org/10.1016/j.autcon.2015.07.020

Llewellyn Consulting. (2014). *Financing Europe's Investment and Economic Growth*. *Llewellyn Consulting*. Retrieved from www.irsg.co.uk

Loebler, H. (2012). Signs and Practices Coordinating Service and Relationships. *Journal of Business Marketing Management*, *4*, 217–230. http://doi.org/10.1007/s12087-010-0045-1

Loebler, H., & Lusch, R. (2013). *Signs and Practices as Resources in IT-Related Service Innovation. Working Paper. Universitat Leipzig*.

López, M., Martínez, J., Matías, J. M., Taboada, J., & Vilán, J. a. (2010). Functional classification of ornamental stone using machine learning techniques. *Journal of Computational and Applied Mathematics*, *234*(4), 1338–1345. http://doi.org/10.1016/j.cam.2010.01.054

Lu, Q., Won, J., & Cheng, J. C. P. (2015). A financial decision making framework for construction projects based on 5D Building Information Modeling (BIM). *International Journal of Project Management*, *34*(1), 3–21.

http://doi.org/10.1016/j.ijproman.2015.09.004

Luo, Y., & Wu, W. (2015). Sustainable Design with BIM Facilitation in Project-based Learning. *Procedia Engineering*, *118*, 819–826. http://doi.org/10.1016/j.proeng.2015.08.519

Lusch, R. F., & Nambisan, S. (2015). Service Innovation: A Service-Dominant-Logic perspective. *MIS Quarterly*, *39*(1), 155–175.

Lusch, R. F., & Vargo, S. L. (2006). *The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions*. *Routledge*.

Lusch, R. F., & Vargo, S. L. (2008). Service-dominant logic: Continuing the evolution. *Journal of the Academy of Marketing Science*, *36*(1), 1–10. http://doi.org/10.1007/s11747-007-0069-6

Lusch, R. F., Vargo, S. L., & Gustafsson, A. (2016). Fostering a trans-disciplinary perspectives of service ecosystems. *Journal of Business Research*, *69*(8), 2957–2963. http://doi.org/10.1016/j.jbusres.2016.02.028

Lusch, R. F., Vargo, S. L., & Tanniru, M. (2010). Service, value networks and learning. *Journal of the Academy of Marketing Science*, *38*(1), 19–31. http://doi.org/10.1007/s11747-008-0131-z

Lusch, R., & Vargo, S. (2006). Service-dominant logic: reactions, reflections and refinements. *Marketing Theory Volume*, *6*(3), 281–288. http://doi.org/10.1177/1470593106066781

Lusch, R., Vargo, S., & O'Brien, M. (2007). Competing through service: Insights from service-dominant logic. *Journal of Retailing*, *83*(1), 5–18. http://doi.org/10.1016/j.jretai.2006.10.002

Lyons, A. C., Vidamour, K., Jain, R., & Sutherland, M. (2013). Developing an understanding of lean thinking in process industries. *Production Planning & Control*, *26*(6), 475–494. http://doi.org/10.1080/09537287.2011.633576

MacDougall, W. (2014). *Industrie 4.0: Smart Manufacturing for The Future*. *Germany Trade & Invest*.

Maglio, P. P. (2016). Service Science, Management, Engineering & Design. In *UC Merced and IBM Research* (pp. 1–83). Retrieved from paul-maglio-ucsc-

20120415.pdf

Maglio, P. P., & Spohrer, J. (2008). Fundamentals of service science. *Journal of the Academy of Marketing Science*, *36*(1), 18–20. http://doi.org/10.1007/s11747-007-0058-9

Maglio, P. P., & Spohrer, J. (2013). A service science perspective on business model innovation. *Industrial Marketing Management*, *42*(5), 665–670. http://doi.org/10.1016/j.indmarman.2013.05.007

Maglio, P. P., Vargo, S. L., Caswell, N., & Spohrer, J. (2009). The service system is the basic abstraction of service science. *Information Systems and E-Business Management*, *7*(4 SPEC. ISS.), 395–406. http://doi.org/10.1007/s10257-008-0105-1

Malleson, A., & Watson, D. (2016). *International BIM Report 2016 Views from the countries Survey 2015. NBS International*. Retrieved from https://www.thenbs.com/knowledge/nbs-international-bim-report-2016

Malsane, S., Matthews, J., Lockley, S., Love, P. E. D., & Greenwood, D. (2014). Development of an object model for automated compliance checking. *Automation in Construction*, *49*, 51–58. http://doi.org/10.1016/j.autcon.2014.10.004

Marinho, A. J. C. (2014). *Aplicação do Building Information Modeling na gestão de projetos de construção*. *Master's thesis - Universidade do Minho*.

Marodin, G. A., & Saurin, T. A. (2013). Implementing lean production systems: research areas and opportunities for future studies. *International Journal of Production Research*, *51*(22), 6663–6680. http://doi.org/10.1080/00207543.2013.826831

Matthews, J., Love, P. E. D., Heinemann, S., Chandler, R., Rumsey, C., & Olatunj, O. (2015). Real time progress management: Re-engineering processes for cloud-based BIM in construction. *Automation in Construction*, *58*, 38–47. http://doi.org/10.1016/j.autcon.2015.07.004

Matthies, B. D., & D'Amato. (2016). An ecosystem service-dominant logic? - Integrating the ecosystem service approach and the service-dominant logic. *Ournal of Cleaner Production*, *124*, 51–64. http://doi.org/10.1016/j.jclepro.2016.02.109

Melton, T. (2005). The Benefits of Lean Manufacturing: What Lean Thinking has to Offer the Process Industries. *Chemical Engineering Research and Design*, *83*(6), 662–673.

http://doi.org/10.1205/cherd.04351

Merschbrock, C., & Munkvold, B. E. (2015). Effective digital collaboration in the construction industry - A case study of BIM deployment in a hospital construction project. *Computers in Industry*, *73*, 1–7. http://doi.org/10.1016/j.compind.2015.07.003

Mertens, D. M. (2014). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods, (4th ed.). Thousand Oaks - Sage*.

Meynhardt, T., Chandler, D., & Strathoff, P. (2016). Systemic principles of value co-creation: Synergetics of value and service ecosystems. *Journal of Business Research*, *69*(8), 2981–2989. http://doi.org/10.1016/j.jbusres.2016.02.031

Morgan, D. (2007). Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research*, *1*(1), 48–76. http://doi.org/10.1177/2345678906292462

Mosterman, P. J., & Zander, J. (2015). Industry 4.0 as a Cyber-Physical System study. *Software and Systems Modeling*, *15*(1), 17–29. http://doi.org/10.1007/s10270-015-0493-x

Motamedi, A., Setayeshgar, S., Soltani, M. M., & Hammad, A. (2016). Extending BIM to incorporate information of RFID tags attached to building assets. *Advanced Engineering Informatics*, *30*(1), 39–53. http://doi.org/10.1016/j.aei.2015.11.004

Motawa, I., & Almarshad, A. (2013). A knowledge-based BIM system for building maintenance. *Automation in Construction*, *29*, 173–182. http://doi.org/10.1016/j.autcon.2012.09.008

Naor, M., Bernardes, E. S., & Coman, A. (2013). Theory of constraints: is it a theory and a good one? *International Journal of Production Research*, *51*(2), 542–554. http://doi.org/10.1080/00207543.2011.654137

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: Interfacing the lean and agile manufacturing paradigm in the total supply chain. *International Journal of Production Economics, 62*, 107–18.

Newell, A. (1980). *Physical Symbol Systems*. *Research Showcase @ CMU* (Vol. 183). Retrieved from http://repository.cmu.edu/compsci

Nickul, D., Reitman, L., Ward, J., & Jack, W. (2007). Service Oriented Architecture (SOA) and Specialized Messaging Patterns. *Technical White Paper*, *345*, 1–15. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.84.5751&rep=rep1&type=pdf

Nielsen, A. P. (2006). Understanding dynamic capabilities through knowledge management. *Journal Of Knowledge Management*, *10*(4), 59–71. http://doi.org/10.1108/13673270610679363

O'Brien, H. M. (2016). the Internet of Things. *Journal of Internet Law*, *19*(12), 1–20. Retrieved from http://biblio.uptc.edu.co:2048/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=116080288&lang=es&site=eds-live

Oliveira, E. (2010). MIC- Metodologias de Investigação Científica : Uma Visão sobre Teorias acerca do desenvolvimento e da caracterização da Investigação Científica. In *FEUP* (pp. 1–43). Retrieved from http://paginas.fe.up.pt/~eol/PRODEI/mic1011.htm%0A1.

Pakdil, F., & Leonard, K. M. (2013). Criteria for a lean organisation: development of a lean assessment tool. *International Journal of Production Research*, *52*(15), 4587–4607. http://doi.org/10.1080/00207543.2013.879614

Pan, M., Sikorski, J., Kastner, C. A., Akroyd, J., Mosbach, S., Lau, R., & Kraft, M. (2015). Applying Industry 4.0 to the Jurong Island Eco-industrial Park. *Energy Procedia*, *75*, 1536–1541. http://doi.org/10.1016/j.egypro.2015.07.313

Payne, A. F., Storbacka, K., & Frow, P. (2008). Managing the co-creation of value. *Journal of the Academy of Marketing Science*, *36*(1), 83–96. http://doi.org/10.1007/s11747-007-0070-0

Pedraza Martinez, A. J., Stapleton, O., & Van Wassenhove, L. N. (2011). Field vehicle fleet management in humanitarian operations: A case-based approach. *Journal of Operations Management*, *29*(5), 404–421. http://doi.org/10.1016/j.jom.2010.11.013

Peirce, C. S. (1932). *Collected Papers of Charles Sanders Peirce, Volumes I and II: Principles of Philosophy and Elements of Logic*. *Harvard University Press.*

Peres, M., & Costa, C. Projeto AMA: Ações de Melhoria Ambiental do Setor das Pedras

Naturais, Cevalor-Assimagra 98 (2006). Retrieved from www.assimagra.pt

Peres, M., Goulão, M., & Martins, L. (2016). The Portuguese Cluster of Mineral Resources. In *Brussels Mineral Resources Conference December 2016*. Retrieved from https://ec.europa.eu/growth/tools-databases/eip-raw-materials/sites/rawmaterials/files/4 3 PMRCluster_DEC_Brussels.pdf

Perry, C. (1998). Processes of a Case Study Methodology for Postgraduate Research in Marketing. *European Journal of Marketing*, *32*(9–10), 785–802. http://doi.org/doi.org/10.1108/03090569810232237

Pinto, J. P. (2010). *Gestão de Operações na Indústria e nos Serviços. ed. Lidel Porto.*

Pinto, J. P. (2013). *Manutenção Lean. ed. Lidel, Porto.*

Portland Cement Association. (2013). *Market Intelligence-World Cement Consumption. Portland Cement Association*. Retrieved from http://www.cement.org/

Prymon, M. (2016). Dynamic aspects of brand management. *Economics, Management, and Financial Markets*, *11*(1), 135–142. Retrieved from https://search.proquest.com/openview/a48b0292881b9a385311800753166d28/1?pq-origsite=gscholar&cbl=136107

Quivy, R., & Campenhoudt, L. (2013). *Manual de Investigação em Ciências Sociais 6th Edition. ed. Gradiva, Lisboa.*

Race, S. (2013). *BIM Demystified - An architect's guide toBuilding Information Modelling/ Management (BIM)*. (L. E. 2EAISBN 978 1 85946 520 2Stock code 81044 RIBA Publishing, 15 Bonhill Street, Ed.), *RIBA Publishing*. Retrieved from http://www.thenbs.com/topics/BIM/articles/aBriefHistoryOfBIM.asp

Re, E. E., & Academy, P. (2015). Structural-textural nature and sorption properties of limestones from the mesozoic-neogene contact zone in the Bełchatów deposit. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management*, *31*(4), 75–94. http://doi.org/10.1515/gospo-2015-0033

Rennung, F., Luminosu, C. T., & Draghici, A. (2016). Service Provision in the Framework of Industry 4.0. *Procedia - Social and Behavioral Sciences*, *221*, 372–377. http://doi.org/10.1016/j.sbspro.2016.05.127

Ribeiro, D. C. (2012). *Avaliação Da Aplicabilidade Do IPD Em Portugal. Master's thesis*

- *Faculdade de Engenharia da Universidade do Porto*.

Rice, J., Liao, T., Martin, N., & Galvin, P. (2012). The role of strategic alliances in complementing firm capabilities. *Journal of Management & Organization*, *18*(6), 858–869. http://doi.org/10.1017/S1833367200000493

Rid, J., & Pfoertsch, W. (2013). Ingredient Branding of Industrial Goods : A Case Study of Two Distinct Automotive Suppliers. *The IUP Journal of Business Strategy*, *X*(4), 49–65.

Rocco, T., Linda, B., Suzanne, G., & Aixa, P.-P. (2003). Taking the Next Step: Mixed Methods Research in Organizational Systems. *Information Technology, Learning, and Performance Journal*, *21*, 19–29.

Rohac, T., & Januska, M. (2015). Value Stream Mapping Demonstration on Real Case Study. *Procedia Engineering*, *100*, 520–529. http://doi.org/10.1016/j.proeng.2015.01.399

Rowlinson, S., Collins, R., Tuuli, M. M., & Jia, Y. (2010). Implementation of Building Information Modeling (BIM) in construction: a comparative case study. *American Institute of Physics*, *978*, 572–577. http://doi.org/10.1063/1.3452236

Sandstro, J., & Kyla, K. (2007). Strategic options-based framework for management of dynamic capabilities in manufacturing firms. *Journal of Manufacturing Technology Management*, *18*(8), 966–984. http://doi.org/10.1108/17410380710828280

Schlechtendahl, J., Keinert, M., Kretschmer, F., Lechler, A., & Verl, A. (2015). Making existing production systems Industry 4.0-ready: Holistic approach to the integration of existing production systems in Industry 4.0 environments. *Production Engineering*, *9*(1), 143–148. http://doi.org/10.1007/s11740-014-0586-3

Schuh, G., Potente, T., Varandani, R., & Schmitz, T. (2014). Global Footprint Design based on genetic algorithms - An "industry 4.0" perspective. *CIRP Annals - Manufacturing Technology*, *63*(1), 433–436. http://doi.org/10.1016/j.cirp.2014.03.121

Sehgal, V. K., Patrick, A., & Rajpoot, L. (2014). A comparative study of cyber physical cloud, cloud of sensors and internet of things: Their ideology, similarities and differences. *IEEE International Advance Computing Conference*, *978*(1), 708–716. http://doi.org/10.1109/IAdCC.2014.6779411

Sequeira, L. (2010). A cooperação na distribuição de vinho do Porto. *PhD Thesis - ISCTE*.

Seyring, M., Dornberger, U., Suvelza, A., & Byerns, T. Service Blue Printing Handbook, SEPT - Universitat Leipzig (2009). Retrieved from https://pt.scribd.com/document/225764709/Handbook-Service-Blueprinting

Shannassy, T. O. (2008). Sustainable competitive advantage or temporary competitive advantage Improving understanding of an important strategy construct. *Journal of Strategy and Management*, *1*(2). http://doi.org/10.1108/17554250810926357

Shostack, G. (1982). How to Design a Service. *European Journal of Marketing*, *16*(1), 49–63. http://doi.org/https://doi.org/10.1108/EUM0000000004799

Shove, E., & Pantzar, M. (2005). Consumers, Producers and Practices Understanding the Invention and Reinvention of Nordic Walking. *Journal of Consumer Culture*, *5*(1), 43–64. http://doi.org/10.1177/1469540505049846

Siemens. (2015). A view to the future: Cyberpsychology & behavior: the impact of the Internet, multimedia and virtual reality on behavior and society. *Siemens AG*, *12*(3). Retrieved from siemens.com/stratagy

Sigalas, C., & Economou, V. P. (2013). Revisiting the concept of competitive advantage: Problems and fallacies arising from its conceptualization. *Journal of Strategy and Management*, *6*(1), 61–80. http://doi.org/10.1108/17554251311296567

Sigalas, C., Economou, V. P., & Georgopoulos, N. B. (2013). Developing a measure of competitive advantage. *Journal of Strategy and Management*, *6*(6), 320–342. http://doi.org/10.1108/JSMA-03-2013-0015

Silva, A. da. (2013). *Inovação Tecnológica lean para a Pedra Natural - Incorporação de Tecnologias lean thinking como base para a competitividade e internacionalização da Indústria Transformadora de Pedra Natural*. *Professional Thesis for the Title of Specialist in Engineering and Industrial Management DL/2006/2009- IPP*.

Silva, A. da. (2014). *Tecnologias e práticas lean thinking na fileira das Rochas Ornamentais*. *Master's thesis nstituto Superior de Gestão*. Retrieved from https://comum.rcaap.pt/bitstream/10400.26/10828/1/Tese_Agostinho Silva_Tecnologias Lean Thinking no setor RO_08_11_2014 V6.pdf

Smit, J., Kreutzer, S., Moeller, C., & Carlberg, M. Industry 4.0 - Study for the ITRE Committee, European Parliament (2016).

http://doi.org/10.1017/CBO9781107415324.004

Smith, J., & Colgate, M. (2007). Customer Value Creation: A Practical Framework. *Journal of Marketing Theory and Practice*, *15*(1), 7–23. http://doi.org/10.2753/mtp1069-6679150101

Smith, P. (2014a). BIM & the 5D Project Cost Manager. *Procedia - Social and Behavioral Sciences*, *119*, 475–484. http://doi.org/10.1016/j.sbspro.2014.03.053

Smith, P. (2014b). BIM Implementation – Global Strategies. *Procedia Engineering*, *85*, 482–492. http://doi.org/10.1016/j.proeng.2014.10.575

Spohrer, J. (2007). Service Science: The next frontier in service innovation. *IBM Corporation*. Retrieved from ftp://77.47.130.238/pub/IBM/%F0%D2%CF%C7%D2%C1%CD%CD%D9 %C4%C9%D3%C3%C9%D0%CC%C9%CE/SSME/SSME The next frontier in service innovation.pdf

Spohrer, J., Anderson, L. C., Pass, N. J., Ager, T., & Gruhl, D. (2008). Service science. *Journal of Grid Computing*, *6*(3), 313–324. http://doi.org/10.1007/s10723-007-9096-2

Spohrer, J., Anderson, L., Pass, N., & Ager, T. (2008). Service science and service-dominant logic: Paper 2. *Otago Forum 2*, *1*(2), 1–18.

Spohrer, J., & Kwan, S. K. (2009). Service science,management, engineering, and design (SSMED): an emerging discipline -- outline and references. *San Jose State University - Management Information Systems, Department*, *1*(3), 1–31. http://doi.org/10.4018/jisss.2009070101

Spohrer, J., & Maglio, P. P. (2008). The Emergence of Service Science: Toward Systematic Service Innovations to Accelerate Co-Creation of Value. *Production and Operations Management*, *17*(3), 238–246. http://doi.org/10.3401/poms.1080.0027

Spohrer, J., Maglio, P. P., Bailey, J., & Grughl, D. (2007). Steps toward a science of service systems. *IBM Research, Almaden Research Center*, *40*(1), 71–77. Retrieved from https://www.researchgate.net/publication/220477163

Stock, T., & Seliger, G. (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP*, *40*(Icc), 536–541. http://doi.org/10.1016/j.procir.2016.01.129

Storbacka, K., Brodie, R. J., Böhmann, T., Maglio, P. P., & Nenonen, S. (2016). Actor engagement as a microfoundation for value co-creation. *Journal of Business Research, 69*(8), 3008–3017. http://doi.org/10.1016/j.jbusres.2016.02.034

Stoshikj, M., Kryvinska, N., & Strauss, C. (2016). Service Systems and Service Innovation: Two Pillars of Service Science. *Procedia Computer Science*, *83*(Ant), 212–220. http://doi.org/10.1016/j.procs.2016.04.118

Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction*, *57*, 64–79. http://doi.org/10.1016/j.autcon.2015.04.018

Suhardi, S., Doss, R., & Yustianto, P. (2015). Service Engineering Based on Service Oriented Architecture Methodology. *Telkomnika*, *13*(4), 1466. http://doi.org/10.12928/telkomnika.v13i4.2388

Tarandi, V. (2015). A BIM Collaboration Lab for Improved through Life Support. *Procedia Economics and Finance*, *21*, 383–390. http://doi.org/10.1016/S2212-5671(15)00190-2

Tashakkori, A., & Creswell, J. W. (2007). Exploring the nature of research questions in mixed methods research. *Journal of Mixed Methods Research*, *1*(3), 207–211. http://doi.org/10.1177/1558689807302814

Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. *Thousand Oaks - Sage Publications* (Vol. 46).

Tashakkori, A., & Teddlie, C. (2010). *Sage handbook of mixed methods in social and behavioral research (2nd ed.)*. *Thousand Oaks - Sage Publications*.

Taylor, P., Haque, B., & Moore, M. (2004). Applying Lean Thinking to new product introduction. *Journal of Engineering Design*, *15*(November), 1–31. http://doi.org/10.1080/0954482031000150125

Taylor, P., Jylhä, T., & Junnila, S. (2014). Partnership practices and their impact on value creation – reflections from lean management. *International Journal of Strategic Property Management*, *18*(1), 37–41. http://doi.org/10.3846/1648715X.2013.863813

Taylor, P., Romero, D., & Molina, A. (2010). Virtual organisation breeding environments toolkit : reference model , management framework and instantiation methodology. *Production Planning & Control*, *21*(2), 181–217.

http://doi.org/10.1080/09537280903441963

Teece, D. J. (2014). The Foundations of Enterprise Performance: Dynamic and Ordinary Capabilities in an (Economic) Theory of Firms. *The Academy of Management Perspectives*, *28*(4), 328–352. http://doi.org/10.5465/amp.2013.0116

Teece, D. J., & Augier, M. (2007). Dynamic Capabilities and Multinational Enterprise: Penrosean Insights and Omissions. *MIR Management International Review*, *47*(2), 175–192. http://doi.org/11575-007-0010-8

Teece, D., Pisano, G., & Shuen, A. (1997). Dynamic Capabilities And Strategic Management. *Strategic Management Journal, Vol. 18:7, 509–533 (1997)*, *18*(March), 509–533.

Terkaj, W., & Šojić, A. (2015). Ontology-based representation of IFC Express rules: An enhancement of the ifcOWL ontology. *Automation in Construction*, *57*, 188–201. http://doi.org/10.1016/j.autcon.2015.04.010

Thomas, H. (2011). *Out of the Crisis*. *Lean Enterprise Research Centre: Issue Date: December 2011*.

Thramboulidis, K., & Christoulakis, F. (2016). UML4IoT-A UML profile to exploit IoT in cyber-physical manufacturing systems. *Electrical and Computer Engineering University of Patras, Greece*, *2*, 1–11. http://doi.org/1512.04894v2

Tien, J. M., & Berg, M. D. (2003). A case for service systems engineering. *J. Systems Sci. Systems Engrg*, *12*(1), 113–128. http://doi.org/10.1007/s11518-006-0118-6

United Nations. (2015). Conference of the Parties Twenty-first session (Vol. FCCC/CP/20, p. 32). Retrieved from http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

Valorpedra. (2016). *Projeto Mobilizador Inovstone: Novas Tecnologias para a Competitividade da Pedra Natural*. *Agencia Nacional de Inovação-Lisboa*. Retrieved from https://www.clustermineralresources.pt/projetos

Vargo, S. L., & Akaka, M. A. (2009). Service-Dominant Logic as a Foundation for Service Science: Clarifications. *Institute for Operations Research and the Management Sciences*, *1*(1), 32–41.

Vargo, S. L., & Lusch, R. F. (2004a). Evolving to a New Dominant Logic for Marketing.

Journal of Marketing, *68*(1), 1–17. http://doi.org/10.1509/jmkg.68.1.1.24036

Vargo, S. L., & Lusch, R. F. (2004b). The Four Service Marketing Myths: Remnants of a Goods-Based, Manufacturing Model. *Journal of Service Research*, *6*(4), 324–335. http://doi.org/10.1177/1094670503262946

Vargo, S. L., & Lusch, R. F. (2008). From goods to service(s): Divergences and convergences of logics. *Industrial Marketing Management*, *37*(1), 254–259. http://doi.org/10.1016/j.indmarman.2007.07.004

Vargo, S. L., & Lusch, R. F. (2010). It's all B2B...and beyond: Toward a systems perspective of the market. *Industrial Marketing Management*, *40*(1), 181–187. http://doi.org/10.1016/j.indmarman.2010.06.026

Vargo, S., & Lusch, R. (2016). Institutions and Axioms: An Extension and Update of Service-Dominant Logic. *Journal of the Academy of Marketing Science*, *44*(1), 5–23. http://doi.org/10.1007/s11747-015-0456-3

Vastag, G. (2000). Theory of performance frontiers. *Journal of Operations Management*, *18*(1), 353–360. http://doi.org/10.1016/S0272-6963(99)00024-8

Veludo, S. C. (2015). Sustentabilidade na Arquitectura: Escolhas projectuais mais eficientes. *Master Thesis - ISCTE*. Retrieved from https://repositorio.iscte-iul.pt/handle/10071/11333

Venâncio, M. (2015). *Avaliação da Implementação de BIM – Building Information Modeling em Portugal*. *Master Thesis - FEUP*. Retrieved from http://www.fe.up.pt

Vieira, S. M., Silva, A., Sousa, J. M. C., Brito, J. De, & Gaspar, P. L. (2015). Automation in Construction Modelling the service life of rendered facades using fuzzy systems. *Automation in Construction*, *51*, 1–7. http://doi.org/10.1016/j.autcon.2014.12.011

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings — Literature review and future needs. *Automation in Construction*, *38*, 109–127. http://doi.org/10.1016/j.autcon.2013.10.023

Wang, C., Cho, Y. K., & Kim, C. (2015). Automatic BIM component extraction from point clouds of existing buildings for sustainability applications. *Automation in Construction*, *56*, 1–13. http://doi.org/10.1016/j.autcon.2015.04.001

Wang, C. Y., Wu, Y. H., & Chou, S. C. T. (2010). Toward a ubiquitous personalized daily-life activity recommendation service with contextual information: A services science perspective. *Information Systems and E-Business Management*, *8*(1), 13–32. http://doi.org/10.1007/s10257-008-0107-z

Wang, L., Törngren, M., & Onori, M. (2015). Current Status and Advancement of Cyber - Physical Systems in Manufacturing. *Procedia Manufacturing*, *XXX*, 1–18. http://doi.org/10.1016/j.jmsy.2015.04.008

Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2015). Towards smart factory for Industry 4.0: A self-organized multi-agent system with big data based feedback and coordination. *Computer Networks 101*, *101*, 158–168. http://doi.org/10.1016/j.comnet.2015.12.017

Womack, J., Jones, P., & Daniel, T. (2003). *Lean Thinking, Banish Waste and Create Wealth in your Corporation. ed. Free Press, New York*.

Wong, J. K. W., & Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction*, *57*, 156–165. http://doi.org/10.1016/j.autcon.2015.06.003

Wu, L.-C., & Wu, L.-H. (2013). Improving the global supply chain through service engineering: A services science, management, and engineering-based framework. *Asia Pacific Management Review*, *20*(1), 24–31. http://doi.org/10.1016/j.apmrv.2014.12.002

Wu, Q., He, Q., & Duan, Y. (2013). Explicating dynamic capabilities for corporate sustainability. *EuroMed Journal of Business*, *8*(3), 255–272. http://doi.org/10.1108/EMJB-05-2013-0025

Yang, M. G. (Mark), Hong, P., & Modi, S. B. (2011). *Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms*. *International Journal of Production Economics* (Vol. 129, pp. 251–261). Elsevier. http://doi.org/10.1016/j.ijpe.2010.10.017

Yin, R. K. (2013). *Case study research: Design and Methods (5th edition). Thousand Oaks - Sage Publications*.

Zheng, S., Zhang, W., Wu, X., & Du, J. (2011). Knowledge-based dynamic capabilities and innovation in networked environments. *Journal of Knowledge Management*, *15*(6), 1035–1051. http://doi.org/10.1108/13673271111179352

Contactos:
Universidade de Évora
Instituto de Investigação e Formação Avançada - IIFA
Palácio do Vimioso | Largo Marquês de Marialva, Apart. 94
7002-554 Évora | Portugal
Tel: (+351) 266 706 581