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DESIGN SCIENCE RESEARCH IN OPERATIONS MANAGEMENT: PROPOSAL AND EVALUATION OF A REFERENCE MODEL TO DESIGN ARTEFACTS

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Thesis presented to the Graduate Program in Production Engineering of the Federal University of São Carlos, to obtain the title of Doctor in Production Engineering.

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DEDICATION

To my beloved parents, Claudinéia and Orlando, and brother, Guilherme, who gave me strength and continually provided their support along this journey.

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RESUMO

Apesar do alto potencial de contribuição do *Design Science Research* (DSR) no campo da Gestão de Operações (GO), ainda são poucos os estudos publicados utilizando essa abordagem. Além disso, os modelos de referência para condução do DSR não explicitam como projetar um artefato, elemento central do DSR, e não propõe alternativas para diferentes tipos de DSR. Essa tese inicia com uma revisão sistemática da literatura que identifica as principais características dos estudos utilizando DSR desenvolvidos em OM e propõe a existência de dois tipos de DSR nesse campo: uma focada apenas nas contribuições práticas e outra cujo objetivo também é contribuir para a teoria. Três variáveis distinguem esses dois tipos. A partir dessa caracterização e do estudo de modelos anteriores para condução de pesquisas de DSR no campo de GO, é proposto um novo modelo de referência focado no projeto do artefato. Esse modelo combina a CIMO Logic com o DSR desde o início do estudo, proporcionando um processo estruturado de projeto do artefato, reduzindo o tempo e os recursos necessários. O modelo também inclui de forma explícita o relacionamento entre *kernel theories* e *design theory* no processo geração de conhecimento do segundo modo. Ele é adequado para ambos, os tipos de DSR, embora para o primeiro tipo os benefícios sejam parciais, dado que a etapa final não é realizada (formulação das proposições de *design*). Finalmente, ao avaliar o modelo através da implementação empírica de um processo de *Sales and Operations Planning* (S&OP) focado em novos produtos (situação empírica no qual o modelo proposto na tese foi implementado e avaliado), a tese contribui para essa classe de problemas ao mostrar que é possível coexistirem dois processos de S&OP em uma mesma organização, um focado em itens maduros e outro focado em novos produtos.

Palavras-chave: *Design Science Research*. Pesquisa Empírica. Pesquisa Qualitativa. Gestão de Operações. Planejamento de Vendas e Operações.

ABSTRACT

Despite the high potential contribution of Design Science Research (DSR) in the Operations Management (OM) field, there are still few studies published using this approach. Furthermore, the reference models for conducting the DSR do not explain how to design an artefact, the central element of DSR, and do not propose alternatives for different types of DSR. This thesis begins with a systematic literature review that identifies the main characteristics of studies using DSR developed in OM and proposes the existence of two types of DSR in this field: one focused only on practical contributions and another whose objective is also to contribute to theory. Three variables distinguish these two types. Based on this characterization and the study of previous models for conducting DSR studies in the OM field, a new reference model focused on artefact design is proposed. This model combines CIMO Logic with DSR since the beginning of the study, providing a structured process of designing artefacts, reducing the time and resources required. The model also explicitly includes the relationship between kernel theories and design theory in the second mode knowledge generation process. It is suitable for both types of DSR, although for the first type the benefits are partial, as the final step is not performed (formulation of design propositions). Finally, evaluating the model through the empirical implementation of an S&OP process focused on new products (empirical situation in which the model proposed in the thesis was implemented and evaluated), the thesis contributes to this class of problems by showing that it is possible for two S&OP processes in the same organization, one focused on mature items and the other focused on new products.

Keywords: Design Science Research. Empirical Research. Qualitative Research. Operations Management. Sales and Operations Planning.

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LIST OF ABBREVIATIONS

CIMO	Context, Intervention, Mechanisms and Outcomes
DSR	Design Science Research
NPI	New Products Introduction
OM	Operations Management
SLR	Systematic Literature Review
S&OP	Sales and Operations Planning
KPI	Key Performance Indicator

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1 INTRODUCTION

In this initial chapter, the theme of this thesis (Design Research Science) is contextualized and the problem is presented. It is also stated the research objectives as well as an overview of the research methods and of the thesis structure is provided.

1.1 Design Science Research

In Operations Management (OM), at least in some moments, theory and practice seem to be two distant worlds (HODGKINSON; HERRIOT; ANDERSON, 2001; SINGHAL; SODHI; TANG, 2019). From one side, theory-oriented scientists produce studies with significant theoretical developments, but with little or no practical relevance as rarely those developments are tested in empirical situations (SCHMENNER *et al.*, 2009; HOLMSTRÖM; KETOKIVI; HAMERI, 2009; KETOKIVI, 2009; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; ZINN; GOLDSBY, 2017). On the other side, while practice-oriented scientists focus on empirical problems, they usually are not worried about using a rigorous and reproducible research method, following an almost consulting approach, and sometimes struggling to solve problems that have already been discussed in literature (HATCHUEL, 2009; KUNZ; WASSENHOVE, 2019; ILK; SHANG; GOES, 2020).

The development of theory and the empirical application of formal knowledge are essential to the development of OM. In this context, Design Science Research (DSR) is an approach that many authors claim could bridge the gap between these two distinct worlds (HOLMSTRÖM; KETOKIVI; HAMERI, 2009; SCHMENNER *et al.*, 2009; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; O'KEEFE, 2014; KIESER; NICOLAI; SEIDL, 2015; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016; LAPÃO; SILVA; GREGÓRIO, 2017; KUNZ; WASSENHOVE, 2019), as it aims to solve a problem in a given context but also to transfer the knowledge generated in that specific context to others, helping in the development and refinement of existing theories or the creation of new ones (HOLMSTRÖM; KETOKIVI; HAMERI, 2009; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014).

Despite its potential contributions to the OM field, DSR has not been widely used in OM studies except in the areas of Information Technology and Organizational Studies (PEFFERS *et al.*, 2007; TRUEX; CUELLAR; TAKEDA, 2009; O'KEEFE, 2014; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016). For example, although the Journal of Operations Management (JOM) has created a specific department to evaluate DSR studies, in the first 4.5 years after establishing it, JOM has published only 8 papers using this research approach (CHANDRASEKARAN; DE TREVILLE; BROWNING, 2020).

Although the term Design Science has been used in the literature since the 1930s, the origins of DSR as a scientific research approach go back to the seminal book "Sciences of the Artificial" of Simon (1969) (CROSS, 2001; O'KEEFE, 2014). The central element in DSR is the artefact, which can be defined as anything that embodies the knowledge and represents the proposed solution to the practical problem (O'KEEFE, 2014). As humans always create the artefacts, they are artificial elements and, therefore, the name sciences of the artificial that Simon (1969) refers in the title of his book (e.g., engineering, computer science, management, information technology, medicine, among others). An artefact can be as diverse as a model, process, software, object, construct, among others (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014) and can be physical, digital or both (MARCH; SMITH, 1995).

DSR consists, in its essence, in the proposal, evaluation and understanding of the results generated by an artefact (HOLMSTRÖM; KETOKIVI; HAMERI, 2009). The proposal phase involves the design and refines the artefact. A clear and precise description of how the artefact was developed is a critical element of the quality of a DSR research (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). However, despite its importance, it is still unclear how to design and refine artefacts to solve empirical problems.

From one side, theoretical studies have presented some clues on how to design an artefact, for example, Gibbons's *et al.* (1994) two modes of knowledge production, Bunge's (2004) explanation of how mechanisms work to connect elements of an artefact, and Huff, Tranfield and van Aken's (2006) combination of kernel and design theory to propose an artefact. Despite presenting interesting discussions, these studies do not help practitioners propose artefacts through DSR as they did not provide a model researchers can follow in their studies.

From the other side, many reference models for conducting DSR have been proposed with a series of steps to be followed (e.g., VAN AKEN, 2004; COLE *et al.*, 2005; MANSON, 2006; PEFFERS *et al.*, 2007; HOLMSTRÖM; KETOKIVI; HAMERI, 2009; ALTURKI *et al.*, 2011). However, none of these models explicitly detailed how to design and refine an artefact (DRESCH, LACERDA AND ANTUNES JÚNIOR, 2014). As a result, this step is usually too generic in the models, despite its fundamental importance in the DSR.

Once the artefact is developed, it is necessary to assess whether it solves the practical problem it was designed to (HEVNER, 2004). This evaluation can be performed through empirical implementation, experiments, and computer simulation (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). In this process, a clear definition of the problem evaluated, of the desired results and how those results will be measured (e.g., which performance indicators will be used), are also essential elements to increase the quality of a DSR study.

Finally, although not performed by all DSR studies, an important step is to comprehend how the results were generated, that is, to analyze the transformations that occur in the environment after introducing the artefact (HOLMSTRÖM; KETOKIVI; HAMERI, 2009). One of the possible ways to conduct this step is by applying CIMO Logic, as detailed in the next section.

1.2 CIMO Logic

CIMO Logic (Context, Intervention, Mechanism and Outcomes) was proposed by Denyer, Tranfield and van Aken (2008) to evaluate DSR results in a more formal way. This evaluation aims to increase the potential of generalization of the proposed artefact to similar contexts and to contribute to the refinement of the theory by formulating design propositions, which are statements that explains what contexts and how the artefact generates a certain result (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). Therefore, regarding the three macro phases of DSR studies previous explained, CIMO Logic is used in the understanding of the results generated by an artefact.

The first element of the logic is the Context, which are factors presented in the environment that can influence the outcomes. For example, the traffic in a city is influence by the raining and, therefore, raining is a contextual factor to explaining the outcome traffic. It is significant to identify all the relevant contextual factors involved, as the results obtained with the artefact are limited to a specific context (SCHMENNER *et al.*, 2009; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016). Therefore, the artefact is usually not a general solution for all cases but rather a specific solution for a given context.

This fact has not diminished the importance of DSR, as the knowledge generated by the assessment of the artefact can be transferred to contexts that have similar characteristics, as well as adapted to other contexts, modifying the proposed initially artefact (HOLMSTRÖM; KETOKIVI; HAMERI, 2009; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016; KUNZ; WASSENHOVE, 2019).

The second element is the Intervention, which is the implementation of the artefact to evaluate the results it generates in a given context. This can occur in an empirical situation as well as in a virtual one (e.g., computer simulation) (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014).

The third element are the mechanisms which are the process invoked by the intervention that generated the outcome (DENYER, TRANFIELD AND VAN AKEN, 2008). For example, in the cardiovascular system, pumping of blood through the heart is a mechanism. In an S&OP process, organizational engagement for a common purpose is an example of a possible mechanism.

Identifying the mechanisms involved in an artefact and understanding how they work is certainly the central point to comprehend the results generated by the artefact, but this is not an easy task. For example, a task can be performed by different mechanisms (e.g., documents can be reproduced by printing presses, mimeographs or photocopiers), it can be necessary to combine mechanisms to generate complex results, mechanisms need to be inferred, as they are totally or largely imperceptible, among other challenges. These points will be discussed in detailed in Chapter 3.

Finally, the fourth element is the outcome which is the desired result academics and practitioners expected from starting the intervention of a certain artefact in a given context. Therefore, the connection of the four elements enables to synthesize a set of action-outcomes relationships describing the DSR results (HOLLOWAY *et al.*, 2016).

1.3 Problematization

CIMO Logic has been applied in DSR studies in a sequential way as initially proposed by Denyer, Tranfield and van Aken (2008), that is, to understand the results generated by an artefact. There are many examples of this combination in literature, such as: Ivert and Jonsson (2014), Busse *et al*. (2017), Groop *et al*. (2017), Kaipia *et al*. (2017), Brusset and Bertrand (2018), Akkermans *et al*. (2019), Hedenstierna *et al*. (2019), Kunz and Wassenhove (2019) and Johnson, Burgess and Sethi (2020). In this format, DSR and CIMO Logic exist separately, as CIMO Logic is applied only when the artefact has already been developed and implemented.

We believe, however, that a more integrated use between DSR and CIMO Logic since the beginning of the research can bring benefits to DSR studies, such as structuring the process of projecting and refining artefacts to solve empirical problems. Therefore, this thesis asks:

What are the benefits of an integrated use of DSR with CIMO Logic since the beginning of the research?

How can this combination structure the process of designing and refining artefacts

to solve empirical problems?

For the practice, a structured process can significantly reduce the time and costs to conduct DSR studies, supporting the development of DSR approach in the OM field. For the theory, a structured process can develop design theory, further helping researchers to project and refine artefacts that solve the empirical problems they are facing.

1.4 Research Objectives

Aiming to answer these questions, the main objective of this thesis is to propose a reference model combing DSR and CIMO Logic to conduct DSR studies focused on the artefact design. To achieve this goal, the following specific objectives were defined:

1. To understand the state-of-art of empirical DSR studies in the OM field in order to identify if there is a single DSR group in the OM field or if there is more than one group. If there is more than one group, to identify which characteristics differentiate these groups;
2. To propose a reference model focused on artefact design, adaptable to the different types of DSR identified, by combining DSR and CIMO Logic since the beginning of the study.
3. To evaluate the proposed model and identified potential gaps by conducting an empirical DSR study in the OM field following the proposed model.

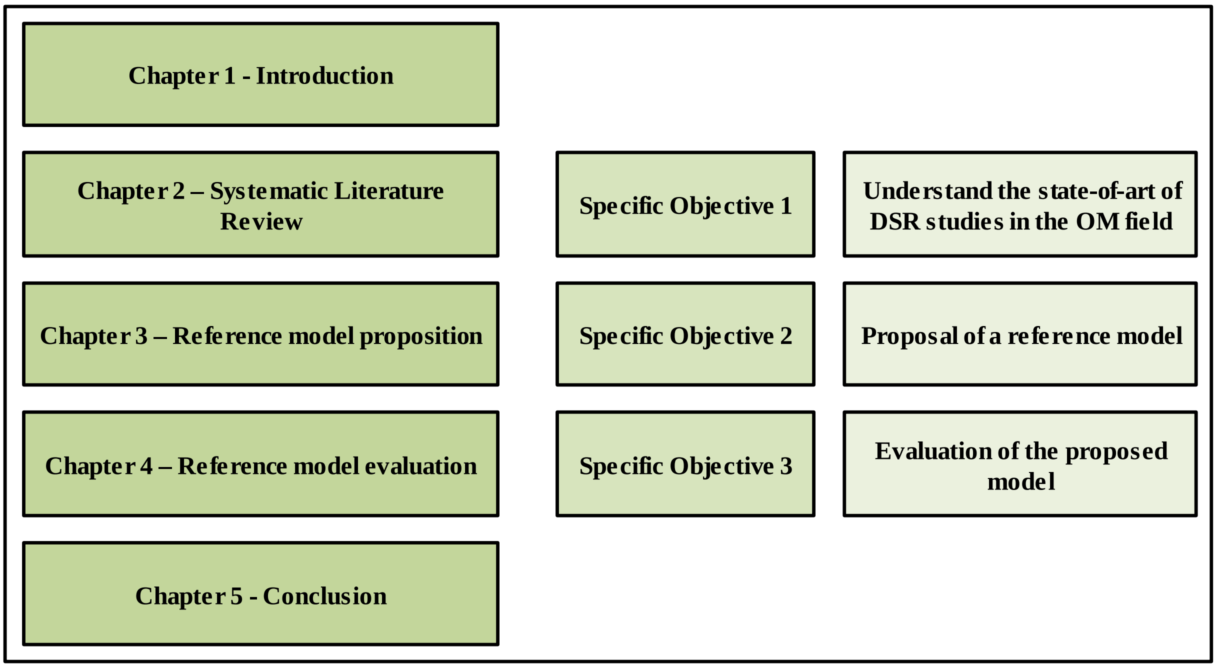
1.5 Overview of Thesis Structure

This thesis is divided into 5 Chapters (Figure 1). Chapter 1 (Introduction) has presented the motivations for conducting this thesis, and the research gaps and objectives that we aim to fulfil. As Chapters 2, 3 and 4 are structured in a scientific paper format, some points already addressed in previous chapters will be redundant, and we apologize for that.

Chapter 2 aims to achieve specific objective 1. First, based on DSR studies, 4 variables were defined to characterize DSR studies. Second, a Systematic Literature Review was conducted to identify 56 DSR studies in the OM field published in top journals from 2011 to 2020. Third, adding 4 bibliometric variables to the 4 specifics of DSR studies, the fundamental characteristics of DSR studies in OM developed from 2011 to 2020 were identified (e.g., growth in the number and quality of papers published over the period and a high frequency of use of the case study as an evaluation method). Fourth, the studies were classified into two distinct groups (one focused only on the empirical contribution of the study and another focused also on the theoretical contribution) using the research development level as the main variable.

Types of artefacts used, publication journals and where the authors are located also differentiate these groups.

Figure 1- Thesis structure and specific objectives



Chapter 3 aims to achieve specific objective 2, proposing a reference model to conduct DSR studies focused on the artefact design step. After presenting previous reference models, knowledge generation theory and CIMO Logic, the proposed model composed of five phases is presented. The model relies on an innovative combination of CIMO Logic with DSR since the beginning of the study. Therefore, researchers have to evaluate through the whole DSR study why the results were generated and in which contexts they are valid, not only at the end of the study, as usually CIMO Logic is used in combination with DSR. It is also discussed how to apply the model to both types of DSR and, why, with the model, researchers should also seek to contribute to both practice and theory.

Chapter 4 aims to achieve specific objective 3, evaluating the proposed reference model in an empirical study in the OM field. The selected study was the implementation of a Sales and Operations Planning (S&OP) process for demand fulfilment after introducing new products (New Product Introduction, NPI) in a transnational consumer goods manufacturer which was facing problems to fulfil the demand of three new products projects. The proposed S&OP New Products was developed, refined and evaluated, helping to identify potential improvements to the reference model that will be discussed in chapter 5. The study also generated contributions to the specific class of problems (e.g., the identification of three mechanisms and six contextual variables and the possibility to have two different S&OP process in a single company, one focused on mature products and another on new products due to their different characteristics).

Finally, Chapter 5 (Conclusion) discusses how the proposed model performs in the empirical evaluation. It also presents the main conclusions of this thesis and a research agenda for further development of the proposed reference model and DSR as a research approach.

2 DESIGN SCIENCE RESEARCH IN OPERATIONS MANAGEMENT: IS THERE A SINGLE TYPE?

This second chapter aims to identify the state-of-art empirical DSR studies in the OM field, their potential classification into different types, and the characteristics that differentiate them. Classifying the 98 studies identified in the Systematic Literature Review according to 7 variables (3 specifics to DSR studies and 4 bibliometrics) the main characteristics of DSR studies developed in the OM field from 2013 to 2022 were identified. The most critical variable found was the research development level, which was used to classify the studies into two different groups.

2.1 Introduction

Design Science Research (DSR) is an empirical approach that aims to solve a practical problem in its natural environment. Briefly, it aims to propose a solution (artefact) to a given problem, to evaluate if the artefact solves the problem and to understand why the artefact solves the problem (that is, what transformations were triggered by the implementation of the solution) (HOLMSTRÖM; KETOKIVI; HAMERI, 2009; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; VAN AKEN *et al.*, 2016). In addition, DSR also contributes to the development and refinement of the theory by providing insights obtained from the empirical resolution of the problem (KUNZ; WASSENHOVE, 2019).

In Operations Management (OM), many authors (e.g. SCHMENNER *et al.*, 2009; O'KEEFE, 2014; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016; KUNZ; WASSENHOVE, 2019) claimed that the use of DSR as the research approach in studies can bring exciting contribution to the field. Previous papers have presented models and good research practices to conduct DSR studies in OM (e.g., MANSON, 2006; PEFFERS *et al.*, 2007; HOLMSTRÖM; KETOKIVI; HAMERI, 2009), classified types of artefacts (e.g., MARCH; SMITH, 2005; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014) and discussed possible ways to evaluate them (e.g., HEVNER; MARCH; PARK, 2004). However, DSR has not been typically used in studies in OM (VAN AKEN; CHANDRASEKARAN; HALMAN, 2016). For example, 4.5 years after establishing a Design Science Department, the Journal of Operations Management has published only 8 papers using this research approach (CHANDRASEKARAN; DE TREVILLE; BROWNING, 2020).

The contradiction in the OM field between the high contribution potential of DSR and its low use is an intriguing aspect that needs to be explained. Therefore, this study proposes the 2 following questions:

RQ1) **What are the main characteristics of DSR in the OM field in the last 10 years (from 2013 to 2022)?**

RQ2) **What are the different types of DSR in the OM field?**

Aiming to answer this question, a systematic literature review (SLR) was conducted to identify the main characteristics of empirical DSR studies published in the field during this period. Furthermore, comparing and clustering the studies, we propose the existence of two distinct types of DSR studies in the OM field. These two types focus on different audiences (practitioners and academics) and aims to achieve different objectives (only to solve an empirical problem or also to understand how and why the implemented artefact works). We also identify and discussed two important barriers that DSR will have to overcome in the next decade to be a more extensively used approach in OM and if both types will coexist in the future.

This chapter is organized as follows. Section 1.2 highlights how SLR was developed and presents the seven variables used in this study (4 bibliometrics and 3 specifics of DSR). Section 1.3 presents four main findings of how DSR studies in OM has been developed from 2013 and 2022 and the two DSR types resulted from the cluster analysis. Section 1.4 discuss the main barrier DSR have to overcome to be more used in the OM field and if both types will coexist in the future. Finally, Section 1.5 presents the main contribution of this study and a future research agenda

2.2 Research Method

To identify the state-of-art of DSR studies in the OM field, a SRL was conducted as it is appropriate to identify the state of art of a given subject and to propose future research directions, minimising the bias in the selection of articles (TRANFIELD; DENIER; SMART 2003; FAWCETT *et al.*, 2014; GOVINDAN *et al.*, 2015). The SLR was conducted in a three-phase process. Following the benefits of Sharma, Jabbour and Jabbour (2020)'s model, the first phase consists of defining the research protocol (Table 1). This phase is the most important in a SLR, as it encompasses strategic decisions that will determine the research's quality. Therefore, researchers must devote a significant amount of time to this step to reflect on their decisions and conduct preliminary studies, as phase 2 consists of the operationalisation of phase 1, following the steps proposed by Tranfield, Denier and Smart (2003). Finally, phase 3 consists of analysing the final papers to extract and document the relevant information to the analysis conducted in Section 2.4.

Table 1 – Research protocol

Research Protocol	
Database	Web of Science, Scopus and Engineering Village
Publication Years	From 2013 to 2022
Document type	Journals classified as 2, 3, 4 or 4* in the 2018th Academic Journal Guide in the fields of Operations and Technology Management and General Management, Ethics, Gender and Social Responsibility
Language	English
Strings	"design science" "intervention-based research" "artefact design" "action design research"
Inclusion criteria	• Studies that conduct DSR in OM
Exclusion criteria	• Non-empirical studies, such as literature reviews and simulation papers • Studies that do not propose and implement an artefact • Studies outside the area of OM

2.2.1. Phase 1: Definition of Research Protocol

The first decision in phase 1 is the definition of the databases, which should contain the most relevant papers in the topic studied and should be regularly updated. In this study, we selected three databases (Web of Science, Scopus and Engineering Village) as they contain relevant literature in OM and are updated frequently (THOMÉ; HOLLMANN; SCAVARDA, 2014; BAGNI *et al.*, 2020). Moreover, the relevant journals for this study were all included in at least one of the three databases.

The second decision is to define which studies are relevant to the research. Some papers identify a relevant event in the search subject and use this event as the beginning or end of the research interval (BAGNI *et al.*, 2020). However, when there is no relevant event, such as in this search, a more subjective decision is usually taken. For example, when the objective is to map recent literature, many papers limit their literature review to the last decade to focus on contemporary literature, such as Martin, Sun and Westine (2020) and Morse-Brady and Hart (2020). In this paper, we follow this pattern.

Thirdly, it is necessary to define the documents to include in the search. Our objective is to analyse the state of the art in using DSR in OM. Therefore, we included only papers published in the seventy journals ranked 2 or above in the Academic Journal Guide (2018) in

Operations and Technology Management and General Management, Ethics, Gender and Social Responsibility. Moreover, with the definition of the journals, we also defined that we would only include studies published in English, as this is the publication language of those journals.

Fourthly, there is the definition of research strings. In this search, we defined the string in an iterative cycle similar to Sharma, Jabbour and Jabbour (2020). The cycle consists of defining strings, researching databases, analysing the main results to refine the keywords, and conducting another round of refinement. For example, our study started with design science research as the only research string and identified that some articles refer to the approach as only design science. In another round, we observed that some recent articles use the term intervention-based research to refer to DSR (CHANDRASEKARAN; DE TREVILLE; BROWNING, 2020) and action design research (OBERDORF; STEIN; FLATH, 2021),

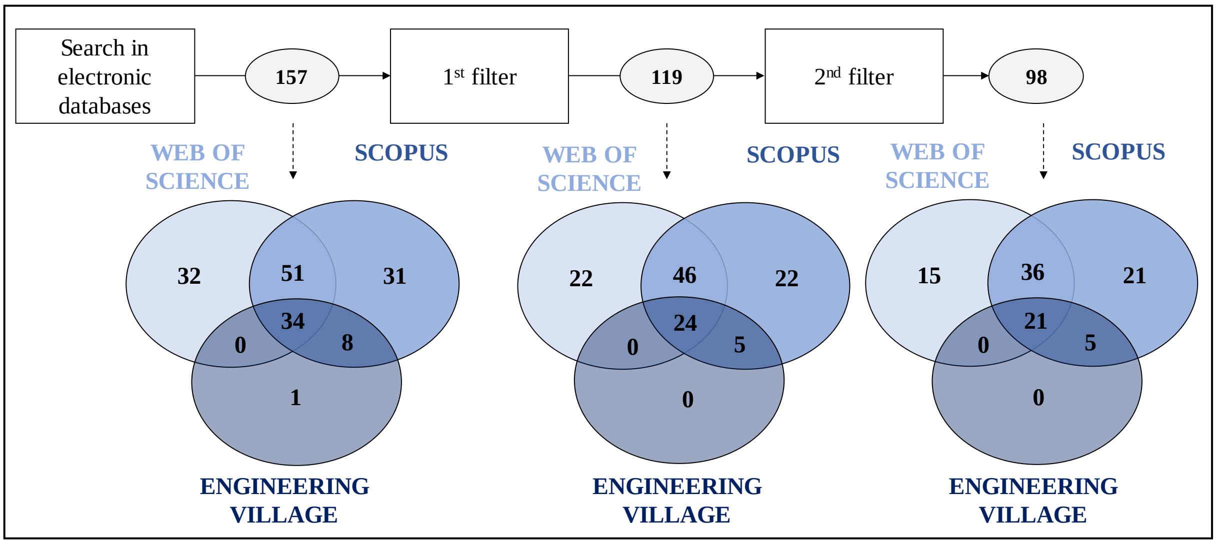
We also tried variations such as empirical studies, practical studies and implementation, but search results increased significantly (more than 12,000 papers) with many studies that use an approach different from DSR. Filtering all of those articles would be an unfeasible task, as it would be necessary to read many articles in total to identify their methodology. Therefore, we decided to follow with four strings (“design science”, “intervention-based research”, “artefact design” and “action design research”). Our search using these strings resulted in all the papers reported by Chandrasekaran, de Treville and Browning (2020) as the ones published by the Journals of Operations Management using DSR in the last 4.5 years.

Fifthly, it is necessary to define inclusion and exclusion criteria to filter the articles in steps 3 and 4. Our inclusion criteria are simple all OM studies using DSR as its research approach. Therefore, non-empirical papers and empirical studies that do not propose and test an artefact (an essential characteristic of DSR) and studies outside OM were not included in the final list.

2.2.2. Phase 2: Operationalisation of the SLR

Having defined the research protocol, searches in the three databases were performed, resulting in 157 papers. In the first filter, the papers' title and summary were evaluated to analyse if they met the inclusion and exclusion criteria defined in the research protocol, resulting in 119 papers. The second filter consists of the full reading of the remaining 119 papers, applying the same criteria defined in the research protocol. After this filter, the number of papers was reduced to 98 papers (Appendix A). Those steps are summarised in Figure 2.

Figure 2- Operationalisation of the SLR



2.2.3. Phase 3: Definition of the variables

Four bibliometric variables were used to characterize the 98 SLR. Three of them were based on Börner and Polley (2014) reference book to visualize data and aiming to characterize studies regarding time (publication year), authors (number of studies published per author during the period) and location (number of studies published per country where each author was located) (Table 2). A fourth bibliometric variable, source (journal), was included aiming to answer how the studies were published as other authors have also done in different context (e.g., FLIESS; LEXUTT, 2017; COLLINS; DENNEHY; CONBOY; MIKALEF, 2021; SIACHOU; TRICHINA; PAPASOLOMOU; SAKKA, 2021).

Table 2 – Variables to classify the SLR studies

Type	Variable	Source
Bibliometric Variables	Publication year	Börner and Polley (2014)
	Number of studies published per author	Börner and Polley (2014)
	Number of studies published per country	Börner and Polley (2014)
	Journal	Many examples (some provided in the previous paragraph)
DSR Variables	Research development level	Holmström, Ketokivi and Hameri (2009)
	Type of artefact	Dresch, Lacerda and Antunes Júnior (2014)
	How the artefact was evaluated	Dresch, Lacerda and Antunes Júnior (2014)

Moreover, based on key choices authors made in their DSR study, three additional variables were defined to characterize further the studies identified in the SLR. They are: the research development level (which phases of Holmström, Ketokivi and Hameri (2009)'s model were conducted), the type of artefact and how the artefact was evaluated. In the following subsection, we briefly explain each of these three variables and how they were defined.

Research development level

Among many reference models proposed for conducting a DSR study (e.g., TAKEDA, VEERKAMP; YOSHIKAWA, 1990; VAN AKEN, 2004; COLE *et al.*, 2005, MANSON, (2006; PEFFERS *et al.*, 2007; BASKERVILLE; PRIES-HEJE; VERNABLE, 2009; ALTURKI *et al.*, 2011), Holmström, Ketokivi and Hameri (2009) is the most extensive model placing great emphasis on explaining the artefact and generalizing the results obtained, phases that other models barely discussed (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). Therefore, the research development level of the empirical DSR studies identified in our SLR will be classified using the four phases of Holmström, Ketokivi and Hameri (2009)'s model (Table 3). For example, a study classified in level 2 proposed and evaluated an artefact but did not explain why the results were generated.

Table 3 – Research development level

Phases	Holmström, Ketokivi and Hameri (2009)'s model	Characteristics	Illustrative Example in OM
1	Solution incubation	Studies that propose an artefact, but do not clearly evaluate its validity	Proposal of a new method for a project selection
2	Solution refinement	Studies that propose and evaluate an artefact, but do not evaluate why the results were obtained or compared the situation or the artefact with previous literature	Implementation of the proposed method in a company and validation the desired results are generate
3	Explanation I – Substantive theory	Studies that propose and evaluate an artefact and compare the observed results, mechanism, and/or contextual variables with previous literature research. However, results are not generalised; that is, they are valid for a specific situation	Understand why the desired results were generated (identification of mechanism and contextual variables)
4	Explanation II – Formal theory	In addition to level 3 achievements, studies in this level generalise the results for others situation and context	Validation of the method not only for that particular company but for all companies with a specific characteristic

Source: Adapted from Holmström, Ketokivi and Hameri (2009).

Type of artefact

Artefacts are the centerpiece in the development of DSR as they enable to achieve a specific goal with great assertiveness in a given environment (GILL; HEVNER, 2011; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). Therefore, the type of artefact used is a relevant variable to classify DSR studies. In DSR theory, however, there is no uniform classification of types of artefacts, but the one proposed by March and Smith (1995) is one of the most traditional (ALTURKI; GABLE; BANDARA, 2011). Dresch, Lacerda and Antunes Júnior (2014) added a fifth type of artefact (design prepositions) to the original classification of March and Smith (1995), which is an essential addition considering the theoretical contributions DSR studies can provide (Table 4). Therefore, the artefacts types will be evaluated following Dresch, Lacerda and Antunes Júnior (2014) classification.

Table 4 – Types of Artefacts

Types of Artefacts	Definition	Illustrative Example in OM
Construct	A concept used to describe a problem and specify its solution in a given domain of knowledge	Lead time concept
Model	Representation of the reality that contains the variables of a system and the relationship among them	Simulation model of a new factory shop floor
Method	Steps necessary to conclude a task	Steps to implement an Enterprise Resource Planning in a manufacturing company
Instantiations	Artefacts that help to operationalise other types of artefacts	A knowledge portal for the management of all the findings occurred during the proposal and evaluation of artefacts in an organisation
Design Propositions	Statements in which is declared that to achieve a certain goal in a given situation, some defined action must be performed	To increase the chances of success of a project (goal), if the team is not motivated to performed the necessary task (situation), the manager should initially convince the team of the benefits of the project (action).

Source: Adapted from March and Smith (1995) and Dresch, Lacerda and Antunes Júnior (2014).

How the artefact was evaluated

Validation is essential in DSR studies to differentiate a scientific rigor research from a practical solution of an empirical problem. It involves the authors proving, in pre-established conditions, that the artefact solves a defined problem (PRIES-HEJE; BASKERVILLE, 2008; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016). Among the many ways an artefact can be evaluated, a classical reference list is provided by Hevner, March and Park (2004). Similar to artefacts types, Dresch, Lacerda and Antunes Júnior (2014) added a sixth (focus group) evaluation method to the original classification of Hevner, March and Park (2004), which is an essential addition in the OM context. Therefore, the evaluation methods will be classified according to Dresch, Lacerda and Antunes Júnior (2014) (Table 5).

Table 5 – How the artefact was evaluated

Ways to evaluate an artefact	Possible methods and techniques	Main characteristic	Illustrative Example in OM
Observational	Case and field studies	The researchers are not part of the study, that is, they do not interact with the artefact or other actors during the evaluation	A company decide to implement a model to develop new products and the researchers observe the results of the model, without participating in the development of the products
Analytical	Architecture and dynamic analysis	The focus is on testing in a real context the performance of the artefact and ways to improve it	Evaluation of the technical performance of a hardware under a certain condition (temperature, memory capacity, among others)
Experimental	Computer simulation and controlled experiments	A controlled or artificial environment is created to see how the artefact perform in that situation	A laboratory experiment in the development of a new ink before producing it in large-scale
Testing	Functional and structural test	Usually associated with artefacts related to information systems and consists of testing the internal structure of the software as well as if satisfy the needs of the users	Beta evaluation of a software
Descriptive	Informed argument	This form aims to validate the artefact by using previous arguments discussed in literature	A new political tax program could be validated by the benefits it will bring to local society
Focus group	Exploratory and confirmatory groups	Focus group can be used in the development of the artefact (as exploratory groups) or in this evaluation (as confirmatory groups)	A company can used confirmatory groups to test a new function in a smartphone

Source: Adapted from Hevner, March and Park (2004) and Dresch, Lacerda and Antunes Júnior (2014).

2.2.4. Phase 4: Evaluation of the selected studies

Having defined the variables, information was extracted and documented from the 98 selected papers. This process was conducted independently by the authors and subsequently cross-checked to minimize subjectivity in the analysis. The authors then analysed the results of the variables to identify the characteristics of DSR studies in the OM published from 2013 to 2022. The most relevant findings are presented in Section 2.4.

2.2.5. Phase 5: Cluster analysis

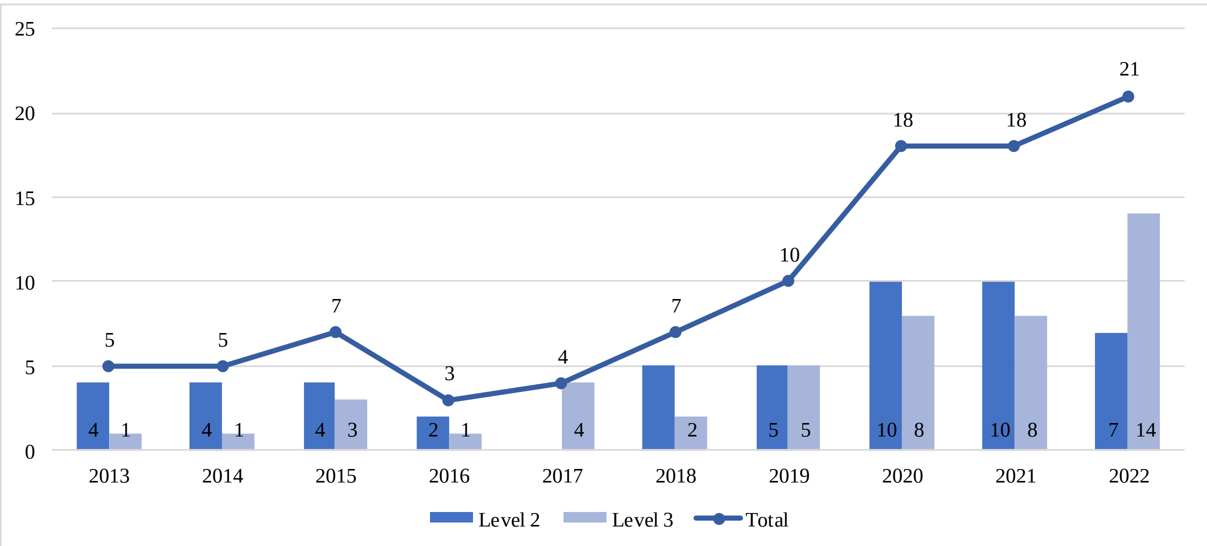
Further to classifying the studies according to the above-mentioned variables, we investigated if there is a single type of DSR in the OM field or, in case of more than one, how many types there are, their characteristics and which variables differentiate them. To do so, a cluster analysis was conducted using Statistica 14.0.0. To construct the dendrogram, the agglomeration method was used, and several combinations of linkage rules (e.g., single linkage, complete linkage, Ward's method) and distance measures were evaluated (e.g., Euclidean distances, squared Euclidean distances, 1-Pearson r). The best fit was obtained with the combination of single linkage with Euclidean distances. After identifying two distinct groups, a K-means clustering was conducted to evaluate which variables distinguish more the two groups. Those results are presented in Section 2.5.

2.3 Results

2.3.1 The main characteristics of DSR studies in OM (2013-2022)

Regarding quantity, 58% of the papers identified in the SLR were published in the last 3 years, indicating an increase in OM researchers' interest in developing studies using DSR (Figure 3).

Figure 3- Evolution of DSR studies in number and quality



In terms of quality, development level of DSR studies have increased in number and proportion over the last decade. To corroborate this information, we first observed that 47% of the third research development level papers were published during the previous 2 years. Second, while from 2013 to 2016 only 30% of the studies published were classified in the third level, this number increased to 52% from 2019 to 2022. However, there is no level 4 study up to now. From this result, we come to finding 1.

Finding 1: DSR studies in OM have grown in number and quality during the 2013-2022 period.

In the last decade, 56% of the studies were published in only 5 journals (Business Process Management Journal, Computers in Industry and Journal of Operations Management), while 80% is concentrated in the top ten (Table 6). Moreover, only 14 journals have published more than 2 studies using DSR in the 10 years period analysed.

Table 6 – DSR studies published per journal

Journal	**Total**
Business Process Management Journal	15
Computers in Industry	14
Journal of Operations Management	10
IEEE Transactions on Engineering Management	9
International Journal of Operations and Production Management	7
Production Planning and Control	5
International Journal of Physical Distribution and Logistics Management	5
International Journal of Project Management	5
International Journal of Production Economics	4
Journal of Business Research	4
International Journal of Production Research	4
Journal of Construction Engineering and Management	4
International Journal of Quality and Reliability Management	2
Journal of Intellectual Capital	2
Journal of Purchasing and Supply Management	1
Management Decision	1
Journal of Revenue and Pricing Management	1
International Journal of Computer Integrated Manufacturing	1
British Journal of Management	1
Total Quality Management & Business Excellence	1
Journal of Business Logistics	1
Computers and Industrial Engineering	1

The 98 papers identified in the SLR were written by 334 authors, 308 of which were non-repeated names. Therefore, most researchers have published only a single paper using DSR. Only 20 authors have published more than one study in the last ten years (Table 7).

Among them, Jan Holmström stands out as the author who has published more papers in DSR in the last decade (6). This result contradicted our initial expectations, as we believe that an author who had published a study using DSR would again use this same approach in other studies. However, as there is a large concentration of studies published in the last 3 years (58%), perhaps a large part of the authors is still conducting new research that will be published in the coming years.

Table 7 – Authors who have published more than 2 DSR papers

Author	Studies published	Affiliation
Jan Holmström	6	Aalto University (Finland)
Xavier Brusset	3	Universite Côte d'Azur (France)
Stephan M. Wagner	3	Swiss Federal Institute of Technology (Switzerland)
Xiao Li	2	The Hong Kong Polytechnic University (Hong Kong)
Nils Urbach	2	University of Bayreuth (Germany)
Mikael Öhman	2	Aalto University (Finland)
Atanu Chaudhuri	2	Durham University Business School (UK)
Fan Xue	2	The University of Hong Kong (Hong Kong)
Max Finne	2	University of Warwick (UK)
Weisheng Lu	2	The University of Hong Kong (Hong Kong)
Moacir Godinho Filho	2	Federal University of São Carlos (Brazil)
André Schweizer	2	UCL Centre for Blockchain Technologies (Germany)
João Varajão	2	University of Minho (Portugal)
Christian Busse	2	Carl von Ossietzky University of Oldenburg (Germany)
Frederik Ahlemann	2	University of Duisburg-Essen (Germany)
Ying Wang	2	Beijing Jiaotong University (China)
Liupengfei Wu	2	The University of Hong Kong (Hong Kong)
Aseem Kinra	2	University of Bremen (Germany)
Jon Lerche	2	Aarhus University (Denmark)
Rui Zhao	2	The University of Hong Kong (Hong Kong)

Classifying the studies according to author’s affiliation, we observed that 80% were concentrated in only 12 countries (Table 8). Among these countries, except from Finland, where DSR studies were concentrated in the Aalto University (84% of the occurrences), research is diversified among several universities and companies in other countries. All of these results come to finding 2.

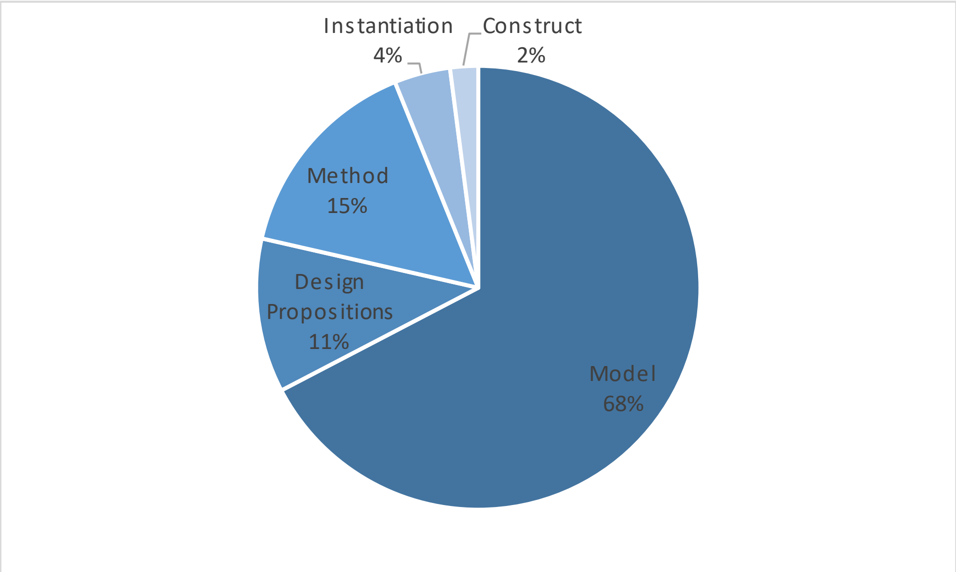
Table 8 – Number of papers published per country

Country	Studies published
Germany	51
UK	39
The Netherlands	33
Brazil	30
Finland	19
Denmark	19
Portugal	16
Hong Kong	14
China	14
USA	13
Switzerland	11
Italy	11

Finding 2: DSR remains a niche approach in OM, with studies concentrated in a few journals, authors and countries.

Models are the primary type of artefact in DSR (66 out of the 98 studies identified in the SLR, as shown in Figure 4), for both second (69%) and third (66%) research development levels. However, design propositions are emerging with increased studies in the third level (23%). The 11 studies published using this artefact are in the third research development level and 7 of the 11 published in the last four years of the analysed period (between 2019 and 2022). This leads to finding 3.

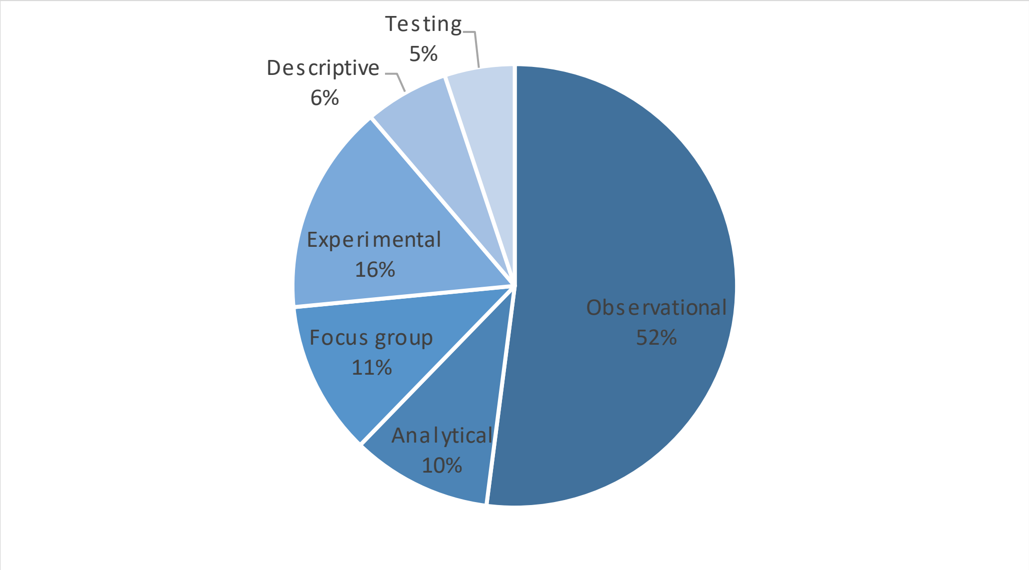
Figure 4- Types of artefacts



Finding 3: DSR artefacts are highly concentrated in models. However, design propositions are emerging as an artefact in OM.

Most of the 98 papers identified in the SLR (51) used an evaluation method classified in the observational category (Figure 5). Further evaluating those 51 studies, 43 used case study as the evaluation method. Although this is not a problem as case study is a suitable method to be used in the DSR approach, its extensive use may additional contributions and views that other methods can bring, refining the study's contribution to theory (e.g., focus groups, structural test, computer simulation, dynamic analysis). From this we have finding.

Figure 5- Form used to evaluate the artefact



Finding 4: DSR is still an approach under development in OM, with strong influence from traditional qualitative methods, especially case study research.

2.3.2 Types of DSR in OM

By conducting a cluster analysis as described in Section 2.3.5, the 98 studies were classified in 2 distinct clusters (with 47 and 51 studies). This is presented in the dendrogram shown in Figure 6 (to relate the numbers in the Figure to each study of the SRL, see Appendix A). Furthermore, having defined the existence of two clusters, by conducting a K-means analysis it was verified that the research development level is the main variable that distinguishes the two clusters. However, type of artefact and journal are also relevant (Figure 7).

Figure 6- Dendrogram

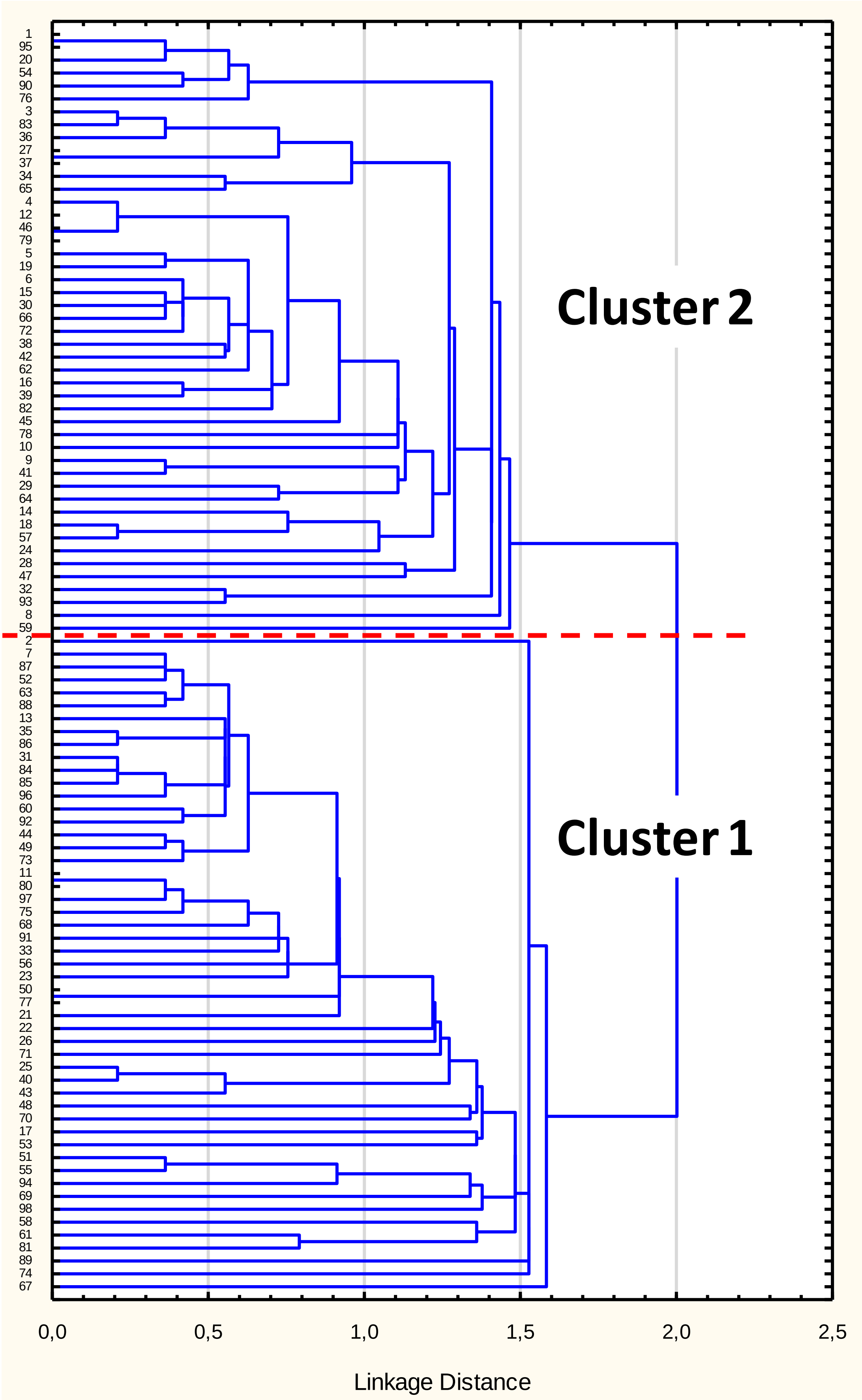
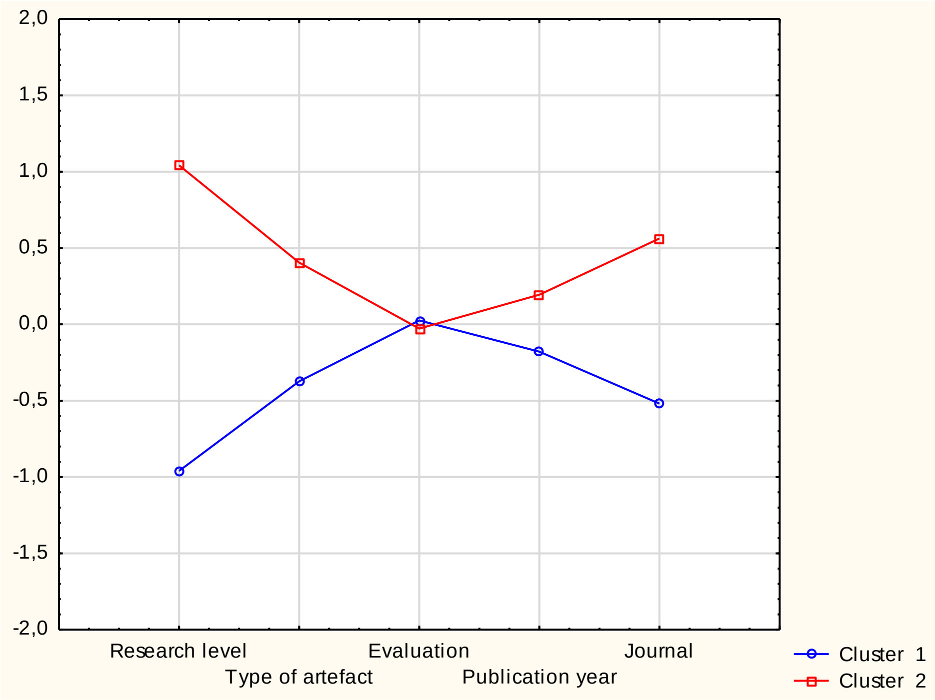


Figure 7- K-means clustering



Cluster 1 is composed of studies that aim to solve empirical problems and are not concerned with understanding how the results were obtained or relating them to previous theories and studies. When this relationship occurs, it is usually punctual and is not intended to compare differences and similarities but only to justify the results obtained. Therefore, the main characteristic of these studies is that all of them were classified in the second level of development of Holmström, Ketokivi and Hameri (2009)'s model.

These studies were published in journals with the same focus and notably aimed at practitioners (e.g., Journal of Construction Engineering and Management and International Journal of Quality and Reliability Management). Furthermore, the studies are less concerned with methodological formalism in the conduct and writing of the study, with the description of the empirical situation and the results obtained being at the heart of the paper.

Cluster 2 is composed of studies aimed mainly at academics. These research are published in a more scientific-focused journal (e.g., Journal of Operations Management and International Journal of Production Economics). These studies present a greater detail of the method used and a denser literature review, which is the basis for further comparting with the empirical results of the artefact, performing the third phase of Holmström, Ketokivi and Hameri (2009)'s model. At this stage, a fundamental difference from the previous type is that the aim is usually to understand why the results were generated, in which contexts the proposed artefact is useful, and which contextual variables can limit it. It is only with this development that design propositions can be elaborated; for this reason, they are relevant artefacts for this category of studies. The final figure of the article by Kaipia *et al.* (2017) is an example of this degree of development, building propositions that relate the contextual variables, the result obtained and why it was generated. The main characteristics of each cluster are presented in Table 9.

Table 9 – The 2 categories of DSR in OM

Variable	**(1) Focused on empirical contribution**	**(2) Focused on theoretical and empirical contribution**
Research development level	The study is focused on proposing and evaluating the artefact (Phases 1 and 2 of Holmström, Ketokivi and Hameri (2009)'s model), but not on understanding how the results were generated.	A significant portion of the study is dedicated to Phase 3 of Holmström, Ketokivi and Hameri (2009)'s model, discussion how the results were generated and in what contexts it is a solution to the problem evaluated.
Type of Artefact	Model is the most relevant (68% of studies). No study uses design propositions.	Although models are the most used artefact (66%), design proposition are also relevant (23%)
Main Journals	Business Process Management Journal and Computers in Industry	Journal of Operations Management
Countries	The Netherlands, Brazil, Canada and Switzerland. Germany is divided among the two levels.	Denmark, The UK and Finland
Focal audience	Practioners	Academics
Number of studies identified in the SRL	51	47
Examples of studies identified in the SLR	Teixeira *et al.* (2019), Oppong-Tawiah *et al.* (2020) and Santos, Pereira and Vasconcelos (2020)	Johnson, Burgess and Sethi (2019), Hoffmann, Ahlemann and Reining (2020) and Öhman *et al.* (2020)

2.4 Discussion

Based on the findings of this study, it is possible to state that DSR is in developing stage and gaining importance as a research approach in the OM context, but still in a limited niche of authors, countries and journals. Therefore, this approach is still off the radar of the main public which may explain the contradiction between the potential contribution of DSR for the OM field and the reduced number of studies. Therefore, discussing how this approach could be more known and used for practitioners and academics is essential.

First, there are limited reference materials for DSR compared to more traditional qualitative methods, being Dresch, Lacerda and Antunes Júnior (2014) one of the the main didactic reference on DSR. See, for example, that two of the DSR research variables of this study were proposed based on this book. Although many scientific studies have presented models and good research practices, , they do not provide in a single place and in an easy way the possible ways to conduct a design science study. Therefore, the existence of more reference didactic materials on DSR can reduce the barrier practioners and academics must overcome to conduct DSR studies.

Second, up to now, DSR has been discussed as a single type with models that are presented as suitable to all studies in the OM field (e.g., MANSON, 2006; PEFFERS *et al.*, 2007; HOLMSTRÖM; KETOKIVI; HAMERI, 2009). These models are too complex for practioners who just want to solve their day-to-day problems in an empirical context. From the other hand, they are also be to simply to provide relevant theoretical contributions to academics publishing state-of-art studies in the top journals. Therefore, we strongly argued that there is no single research steps list suitable to all DSR studies, but there must be different steps based on the type of the DSR study. Models specific to each type of DSR can significantly help practitioners and academics to achieve their DST studies objectives.

Regarding DSR development in the OM, it is also interesting to discuss if there will be room for both types to coexist in the future. Due to the characteristics of the two types in the last 10 years, we believe that in the next decade (2023-2032), there will be a much larger number of articles from the second type compared to the first, giving the evolution of the last years. However, we do not believe that the first type will cease to exist, since this approach is effective in reaching a target audience (practioners) who are not interested in the theoretical contributions and the methodological formalism (for which a second type study may be to complex to be understood), but rather in understanding how the artefact has been implemented, the generated results and whether it can be useful or not in practice. Therefore, we project an increase in the proposition of studies of the second type, but still with a relevant number of studies of the first type.

2.5 Conclusion

The contributions of this study reside in three central pillars. In the first one, this study provided a state-of-art map of DSR in the OM field, detailing characteristics and main trends that authors can evaluate to include in their future research to analyse problems from different angles and maybe find new insights. Up to now, authors would have to read and analyse many studies to reach this point.

In the second one, this study proposed the existence of two different types of DSR in the OM field (one focused on practitioners and another on academics). Therefore, there is no DSR model adequate to all DSR studies. Specific models for each type of DSR can helps researchers to easily achieve their studies objectives.

In the third one, this study identified two barriers DSR need to overcome to increase the number of DSR studies in the OM field (lack of didactic materials and of specific materials to each type of DSR). Overcoming this barriers, we expected DSR can bring a large number of new insights to the OM field, in agreement with several previous authors who emphasize the relevance of this approach.

Based on these pillars, we proposed some possible directions for disseminating DSR in the OM field (Table 10).

Table 10 – Research Agenda

Potential research directions	**Motivation**
Publication of didactic materials (books, courses) showing the entire DSR process	There is a lack of didactic materials so that researchers need to learn design science by reading scientific papers. Those materials may also include examples of use of different artefacts and evaluation ways in the OM field
Proposal of specific models and research practices to conduct each type of DSR	Current models are too generic. Specific models can help researchers to easily achieve their study objectives
Proposal of a model to conduct DSR that detailed how to project an artefact (and its mechanism) and how to explain why it works	Current models do not explain this central process of the second type of DSR in detailed. A model addressing this point can help structuring studies of this cluster
Use of not traditional combinations of artefacts (different from models) and evaluation ways (different from observational) in the OM field	Different artefacts and evaluation ways, even if combined with traditional ones, can bring new insights to traditional OM themes
Identification of research barrier to the DSR dissemination in OM (additional to the two proposed in this study)	The identification of additional barriers can help to fast disseminate DSR to a broader OM audience

This study also has its limitations. First, our study only evaluated papers written in English, therefore DSR studies published in other languages were not included in our results and could be evaluated by future studies. Second, we categorized the OM field as two fields of the Academic Journal Guide (Operations and Technology Management and General Management, Ethics, Gender and Social Responsibility). Studies that were not classified in these fields, even though they may be part of the OM field, were not included in the results of the SRL. Therefore, future studies can use different criteria to evaluate the OM field and compare the results obtained with the conclusions of this study.

3 DSR AND CIMO LOGIC COMBINATION: INSIGHTS ON HOW TO CONDUCT DIFFERENT TYPES OF DSR

In the previous chapter, we identified that specific reference models to conduct each type of DSR as well as a model that detailed how to project an artefact are two relevant research directions to the evolution of DSR approach in the OM field. In this chapter we follow both of these directions proposing a new reference model that combines DSR with CIMO Logic from the very beginning of the study. This innovative combination is the main change in the proposed model compared to previous ones.

3.1 Introduction

Design Science Research (DSR) is a qualitative research approach that aims to contribute to both practice and theory, by solving an empirical problem and refining theory with the insights provided (HOLMSTRÖM; KETOKIVI; HAMERI, 2009). In the centerpiece of DSR is the artefact, which is the solution to the empirical problem researchers want to solve (AIER; FISCHER, 2011; VAISHNAVI; KUECHLER, 2009). Therefore, knowing how to design artefacts focused on a generating a given outcome is an essential ability to academic and practitioners in the DSR context.

Theoretical studies have presented some clues on how to design an artefact (e.g., BUNGE, 2004; HUFF; TRANFIELD; VAN AKEN, 2006). DSR literature, however, did not provide a reference model to design artefacts. Many reference models to conduct DSR studies have been proposed over the years (e.g., VAN AKEN, 2004; COLE *et al.*, 2005; MANSON, 2006; PEFFERS *et al.*, 2007; HOLMSTRÖM; KETOKIVI; HAMERI, 2009; ALTURKI *et al.*, 2011), but none of these models specifically discuss how to design an artefact (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). A reference model focused on this process is a valuable addition to DSR methodology to conduct faster and cheaper studies.

Analysing DSR studies and its combination with CIMO Logic (Context, Intervention, Mechanism and Outcomes) proposed by Denyer, Tranfield and van Aken (2008), we identified that they have been used in a sequential way, that is, CIMO Logic is applied to understand how the results of the implementation of an artefact were generated, after the conduction of the DSR study (e.g., KAIPIA *et al.*, 2017; AKKERMANS *et al.*, 2019; KUNZ; WASSENHOVE, 2019; JOHNSON, BURGESS; SETHI, 2020). However, we believe that CIMO Logic can further help the conduction of a DSR study since the beginning, helping in the design of artefact.

Therefore, this study asks:

RQ1) How can DSR and CIMO Logic be combined in a reference model focused on the design and refinement of artefacts?

Furthermore, as concluded in Chapter 2, DSR studies in the OM field can be classified into two different types: focused only on the empirical contribution or also in the theoretical contribution. We understand that a reference model can bring benefits to both types (e.g., fast and cheaper costs of conducting researches), but a single sequence of steps is not suitable for both types as the have different purposes. Therefore, this study also asks:

RQ2) How can the proposed reference model be adaptable to both types of DSR in the OM field?

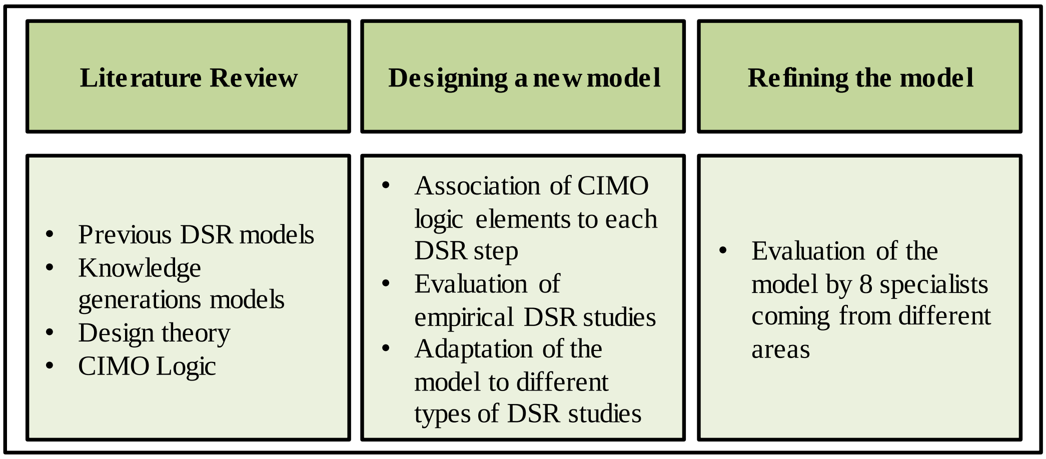
Aiming to answer this question, this study first conducted a literature review to identify elements that will be further included in the proposed model. The review's main focus is on previous reference models to conduct DSR studies, knowledge generation modes, designing artefacts theory and CIMO Logic. Having review these topics, the authors proposed an initial reference model which was evaluated by a panel of experts. The final model includes suggestions and adaptations proposed by the experts. Finally, an in-depth discussion of the model is conducted, highlighting why we understand that the proposed model is more suitable than the previous ones in the design and refinement of artefacts and in the adaptation to the conduction of different types of DSR studies.

This study is organized as follows. Section 3.2 presents the main research methods used in this study. Section 3.3 highlights the main points of literature that will contribute latter to the proposal of the reference model. Section 3.4 presents the reference model after the inclusion of the suggestions of the experts. Section 3.5 discusses why this model is suitable to design artefacts and why it is abatable to different types of DSR studies. Finally, Section 3.6 presents the conclusions.

3.2 Research Method

This research was developed following a sequence of three main steps. First, a multi topic literature review was conducted to identify the building blocks of the proposed model (Figure 8). Second, the model was in fact designed by the authors in a sequence of three joint construction sessions. Third, the model was refined by eight specialists coming from university, manufacturing and consultancy. Each of these steps will be detailed in the following paragraphs.

Figure 8- Research method overview



In the literature review, we evaluated the main previous reference models to conduct DSR studies. This evaluation was mainly based on Dresch, Lacerda and Antunes Júnior (2014)' review of the main reference models proposed over the years. Furthermore, to identify new elements to be included in the new model, we conducted literature reviews about the topics associated with design of artefacts, especially knowledge generation modes and design theory. As this study raises the hypothesis that a potential way to structure the design and refinement of artefacts is the integration of DSR and CIMO Logic since the beginning of the research, a short review of CIMO Logic was also conducted.

Having raised a significant theoretical background about how to conduct DSR studies and to propose artefacts, the authors held three joint construction sessions to propose the new reference model. In the first session, the authors selected the models of Manson (2006) and Holmström, Ketokivi and Hameri (2009) as initial bases for the proposal of the new model. These models were chosen because of their high degree of use and broad scope. From these model, the authors evaluated how CIMO Logic could be included since the beginning of DSR the study, associating one or more elements of CIMO Logic to each DSR step (Table 11).

Table 11 – DSR and CIMO Logic combined model

Research Phases according to Holmström, Ketokivi and Hameri (2009)	Research Steps according to Manson (2006)	CIMO Logic steps
(1) Solution Incubation	(1). Description of the problem	Identification of the desired outcome (O) and the context (C)
	(2). Suggestion of the artefact	Planning the mechanism that will be included in the artefact (M) and planning the intervention (I)
(2) Solution Refinement	(3). Development of the artefact	Refinement of the mechanisms (M)
	(4). Evaluation of the artefact	Implementation of the intervention (I) and evaluation of the outcome (O)
(3) Explanation	(5). Understandings of the results	Evaluation of the mechanism (M) and possible construction of design propositions

Source: Adapted Denyer, Tranfield and van Aken (2008)

In the second section, evaluating empirical studies in the same class of problems, authors identified that a common practice is adapting previous artefacts to solve new problems. For example, the collaborative S&OP process for new products proposed by Kaipia *et al.* (2017) , although not explicitly mentioned in the paper, elements from previous artefacts, such as Kaipia and Holmström (2007) (suitable planning mechanisms based on demand and supply conditions) and Goh and Eldridge (2015) (process to plan the demand of new products). This strategy can be a shortcut to designing artefacts. The authors also discussed how researchers could refine and adapt artefacts to solve the specific problems they face. The knowledge about design theory and the kernel theories involved in the class of problems studied were identified as essential for researchers to be able to design and artefact in a structured process.

In the third section, authors evaluated the two different types of DSR in the OM field and identified that the actual structure of CIMO Logic is not suitable to studies focused only on the empirical contribution. This occurs because this type of studies highlight the Intervention (what was done) and the Outcomes (results obtained), but do not explain how the results were generated (Mechanisms) and in what Conditions (Contextual Factors). Based on the knowledge generate in this discussion, the authors propose an adaptative model, suitable to both types of DSR, in which phases are conducted or not based on the type of DSR that is been developed.

The initial model designed by the authors were submitted to eight specialists described in Table 12. Experts were carefully selected, coming from three different areas: university (professor), manufacturing (managers) and consultancy (consultants) (SILVEIRA et al., 2017).

Each expert conducted a qualitative evaluation of the model individually and provided a set of suggestions to the authors to clarify and refine the initial proposal. In this paper, the refined version is presented in Section 3.4 and discussed in Section 3.5.

Table 12 – Expert's characteristics

Expert	Brief Description
Expert 1	Expert 1 is a university professor who has been researching about DSR in OM for the last 20 years and has published theoretical and empirical studies about this approach
Expert 2	Expert 2 is a university professor who has been researching in OM field for more than 25 years, proposing and evaluating solutions for different problems in areas such as logistics, production planning and operations research
Expert 3	Expert 3 is a university professor and a consultant who had worked in leadership position in three multinational companies. He had proposed and implement artefacts in many OM areas, such as finance, human resources and strategic planning
Expert 4	Expert 4 is a consultant with more than 30 years of experience in implementing OM solutions to different industries regarding warehouse control, production control systems, organizational plans, among others
Expert 5	Expert 5 is a consultant with more than 20 years of experience in implementing OM solutions especially regarding quality control and auditing procedures
Expert 6	Expert 7 is a production planning coordinator in a multinational company with more than 10 years of experience and has implemented many artefacts in areas such as production planning, logistics and sustainability
Expert 7	Expert 8 is a production planning coordinator in a multinational company with more than 25 years of experience and has implemented many artefacts in areas such as production planning, logistics, finance, quality and human resources
Expert 8	Expert 8 is a production planner in a multinational with 4 years of experience. He had led the process of revising the registration and planning process of maintenance, repair and operations materials with more than 25 years of experience and has implemented many artefacts in areas such as production planning, logistics, finance, quality and human resources

3.3 The building blocks of the proposed model: the results of the multi topic literature review

3.3.1 Previous reference models to conduct DSR studies

Many reference models have been proposed over the years to conduct DSR studies. In this review, the most relevant ones will be highlighted. Bunge (1980) proposed a sequence of steps to solve real problems in accordance to the design science principles. His simple model basically involves understanding the problem, trying to solve the problem until a suitable solution is found. Therefore, this solution is tested to evaluate if it really solves the problem studied.

Cole *et al.* (2005) proposed a model with initial steps similar to Bunge (1980), that is:

problem identification, intervention and evaluation. However, he added a fourth step called reflection and learning to ensure the study generates theoretical and practical knowledge. This step was a fundamental addition, as DSR is not a consultant approach that aims to only solve an empirical problem, but also to understand how the problem was solved.

Manson (2006)'model proposed a sequence of two abductive steps to propose an artefact (description of the problem and suggestion of the artefact) followed by two deductive steps to refine and evaluate the artefact (development and evaluation). The segregation of the construction of the artefact into two steps (compared to Bunge (1980) and Cole *et al.* (2005)) is of great importance, because researchers were direct to seek previous solutions and theories that could help to build an initial proposal of the artefact to be further refined. Once more, knowledge generation is the focus of the last steps, called understanding of the results.

The four phases' model proposed by Holmström, Ketokivi and Hameri (2009) is the most extensive one placing a significant emphasis on understand and explaining the results generated by the artefact. In the first two phases (solution incubation and solution refinement), the artefact to solve the empirical problem is proposed, refined and evaluated in the empirical situation. Therefore, these two phases comprehend all the steps of Bunge (1980) and, except for the last one, also all the steps of Cole *et al.* (2005) and Manson (2006) (Table 13).

Table 13 – DSR reference model comparison

Bunge (1980)	**Cole *et al.* (2005)**	**Manson (2006)**	**Holmström, Ketokivi and Hameri (2009)**
Understanding the problem	Problem identification	Description of the problem	Solution incubation
		Suggestion of the artefact	
Trying to solve the problem	Intervention	Development of the artefact	Solution refinement
Evaluation of the solution	Evaluation	Evaluation of the artefact	
	Reflection and learning	Understanding of the results	Explanation I – Substantive Theory
			Explanation II – Formal Theory

The third step involves explaining the results obtained for that particular condition of the study (therefore, researchers need to clear to identify all the relevant contextual variables involved.). Previous models (COLE *et al.*, 2005; MANSON, 2006) have discussed this step, but not without a significant emphasis. Furthermore, Holmström, Ketokivi and Hameri (2009) include a further step of explanation which involves to generalize the proposed artefact to other situations (that is, the artefact does not only generate the desired solution in some particular context but in a range of contexts). To do so, it would be necessary to evaluate the artefact in different conditions and to profoundly understand why it generates the desire result. In this process, theoretical knowledge would be generated, refining actual theories.

3.3.2 Knowledge generation modes

According to Gibbons *et al.* (1994), there are two modes of knowledge production. Mode 1 is the traditional knowledge generation, in which a problem is solved within a specific area (VEIT *et al.*, 2017), such as supply chain management, performance measurement, e-commerce, among others identified by Sidorova and Isik (2010) in the OM field context. However, the separation of knowledge into specific areas (silos) does not occur in practice. Consequently, studies conducted in Mode 1 usually have a low empirical relevance (GIBBONS *et al*., 1994; STARKEY; MADAN, 2001; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016).

Mode 2 aims to solve a practical problem holistically, breaking the silos of Mode 1 and using interdisciplinary and integrated knowledge (GIBBONS *et al.*, 1994; BURGOYNE; JAMES, 2006; VEIT *et al.*, 2017). DSR is one of the ways of generating knowledge in Mode 2, as this approach design an artefact (solution) that transcends that specific situation (LANAMÄKI; STENDAL; THAPA, 2011; OLIVA, 2019). The knowledge generated from the artefact can be classified into problem classes, which can be understood as generalizations of the empirical specific problem solved by the artefact (VAN AKEN, 2004; DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; VEIT *et al.*, 2017).

According to Huff, Tranfield and van Aken (2006), knowledge generation in Mode 2 process involving combing kernel theories (traditional theories of natural and social sciences – Mode 1) (GIBBONS *et al*., 1994; DRESCH; LACERDA; CAUCHICK-MIGUEL, 2019) with the knowledge of how to design (design theory) (VAN AKEN, 2004; AIER; FISCHER, 2011; BASKERVILLE; KAUL; STOREY, 2015; HATCHUEL *et al.*, 2018). The knowledge of how to design corresponds to the *phronesis* knowledge proposed by Aristoteles, which is the application of theory to solve a practical problem (HOOKER, 2004).

There is, however, no general design theory but specific knowledge about each class of problems that need to be adapted to other problems (VAN AKEN; CHANDRASEKARAN;

HALMAN, 2016). This occurs because DSR studies usually contribute to design theory by proposing a better solution to an existing problem than the current one, extending a solution to other classes of problems and solving relevant practical problems (OFFERMAN *et al.*, 2011). However, researchers rarely present in their studies the lessons learned through the study on how to design an artefact. Therefore, no general design theory has been consolidated.

3.3.3 Designing artefacts theory

Bunge (2004) has provided some additional important clues about design theory, leading to an in-depth discussion of how artefacts work, providing insights into how to design them. Practically, the artefact is a solution to a given empirical problem. However, conceptually, it can also be seen as a set of interconnected elements that communicate through mechanisms. For example, the cardiovascular system is an artefact composed of elements (e.g., heart, arteries, veins) to transport blood around the human body. This objective is accomplished only when the mechanism (pumping of blood through the heart) is activated. Therefore, designing an artefact involves understanding which mechanisms to add to generate the desired outcome (solution to the empirical problem) (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014).

This task, however, is not simple. First, the same task can be performed by different mechanisms (e.g., documents can be reproduced by printing presses, mimeographs or photocopiers) (BUNGE, 2004). Second, it can be necessary to combine mechanisms to generate the desired result in complex systems (e.g., aiming to increase productivity of a factory, it can be necessary to combine the division of labor, a variable rewards system, among other mechanisms).

Third, in general, mechanisms need to be inferred, as they are totally or largely imperceptible. Therefore, it is usual in science that a phenomenon was observed decades or centuries before it was explained (identification of its mechanisms). For example, biological evolution had been suspected long before Charles Darwin established it, but he identified the mechanisms involved (inheritance with modification and natural selection).

Fourth, mechanisms must be associated with a scientific law (DRESCH, 2018). Otherwise, there is something similar to magic, without explaining how and why the result was generated. This process is more straightforward in natural sciences because there are theories and equations more powerful and reasonably than in social science, in which few equations can be enumerated to predict a certain behavior (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014). It is important to highlight that a scientific law can explain different phenomena. The normal probability distribution, for example, is used in different branches of science, from statistics to physiology (BUNGE, 2004).

Creativity is a key element (BUNGE, 2004) and the assessment of the empirical environment is relevant (BASKERVILLE; KAUL; STOREY, 2015), but literature still views the design artefact design as an unstructured trial and error iterative process (DRESCH, 2018), in which researchers propose an artefact, implement it, observe the results, refine it, implement it again and observed the results, until the artefact generates the desired result.

It is crucial to understand how design theory can be represented to propose a more structured way of designing artefacts. Dresch (2018) presented four ways. First, constructive heuristics focus on the rules for constructing a given artefact. Second, contingency heuristics focus on contextual factors (environment) that interfere with the functioning of the artefact. Third, interventional heuristics focus on implementing the artefact itself and evaluating its efficiency in solving the focus problem. Finally, design propositions result from the refinement of the three previous heuristics and can be generated using CIMO Logic, which will be discussed in the next section (VAN AKEN; CHANDRASEKARAN; HALMAN, 2016).

3.3.4 CIMO Logic

The CIMO logic was proposed by Denyer, Tranfield and van Aken (2008), aiming to bring a more formal way to evaluate DSR results and the potential of generalization of this artefact to similar contexts. In particular, the authors sought to propose a pragmatic logic to facilitate the formulation of design propositions (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; VAN AKEN; CHANDRASEKARAN; HALMAN, 2016).

This logic is composed of 4 elements (Context, Intervention, Mechanisms and Outcomes) and aims to synthesize an action-outcomes relationship, which occurs through mechanisms and is influenced by a set of contextual factors (DENYER; TRANFIELD; VAN AKEN, 2008; HOLLOWAY *et al.*, 2016). Those elements and their connection in CIMO Logic are exemplified in Table 14.

Table 14 – CIMO Logic

Element	Description	Example
Context	Factors presented in the environment that can influence the outcomes.	If the response time to maintenance problems in production is high
Intervention	Implementation of the artefact.	the implementation of an alert system
Mechanisms	Processes invoked by the intervention and, in the presence of certain contextual factors, generated the outcomes.	can direct managers attention
Outcomes	Results generated by the artefact.	and help to increase the availability of equipments in the shop floor

Source: Adapted from Denyer, Tranfield and van Aken (2008)

Understanding in which contexts the artefact generates the desired outcomes (Context) and why the results were generated, that is, which processes are triggered by the implementation of the artefact (Mechanisms) are essential steps to an empirical study generate theoretical knowledge and to be generalized to other contexts (BASKERVILLE; KAUL; STOREY, 2015; JONSSON; HOLMSTRÖM, 2016; HATCHUEL *et al.*, 2018).

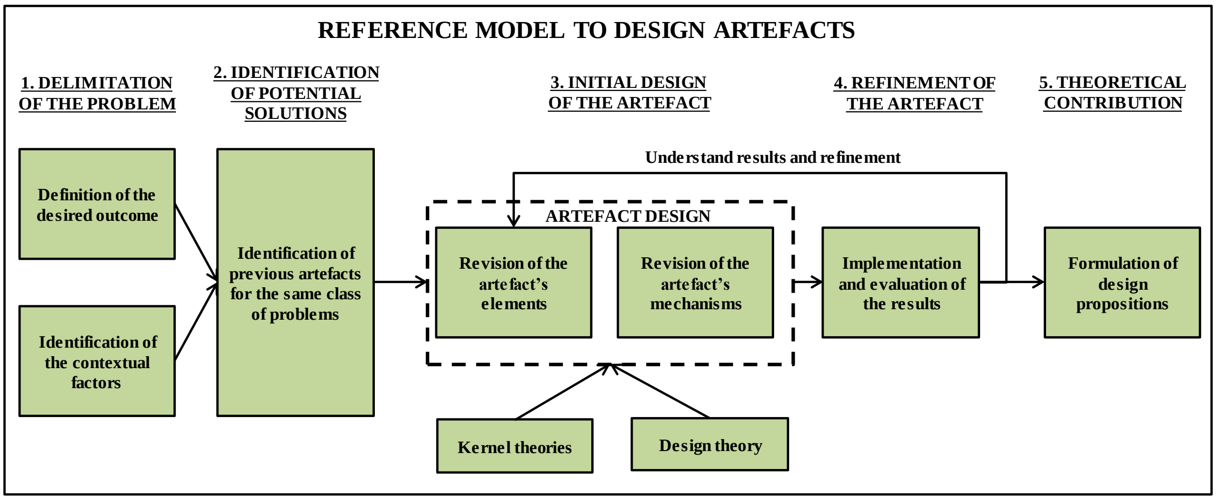
This knowledge can lead to the proposal of a mid-range theory, that is, between a specific empirical case and a universal behavior (VAN AKEN; CHANDRASEKARAN; HALMAN, 2016). This theory is limited to environments with similar characteristics to those in which the artefact has already proven that it can generate the desired results. Therefore, studies must detail all the contextual variables relevant to the artefact so that other researchers can reproduce the artefact.

It is also possible that researchers evaluate the artefact in environments with different characteristics to evaluate if the artefact also generated the desired result with another set of contextual factors. If all the contextual factors could be removed, the artefact would be a universal solution to generate the desired result, and, therefore, the mid-range theory would become a universal theory (HOLMSTRÖM; KETOKIVI; HAMERI, 2009).

3.4 The proposed model

The first step of the model is the delimitation of the problem. Although this step at first can been as similar to the initial steps of the models presented in Table 13 (e.g., understanding the problem, problem identification, description of the problem), the main difference is the combination of CIMO Logic with DSR since the beginning of the research. Therefore, in this phase, researchers need first to clearly define the desired outcome of the intervention (Figure 9). This definition will direct the entire project of the artefact, seeking to solve the identified empirical problem. Therefore, the desired outcomes must be clear and as objective as possible. Ambiguous or challenging to understand definitions can lead to proposals for inadequate artefacts to solve the problem observed. The artefact will be evaluated in a further step if it generated the desired outcome and, if not, it will be refined.

Figure 9 - Reference model to design artefacts



Second, researchers need to identify all the relevant contextual factors that can affect the desired results as the artefact is a solution for a specific context (which can later be generalized to other contexts). If a contextual factor is not identified in this step, the proposed artefact may not generate the expected outcome, so refining it will be necessary. As our model aims to conduct DSR studies in faster and cheaper modes, this refinements should be avoided.

The second phase is similar to the suggestion of the artefact (MANSON, 2006) and the solution incubation (HOLMSTRÖM; KETOKIVI; HAMERI, 2009). However, given the difficulties of generation Mode 2 knowledge presented in Section 3.3, we proposed an alternative from designing the artefact since the beginning. Based on the evaluation of empirical DSR studies, the objective of this phase is to find a similar artefact for the outcome and contextual factors defined in phase 1. These solutions will be the basis for the proposal of the new artefact, one more time, aiming to conduct faster and cheaper studies.

The third phase involves the refinement of the similar artefacts to propose a potential solution for the focal problem. The previous artefacts are adherent to the problem solved, the lower the expected refinement in its design and, therefore, the easier this step. To refine artefacts, researchers need to understand the kernel theories related to the subjects involved and the design theory (how to design). This knowledge will help researchers identify which elements and mechanisms to revise, include and exclude to reach the expected outcome in the context of the empirical situation studied.

Once a first proposal of the artefact is concluded, the intervention will assess whether the artefact actually generates the desired result in the context for which it was designed. The literature proposed many different options to evaluate an artefact, such as empirical implementation, focus groups, controlled experiments, and computer simulation. If the desired outcomes were not generated, researchers should redesign the artefact, revising its elements and mechanisms (phase 4). One more time, knowledge of kernel theories and design theory will be essential in this process to identify potential solutions.

If a research stops at this phase, the study will have generated a practical contribution (solution of the empirical problem), but would not have generated an theoretical contribution (for the class of problems and, more broadly, for the design theory). Therefore, the final step we propose is the construction of design propositions, summarizing the relationships between the elements of CIMO Logic that were drawn along the previous steps. This step is similar to the understanding of results (MANSON, 2006) and Explanation I – Substantive Theory (HOLMSTRÖM; KETOKIVI; HAMERI, 2009). However, contrary to previous models, in our phase, researchers will only summarize the results of previous phases, as the contextual factors, objective, intervention and mechanisms have been identified, planned and refined through the whole DSR study.

In the next two subsection, the model will be applied into two illustrative cases of different DSR types in the OM field.

3.4.1 Using the model for DSR studies focused on empirical and theoretical contributions

In this type of DSR studies, researchers aiming to contribute to practice and theory, by solving an empirical problem and understanding how the problem was solved. Therefore, all the phases of the proposed model applied to this type of DSR. For example, if a student is facing problems in passing in the school year (desired outcome), he first needs to understand the contextual factors. For example, the final grade is composed equally between a continuum grade (based on activities during the whole year) and the final exam grade. There is no substitutive or recovery exam. There are five exams that will be applied in five consecutive days in a predefined order. The student has more difficulties on the subjects of Monday and Friday; these are also the subjects he needs higher grades on the final exam to pass the school year.

Looking for similar solutions, let's suppose there is no artefact proposed for a student passing a school year, but there is one for a worker to prioritize a list of activities based on their impact and effort. This will be the initial artefact, as the student problem involves prioritizing how much to study for each subject, based on his difficulties and the grade he needs to obtain in each exam. Adapting the previous artefact, the impact vs effort prioritizing matrix becomes a matrix based on the grade needed vs the difficulties of the student. Therefore, he now has a number of hours different to study each subject.

The student implements the solutions and evaluates the results. Note that passing or not the school year, the student can refine the artefact to study more efficiently for the next final exams. Based on the results generated, the student can propose a contribution to the design theory by affirming that based on understanding his own difficulties in each subject and the grade he should obtain in each final exam (contextual factors), a student should define his study hours by a prioritizing matrix (mechanism) to pass the school year (desired outcome).

3.4.2 Using the model for DSR studies focused only on empirical contributions

In this type of DSR studies, researchers aiming to contribute only to practice, by solving an empirical problem. Understanding why the problem was solved is not an objective of this type of DSR. Therefore, it is not necessary to conduct phase 5. Regarding the others phases (1 to 4), not conducting one (partially or fully) will lead to more difficulties in designing an artefact and, consequently, more difficult and expensive research. For example, suppose the contextual factors are not identified in the first phase. In that case, researchers will not be able to identify adherent solutions to the empirical situation or they will have more difficulty to refine it until reach a suitable artefact.

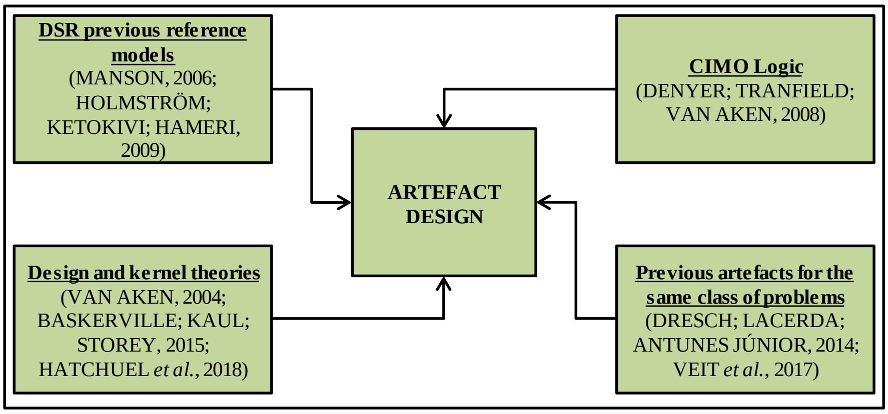
Therefore, we understand that our model should be applied from phase 1-4 fully for DSR type 1 and, as phase 5 is just the consolidation of the CIMO Logic applied in the previous phases, we recommend that also this phase is conducted to increase the study contribution to also comprehend the theory.

3.5 Discussion

The main objective of the model developed in this study was to propose a structured method to design artefacts, as previous models for conducting DSR studies did not address this step in details (e.g., VAN AKEN, 2004; COLE *et al.*, 2005; PEFFERS *et al.*, 2007; ALTURKI *et al.*, 2011). In the proposed model, this step occupies the central position, corresponding to the central role of the artefact in the DSR. The other steps were designed as means to enable and facilitate the project of the artefact.

Conceptually, the proposed model is based on four pillars (Figure 10). The first of these pillars are previous reference models proposed in literature to conduct DSR studies. Although these models do not focus on artefact design, they propose a robust sequence of steps to conduct DSR studies that has been used by different empirical studies. Therefore, the model design started based on previous models, especially Holmström *et al.* (2009) and Manson (2006).

Figure 10 – Conceptual bases for the model proposal



The second pillar is the combination of kernel theories and design theory to propose artefacts. Despite the theoretical references on the proposition of artefacts through this combination (e.g., VAN AKEN, 2004; BASKERVILLE; KAUL; STOREY, 2015; HATCHUEL *et al.*, 2018), previous DSR models had not yet explicitly included these two elements. The inclusion of these elements in our model created a link between the knowledge of traditional theories and the design of artefacts, a relationship that Gibbons *et al.* (1994) present as essential to the generation of knowledge in Mode 2 but that previous DSR models did not make it explicit.

Furthermore, the model proposes another looping, by inserting the formulation of design propositions as a last step, which refine the design theory, which is the basis for the design of new artefacts and will generate new design propositions. Therefore, the model can generate the *phronesis* knowledge proposed by Aristoteles (judgment of how to combine theory and practice to solve an empirical problem) (HOOKER, 2004) and can help to develop design theory and DSR as a research approach (VAN AKEN; CHANDRASEKARAN; HALMAN, 2016).

The third pillar is, in our view, the most innovative in the proposed model compared to previous ones. The use of CIMO Logic (DENYER; TRANFIELD; VAN AKEN, 2008) since the beginning of the DSR study directed the entire model to the project of the artefact, identifying at the outset the desired outcome with the artefact and the most relevant contextual factors that may affect that result. Previous model have used CIMO Logic only to understand the results generated by the artefact implementation (e.g., KAIPIA *et al.*, 2017; BRUSSET; BERTRAND, 2018). Previous literature has also highlighted the importance of assessing the empirical environment to propose artefacts (e.g., BASKERVILLE; KAUL; STOREY, 2015), but this process typically occurs in an unstructured way in the beginning of the research. In the proposed model, the application of CIMO Logic since the beginning of the study formalizes a structure to understand the environment.

Finally, the fourth pillar is a shortcut to ease the artefact design process, reducing the number of interactions between design, testing, and evaluation. By identifying artefacts similar to the one they want to propose, that is, from the same class of problems, researchers can use already-tested solutions and adapt them to specific contextual factors and objectives (DRESCH; LACERDA; ANTUNES JÚNIOR, 2014; VEIT *et al.*, 2017). This point is relevant given that the design of an artefact and its mechanisms is not a simple process, as discussed by Bunge (2004).

Therefore, using artefacts already proposed as a reference base, the artefact design starts at a more advanced stage of development. However, although it simplifies the process, this action does not eliminate the need to infer and understand the mechanisms involved. After all, to adapt the artefact to desired outcomes and contextual factors different from the ones it was originally designed for, it is necessary to decide almost elements and mechanisms to remove and which to include in the artefact.

3.6 Conclusion

3.6.1 Main differences from previous models to the proposed one

In the brief presentation of previous models proposed to conduct DSR in Section 3.3.1, we highlighted how each of the selected models added additional elements to the previous ones. Cole *et al*. (2005) added the generation of theoretical contribution to Bunge (1980). Manson (2006) introduced the construction of the artefact as a formal step in the proposal of Cole *et al.* (2005). Holmström, Ketokivi and Hameri (2009) divided the understanding of the results into substantive and formal theory, giving a much higher importance for theoretical knowledge generation. In this context, it is also important to understand the additions that the proposed model makes. Two of them stand out.

First, the proposed a sequence of phases which aiming, since the beginning, to design and refine artefacts. Shortcuts were included to facilitate the process, such as the evaluation of previous artefacts with similar objectives and contexts, aiming to conduct faster and cheaper DSR studies.

Second, the proposed model was planned to be suitable to both types of DSR in the OM field. However, understanding the importance of evaluating the elements of the CIMO Logic since the beginning of the DSR study to design faster and cheaper artefacts, we argued that produce theoretical contributions will an easy task for researchers. Therefore, why not to have just one type of DSR in the OM field, aiming to contribute to practice and theory?

3.6.2 Contributions, limitations and future studies

The proposed model contributes to theory by solidifying DSR as a research approach, combining DSR with CIMO Logic from the beginning of the study and transforming existing theoretical knowledge on how to design artefacts into a reference model for conducting empirical research using this approach. To practice, the main practical contribution of this study is the proposal of a model that facilitates the conduction of RSD studies by researchers. This is, in our view, a fundamental addition, to increase the number of DSR studies in the OM field.

The main limitation of this study is that the proposed model was not evaluated in conducting empirical DSR studies. Future studies may carry out this analysis, evaluating the method's adherence to different contexts and objectives. Second, this research focused only on the use of DSR in the OM field. Future studies will be able to evaluate the proposed model for other areas of knowledge, making potential adjustments to adapt it to the specific needs of this area. Finally, future studies can detail other steps of the proposed model, such as the identification of the desired outcome and contextual factors, proposing an association with other methods and techniques that can bring more robustness to these stages of the DSR.

4 SALES AND OPERATIONS PLANNING FOR NEW PRODUCTS: A PARALLEL PROCESS?

In this chapter, we conducted an empirical DSR using the reference model proposed in Chapter 3. In terms of the general thesis, this chapter is fundamental to evaluate the proposed model and exemplified how to conduct DSR studies employing it. Applying all steps of this model, we design, implemented and evaluated an Sales and Operations Planning (S&OP) process for demand fulfillment after introducing new products (New Product Introduction, NPI). A version of this chapter was published in the International Journal of Physical Distribution & Logistics Management in 2021.

4.1 Introduction

To increase competitiveness and the probability of survival, companies must be increasingly flexible, meeting each client's specific needs. Therefore, the timely launch of new products is essential to meet the needs of evolving technological trends and volatile customer preferences (KISS; BARR, 2017). However, the demand forecasting of these products becomes a challenge due to the lack of historical data, especially for those products that are not similar to the ones already existing in the company's portfolio (NAGASHIMA *et al.*, 2015; NOROOZI; WIKNER, 2017). Predicting new product demand is still a problem in practice (IYENGAR; GUPTA, 2013; PEDROSO; SILVA; TATE, 2016), even with the combined use of quantitative and qualitative forecasting methods. This difficulty remains despite the advent of technologies such as online data (FAN; CHE; CHENG, 2017), big data (CHONG *et al.*, 2017), and cloud computing (BOONE *et al.*, 2019).

In this context, some previous research has discussed the introduction of a collaborative process of Sales and Operations Planning (S&OP) for new products, aiming to increase the company's responsiveness to the demand variations (PLANK; HOOKER, 2014; THOMÉ; SOUZA; SCAVARDA DO CARMO, 2014). Goh and Eldridge (2015) evaluate the performance benefits of S&OP implementation and focus on incorporating suppliers' inputs into S&OP to facilitate the new products' introduction (NPI). Kaipia *et al.* (2017) investigate the effects of sharing and using retailer sales information in collaborative S&OP. However, none of the previous papers has described in detail the process implementation. In response, this study started by asking: **How can the S&OP process be designed to support the planning requirements of recently introduced products?**

Aiming to answer this question, we conducted design science research (DSR) in which we proposed an S&OP New Products process and tested this process in a manufacturer of consumer goods. The company had been suffering from high additional costs in the launch of new products due to wrong sales forecast. DSR allows the researchers to test the artefact (S&OP New Products process) in the real environment, solving a practical problem but also developing actionable knowledge, explaining the outcomes achieved.

This paper is organized as follows. In Section 4.2, we briefly revise CIMO (Context, Intervention, Mechanisms and Outcomes) logic. In Section 4.3, we present the design science research steps, which are applied in Section 4.4. In Section 4.5, we discussed the results from the implementation of the artefact and formulated six design propositions. Finally, Section 4.6 presents the conclusions and future research agenda.

4.2 CIMO Logic

Empirical studies are subjected to contextual factors, such as the geographical, demographic, commercial and economic features of the studied organizations; these factors may bring interesting insights for theory and practice (JONSSON; HOLMSTRÖM, 2016; GOH; ELDRIDGE, 2019). Therefore, it is essential to understand in which circumstances the artefact yields the desired outcomes. Additionally, identifying the mechanisms that triggered the outcomes is vital for originating theory (HOLMSTRÖM; KETOKIVI; HAMERI, 2009).

The CIMO logic (i.e., Context, Intervention, Mechanisms and Outcomes) states that if the context contains some defined contextual factors, then some defined interventions should be applied to invoke generative mechanisms and generate the desired outcomes (DENYER; TRANFIELD, VAN AKEN, 2008; KAIPIA *et al.*, 2017; AKKERMANS *et al.*, 2019). Therefore, the generative mechanisms constitute the bridge between the contextual factors and the outcomes and the intervention is the trigger which starts the operation of one or more mechanisms. To clarify the function of the four elements, we will illustrate CIMO logic's application in a made-up situation. In a mango plantation, if air humidity is below 30% (context), the central computer triggers the irrigation system (intervention), which increases soil humidity (mechanism) so that the trees bear fruits (outcome).

In Operations Management, many papers (DENYER; TRANFIELD, VAN AKEN, 2008; JONSSON; HOLMSTRÖM, 2016; AKKERMANS *et al.*, 2019) integrated the CIMO logic into the steps of the DSR, since it aids in the analysis, discussion and generalization of the results. In this research, we also used this combination, as detailed in Section 3.3.2.

According to Thomé *et al.* (2012) and Tuomikangas and Kaipia (2014), an S&OP process should be formalized and strictly scheduled, such as in Oliva and Watson (2011). In contrast, there are few works (KAIPIA; HOLMSTRÖM, 2007, IVERT *et al.*, 2015; KAIPIA *et al.*, 2017) which focus on a contextual perspective, that is, how the process should be designed considering contextual factors to provide a better fit to the environment and to render better outcomes.

In this paper, both the processual/formal perspective and the contextual perspective (KAIPIA *et al.*, 2017) are considered essential for NPI S&OP research, showing how the formal and processual structure of the S&OP design generates the mechanisms that lead to the observed outcomes and also how the contextual factors of NPI are linked to the generative mechanisms.

4.3 Method

4.3.1 Research general features

Design science research aims to solve a problem in a given context, and it is helpful when the objective of a study is to develop an artefact that produces the desired outcomes in a given context (SIMON, 1996; HOLMSTRÖM; KETOKIVI; HAMERI, 2009, VAN AKEN; CHANDRASEKARAN; HALMAN, 2016; KUNZ; WASSENHOVE, 2019). The artefact can be an object (e.g., a robot), a software or app, a reference model (e.g., a framework for writing a paper), a process (such as the case of this paper), among others. Furthermore, design science research also aims to develop general knowledge that can be transferred to other contexts and to develop a new theory (HOLMSTRÖM; KETOKIVI; HAMERI, 2009, VAN AKEN; CHANDRASEKARAN; HALMAN, 2016; KUNZ; WASSENHOVE, 2019).

In this paper, we aim to develop actionable knowledge about reducing additional costs for market fulfilment after introducing new products through the design and evaluation of a specific forum for discussing a new product forecast and fulfilment plan, S&OP New Products. The process was developed and tested in a transnational manufacturer of consumer goods. The research team of this study consists of three people, in a configuration similar to Akkermans *et al.* (2019). The first author, an academic and practitioner, works at the company where the intervention was performed. He was directly involved in the intervention, conducting many of the actions to establish the S&OP New Products forum himself. The second and third authors, academics, collaborated in the artefact proposal, analysed the observed mechanisms, and the theoretical implications of the findings.

4.3.2 Research steps and data collection

This study follows the model proposed in Chapter 3, which is summarized in Table 15. In the first step, we understood the problem in depth by multiple means of data collection to define the scope of the study, the desired outcome and the potential contextual variables involved. First, we conducted seven semi-structured interviews with the key company's managers directly involved with introducing new products, as follows: S&OP, Sales Planning, Marketing, Production Planning, Product Development (2) and Purchasing.

Table 15 – Research methodology framework

Section	Research Step	Main Activities	Data collected	Outputs
4.4.1	Delimitation of the problem	• Definition of the desired outcome • Identification of the contextual factors	• Semi-structured interviews with key company's employees; • Sales performance and additional costs of new products in their first year of sales.	• Desired outcome • Contextual factors
4.4.2	Identification of potential solutions	• Identification of previous artefacts for the same class of problems	• Evaluation of previous artefacts for the same class of problems	• Tentative Design
4.4.3	Initial design of the artefact	• Revision of the artefact's elements • Revision of the artefact's mechanisms • Initial evaluations (pilots)	• Conduction of two pilot projects to adjust the process characteristics based on the results observed.	• Artefact
4.4.4	Refinement of the artefact	• Implementation and evaluation of the results	• Implementation and monitoring of the proposed S&OP process into the 3 projects in the focal company for one year.	• KPIs
4.5	Contribution to design theory	• Formulation of design propositions	• Formulation of design propositions concerning the S&OP New Products process.	• Design Propositions

Second, we analyzed sales data for the first year of sales of items launched in the two years previous to the study regarding two aspects. The first one, sales performance, compares the real sales in the first year of the product introduction and the sales predicted for the first year during the development of the product. The second one, additional costs, compares how much the company spent to produce each unit of the product during the first year and the unitary cost predicted during the product development. Those costs included costs to fulfil incremental sales (such as production costs - overtime, night shifts, production in alternative machines – and logistics costs - dedicated freights, partial deliveries of the sale order) as well as inventory costs associated to holding higher inventory levels due to overestimated sales forecasts (NEGAHBAN; SMITH, 2016).

In the second step, we identified and studied similar artefacts for the same class of problem of this study (especially Goh and Eldridge (2015) and Kaipia *et al.* (2017). In the third step, previously, each researcher listed his/her own ideas; then, we conducted five rounds to propose the initial process without focal organization employees' participation. After those rounds, a process was defined to be followed in the first pilot project in the focal company.

Two pilot projects were conducted in the focal organization, each of them for two months and corresponding to one product introduction in the market, to analyze different ways to configure the S&OP New Products. In this step, we collected data by observing the process and interviewing the members of the process (the same seven managers from step 1). All improvement opportunities observed or suggestions received were explored by the researchers, and most were implemented in at least one of the S&OP NP meetings.

An example of the refinements occurred during this third step is the reduction of KPIs. In the initial proposal, the process had 15 KPIs, which were reduced to 5 during the pilot projects. At the end of the second project, an additional indicator (Actual vs Planned Supply) was included due to a critical supplier's constant delay issue, a possibility not mapped in the initial proposal of the process. As another example, the process team initially included a member of the finance department, which was later removed as the product development function was set responsible for the finance indicator of new products and the finance department itself had little influence on the decisions on S&OP New Products.

After the two pilot projects, a process model was proposed to the company executives, and they agreed to follow this model during the product introduction of the three items with the largest revenues in the following year. The implementation of the S&OP New Products constitutes the intervention of the CIMO logic in this study. The researchers observed all the S&OP New Products’ meetings and analyzed the results of the six KPIs of the process.

Finally, in the fifth step, based on the knowledge gained in this study, we suggested design propositions following the CIMO logic that present how the S&OP process focus on new products should work. We also identified the contextual factors and the generative mechanisms involved.

4.3.3 Research Quality

In a design science project, the research validity is based on the evaluation if, in pre-established conditions, the artefact delivers the expected results (PRIES-HEJE; BASKERVILLE, 2008) and if it is effective to solve real problems (TREMBLAY; HEVNER; BERNDT, 2010). According to the five ways that Hevner, March and Park (2004) suggest to evaluate an artefact, our research is classified in the observational form because the S&OP New Products process was evaluated based on its results in three different new product projects.

Dresch, Lacerda and Antunes Júnior (2014) propose three criteria to evaluate the validity of design science research, as follows:

- Explicitly define the problem, its objectives and the environment involved. In this study, in Section 4.4.1 the company's difficulties in fulfilling the market demand with new products without additional costs are explained and the contextual factors are explicitly listed.
- Clearly, define the way the artefact was tested. Section 4.4.4 describes how the artefact was evaluated by means of the empirical implementation of S&OP New Products into three new products introduced by the focal company. Moreover, details of how data was collected and analysed are presented in Section 4.3.2;
- Evaluate and describe the generative mechanisms involved. Section 4.4.3 describes the generative mechanisms and how they affect the results. Moreover, Section 4.5 states the relationships among the contextual factors, generative mechanisms and results observed in the intervention; these findings are then related to the previous literature

Sections 4.4 and 4.5 were organized according to the research steps shown in Table 15.

4.4 Empirical Research

4.4.1 Delimitation of the problem

Definition of the desired outcome

The focal organization of this research is a transnational manufacturer of consumer goods. Its products are primarily aimed at children, although there are also products for adults and art professionals. The company directly serves more than 5,000 retailers in the Brazilian market, with almost 2,000 products, from which approximately 700 are produced in-house and 1,300 are outsourced.

The problem to be addressed in the focus company in this study was the difficulty in fulfilling the market with new products. We found that the sales forecasts were inaccurate and that it was necessary to incur significant additional costs to meet the effective needs of customers, through the activation of extra production shifts and the use of dedicated freight to receive inputs in a shorter time than expected. Additional inventory costs due to lower-than-expected sales were also noted. Given the impact of these costs on product margins and project viability, the company had a strong desire to reduce them. Therefore, the desired outcome was defined as the reduction of additional costs for market fulfillment after the introduction of new products.

The company's S&OP process follows, monthly, the five steps proposed in the literature by several authors, such as Esper *et al*. (2009) and Thomé *et al.* (2012). In this process, some aspects stand out. The first is that the marketing department reports the initial monthly sales forecast for a new product, which is revised in the subsequent S&OP cycles by the sales department. However, as the initial sales projection is the basis for financial approval of new product projects, adjustments usually do not occur before four months after the product is launched in the market because they need to be justified to the company's executives.

Secondly, the volume forecasted for the first year of sales of a new product usually presents a great divergence from the real volume that will be sold at the end of the first year. Analyzing the 75 products that the focal organization had launched in the two years before the beginning of this research, we identified that only 20% of the products had a sales performance of between 90% and 110% of the volume initially forecasted for the first year of sales. Moreover, a third of the new products had a sales performance of more than 150% of the initial volume forecast for the first year and another third had a sales performance of 70% or less.

Thirdly, while restrictions on demand fulfilment are presented at the pre-executive S&OP meeting, there is often a tendency within the organization to meet demand whenever possible, even if it implies additional production or purchase costs. The motivation behind this decision is the highly competitive industry in which the company is placed, in which the lack of products can lead the customer to switch to competitors' items and permanently stop buying the company's products. Thus, given that the organization already seeks to maximize current and future revenues by attending all the possible demand, reducing additional costs can lead to profit optimization. Moreover, if the company needs to increase its costs to meet an incremental demand (e.g., trigger an extra shift), it cannot increase the sales price to maintain its profit, because the market structure does not allow it (customers will also buy products from a competitor, in this case). Therefore, as sales price is basically fixed, the company need to focus on not having additional costs in order to maintain its profits. However, analyzing the same 75 products launched two years before the beginning of this research, we observed an 8% cost surplus in the first year of sales than the cost planned when developing these new products.

Identification of the contextual factors

The characteristics of the environment in which a given process will be implemented can significantly affect that process' results. Therefore, the results observed in the empirical implementation of S&OP New Products are bounded by contextual factors.

Regarding contextual factors for planning processes, Jonsson and Mattsson (2003) proposed a model in which they classified the environmental variables that affects production planning into three dimensions, as follows: product, demand and manufacturing process variables. Previous studies (e.g., IVERT *et al.*, 2015; KAIPIA *et al.*, 2017) have already highlighted some critical contextual factors related to S&OP and NPI.

In the product dimension, an important factor to this context is the level of innovation that a new product introduces to the company (GERMAIN; CLAYCOMB; DRÖGE, 2008; KAIPIA *et al.*, 2017; NOROOZI; WIKNER, 2017), although the product variety in the shop floor and the complexity of the bill of materials are also relevant factors.

In the manufacturing process dimension, although shop floor layout and batch sizes are relevant factors to the planning process, in the context of NPI, capacity constraints stand out as a relevant contextual factor, since new products usually involve the acquisition of new equipment or change the workload of the existing ones (SHEN; QIAN; CHOI, 2017; HUANG *et al.*, 2020).

Finally, the demand dimension encompasses factors such as production frequency and replenishment lead time (MONTOYA-TORRES; ORTIZ-VARGAS, 2014; NAGASHIMA *et al.*, 2015; KAIPIA *et al.*, 2017; CHANG; LIN, 2019), power of the organization to influence demand (MARQUES *et al.*, 2014; NEGAHBAN; SMITH, 2016; ALTENDORFER, 2017; CANNELLA *et al.*, 2018), among others.

Based on previous studies that highlighted critical contextual factors related to S&OP and NPI (e.g., IVERT *et al.*, 2015; KAIPIA *et al.*, 2017), potential contextual factors that could affect the outcome were listed. These factors were organized around the three dimensions of planning variables proposed by Jonsson and Mattsson (2003) (product, demand and manufacturing process variables), as presented in Table 16.

Table 16 – Contextual factors for the S&OP and NPI from previous literature

Dimension	Contextual factor
Product	Level of innovation that a new product introduces to the company
Manufacturing process	Capacity constraints
Demand	Production frequency
	Replenishment lead time
	Power of the organization to influence demand

In addition to these factors, the researchers added, based on their experience in planning, a sixth factor that they considered relevant (the level of collaboration with suppliers), given that some of the items evaluated in the focus company were not produced internally, but purchased (outsourcing).

4.4.2 Identification of previous artefacts for the same class of problems

Previous studies have discussed that the S&OP process should embrace new products' production planning (THOMÉ *et al.*, 2012; NOROOZI; WIKNER, 2017), applying S&OP's primary function of aligning plans and actions of the different functional areas of the organization (SAGAWA; NAGANO, 2015; KRISTENSEN; JONSSON, 2018; BAGNI; MARÇOLA, 2019; SAGAWA; NAGANO, 2021). Moreover, the availability of new products in the point of sale, especially in the period of introduction of new products in the market, hereafter named market fulfilment, is a critical factor to gain market share and customers' loyalty (ROBERTSON, 1993; GOH; ELDRIDGE, 2015). However, S&OP literature seldom focuses on New Products Introduction (NPI) (THOMÉ *et al.*, 2012; TUOMIKANGAS; KAIPIA, 2014).

Existing literature about NPI in S&OP seems to be treated more using model-based research (e.g., AMINI; LI, 2011; BILGINER; ERHUN, 2015; WOCHNER *et al.*, 2016; WERY *et al.*, 2018) than utilizing qualitative research (GOH; ELDRIDGE, 2015; KAIPIA *et al.*, 2017). The reviewed mathematical models do not propose a broader S&OP policy for NPI (including frequency, horizon and involved functions) nor detail the process or activities to be carried out, as they are restricted to single products (BILGINER; ERHUN, 2015), products with a specific demand pattern (AMINI; LI, 2011) or industry-specific cases (WOCHNER *et al.*, 2016; WERY *et al.*, 2018).

Regarding qualitative research, Goh and Eldridge (2015) studied NPI in a company that did not have an S&OP process implemented. They proposed a routine of monthly meetings focused on NPI, in which the sales, manufacturing, logistic and purchase managers could align their sales forecasts for the next periods, as well as revise, if necessary, the parameters of the inventory policy. With the meetings, they obtained a significant reduction of the delivery lead time and inventory levels.

Kaipia *et al.* (2017) focused on collaborative S&OP based on point-of-sales data to study demand stabilization after NPI. They observed impressive results by increasing the frequency of demand data update (i.e., updating it weekly), reducing the lead time to change production and focusing planning efforts on items for which the demand was not yet stabilized. Moreover, they state that the company should identify products and demand patterns where collaborative S&OP pays off; otherwise, it is enough to use ordinary (supplier's transactional) demand data.

Therefore, as a specific forum for NPI can be an interesting solution (Goh and Eldridge, 2015), and knowing that different planning solutions can co-exist for different groups of items (Kaipia *et al.*, 2017), this study aims to propose, implement and evaluate an S&OP New Products process that co-exist with the Traditional S&OP for mature products. The focus of this proposal is the reduction of additional costs for market fulfilment after NPI. Our research differs from previous studies because the focal organization studied had already implemented an S&OP process for mature items (Goh and Eldridge, 2015) and our focus is not on point-of-sales data, but on how to deal inside the organization with information received from the entire supply chain (Kaipia *et al.*, 2017).

Evaluating the mechanisms present in the two selected artefacts, we identified greater richness of details in Kaipia *et al.* (2017). In their S&OP process, the authors inserted three mechanisms (concentration of planning efforts in a group of items, engagement for a common purpose and the increasing frequency of updating and sharing information) (section 4.2.3). We observed coherence of these mechanisms with theoretical works in the literature (kernel theories) as well as with the objective we want with our S&OP process. So we kept these mechanisms in our initial artefact design.

4.4.3 Initial design of the artefact

To refine this initial model based on Kaipia *et al.* (2017), we conducted two pilots projects to evaluate an initial S&OP version of the S&OP New Products process and identified three key aspects that the company needs to change to reduce additional costs for new product market fulfilment.

First, it was necessary to evaluate the supply decisions to fulfil demand and the possible ways to influence demand (e.g., negotiating sales orders for different periods, offering similar products, and reviewing advertising and distribution strategies, among others). Therefore, instead of incurring an additional cost to meet a sales order in August, the same order could be met in September without additional costs, just by employing commercial negotiation.

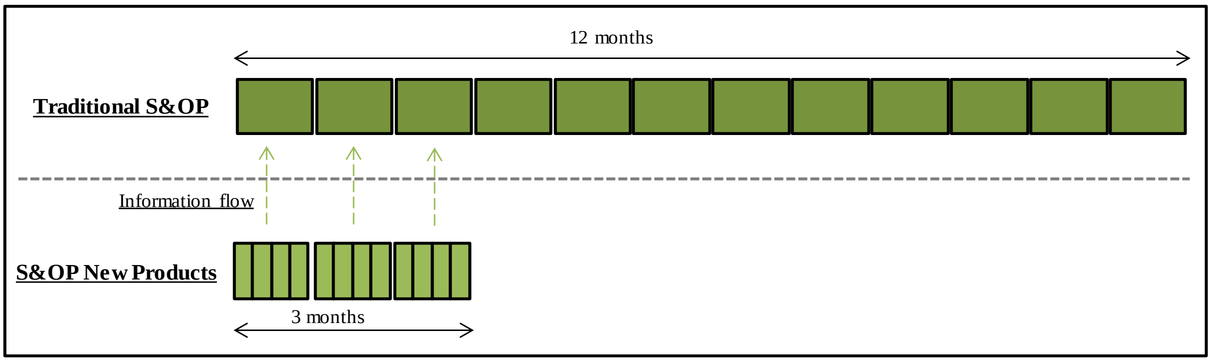
Second, the demand information was mostly revised by the commercial area in the monthly S&OP cycle. This means that if the sales forecast was revised on March 10th and on March 12th incremental sales information was identified in the market (for example, a possible order for an important client), the supply areas will probably not receive this information until April 10th, following the traditional S&OP cycle. However, to respond quickly to variations in demand, the company needs to share demand information more frequently.

Third, the functional areas do not usually align their decisions about each product, such as distribution, adverting, price, safety stock, production capacity, among other strategies. For example, we identified a case in which the marketing function was preparing an interesting advertising campaign for a product for which the company cannot fulfil additional sales due to capacity restrictions. Therefore, many decisions were made locally without evaluating all the variables that the company could influence.

The S&OP process could increase decision alignment regarding the first and third aspects, as well as its frequency could be increased to satisfy the need of the second aspect. However, we understand that this is not the best solution. First, the majority of the company's portfolio consists of mature products, which present a highly predictable demand and would benefit little from more frequent sales reviews. Second, it is crucial to focus the planning efforts only on the products that can lead to different cost and service levels (GOH; ELDRIDGE, 2015; KAIPIA *et al.*, 2017). Otherwise, the process can become very confusing and time-demanding for its members.

Therefore, instead of adapting the whole S&OP process for new products, we decided to keep the current monthly S&OP process for mature and new items, with a planning horizon of 12 months, and to create a new weekly forum with a specific focus on new products, which we called S&OP New Products. Therefore, it would be possible to react faster to any misalignment among the functional areas involving new products. This forum is focused only on items that are in their first seasonal sales period (one year, in the focal organization) and has a planning horizon of three months. Therefore, a new item is revised in the Traditional S&OP in a monthly basis and for a 12 months horizon, but is refined in the short term (3 months) in a weekly basis in the S&OP New Products (Figure 11). The S&OP New Products information is consolidated in the Traditional S&OP (first 3 months) but without any discussion. For the other 9 months (4th to 12th month), the discussion and revision of new products forecast is carried out in the traditional S&OP, maintaining a planning horizon of 12 months for all the items.

Figure 11- S&OP New Products process (parallel process)



Although it is possible to call the proposed process Master Production Planning (MPS) or Sales and Operations Execution (S&OE) focused on New Products, we decided to maintain the name S&OP. First, because the objective of the process is to increase the frequency of alignment among the functional areas of the organization. Secondly, because we do not understand Traditional S&OP and S&OP New Products are two different processes, but two different forums of discussion aiming to complement one another.

Revision of the artefact's elements

In the S&OP New Products process, one person from each of the following six key areas is assigned to a weekly meeting: marketing, sales planning, production planning, purchasing, production and product development. These members are not necessarily the same as those who participate in the Traditional S&OP process, although this occurred for some functions. The process is conducted by the product development member, as he is responsible for the financial result in the first year of the new product launch. His essential functions involve scheduling and coordinating the meeting, defining each member's commitments based on the discussion and following-up on the accomplishment of those tasks. Each week, the group works together to assess the KPIs presented in Table 17 for each new product.

After evaluating the KPIs, additional information can be added by the process members. Thereafter, the following three points are discussed:

- Is there evidence to suggest that demand will not be fulfilled for the next twelve weeks, either due to increased sales or supply problems?

- Is there any suggestion to revise the sales forecast for the next period (increase or decrease)?
- Is there any problem involving a reduction in sales, such as high inventory levels or spoilage risk?

Table 17 – Weekly S&OP analysis KPIs of new products

KPI	Description	Responsible
Actual vs forecasted sales	Values from the previous week and cumulative values (since the launch of the item)	Sales Planning
Order backlog for the next two periods vs the sales forecast	-	Sales Planning
Marketing actions for the item for the next twelve periods	-	Marketing
Actual vs Planned Supply	Values from the previous week and cumulative values (since the launch of the item)	Production Planning
Safety stocks for the next period	-	Production Planning
Actual vs Planned Costs	Values from the previous week and cumulative values (since the launch of the item)	Product Development

For each question, if at least three of the six members answer yes, then the group defines measures to fulfil demand, revises the sales forecast, or thinks of alternatives to increase the demand of the items whose sales did not reach the expected projections. However, it is essential to highlight that each action is taken from a company’s perspective. For example, regarding the first question, a risk of not fulfilling demand could imply increasing the production (e.g., triggering an extra shift), reducing the purchasing lead time (e.g., transporting material with dedicated freight) or reducing demand (e.g., negotiating the delivery date of large orders or reducing advertising levels for some time). All the decisions are made based on financial analysis; from this comes the importance of the product development team leading this forum.

The discussion for each product takes between 2 and 15 minutes, depending on the need for intervention or not, as well as the speed in which the group reaches a consensus to make each decision. The products of similar projects, for example, the launch of three similar products that only differ in colour, are discussed together, as a possible solution for the demand fulfilment of those items involves taking measures to increase the sales of colour A and reduce those of colour B.

Revision of the artefact's mechanisms

In the proposed artefact, three mechanisms are triggered by the implementation of the S&OP New Products. Although these mechanisms were already discussed in the classic management literature (e.g., DRUCKER, 1977; KAPLAN; NORTON, 1992), few studies have discussed these mechanisms in the S&OP context (e.g., TUOMIKANGAS; KAIPIA, 2014; IVERT *et al.*, 2015; NOROOZI; WIKNER, 2017; KRISTENSEN; JONSSON, 2018), in the NPI context (GOH; ELDRIDGE, 2015) and in the S&OP/NPI context (KAIPIA *et al.*, 2017).

First, the concentration of planning efforts on new products is logically expected to improve those products' results (KAIPIA *et al.*, 2017). Benefits of this concentration were reported in the S&OP context by Grimson and Pyke (2007) and Ivert *et al.* (2015). In the NPI context, Kaipia *et al.* (2017) identified evidences that the focus on non-standard demand situations, like the critical phase of product introduction, could increase the service level of the products involved. In the proposed S&OP New Products, the concentration occurs by creating a specific forum for new products, with weekly meetings, a revision of KPIs and an evaluation of specific questions directed to trigger actions.

Secondly, the weekly meetings and standardized KPIs enabled an increase in the frequency of update of sales and supply chain information. Benefits of this mechanism, usually associated with demand information, were reported by Oliva and Watson (2011), Tuomikangas and Kaipia (2014), Noroozi and Wikner (2017) and Negahban and Smith (2016). In the NPI context, Kaipia *et al.* (2017) and Goh and Eldridge (2015) also identified a positive influence of this mechanism in the outcomes, when reviewing demand data weekly instead of bi-weekly and establishing a routine of meetings with the member involved in the NPI process, respectively.

Those papers, however, do not show how to create a mechanism to encourage people to update the functional plans' information as frequently as possible to observe the benefits of those high frequencies. In the S&OP and NPI context, Goh and Eldridge (2015) and Kaipia *et al.* (2017) superficially describe how meetings occur, and some of the decisions made. In our proposed process, this mechanism is enabled by weekly structures focused on KPIs related to the functional plan's performance.

Finally, the proposed S&OP New Products process has a single and clear purpose, i.e., to reduce the additional cost to fulfil the demand for new products, creating engagement in the organisation's decision-making. Evidence of improvement in S&OP outcomes with the activation of this mechanism was reported by Oliva and Watson (2011) and Kristensen and Jonsson (2018). Previous studies have presented different objectives in the S&OP and NPI contexts, such as demand stabilization (KAIPIA *et al.*, 2017), lead time (GOH; ELDRIDGE, 2015), and inventory levels (GOH; ELDRIDGE, 2015), but not cost reduction.

4.4.4 Refinement of the artefact

The S&OP New Products process model, with support of the company's managers, was implemented in the launch of the company's three highest revenue new product projects in that year. Those projects were selected, first, to maximize the impact of the intervention. Second, because the members of the process were highly motivated to deal with those projects, given their high relevance to the executives. Moreover, they also provided an interesting variation of features, as presented in Table 18.

Project A represents a product from the main category of the company but with vastly different features aiming to reach an audience that the company does not usually reach with this category. Project B consists of two similar products (versions with 12 and 24 colours) of the main category of the company. They do not represent any innovation in terms of product, but they are a new line of the company to fight against racial discrimination. This explains the high advertising level for this project. Finally, project C represents 5 different colours of a new category of product that the company was introducing and, unlike the other 2 projects, this product is not produced in house.

Table 18 – Characteristics of the projects analyzed in the intervention

Characteristics	**Project A**	**Project B**	**Project C**
Number of products	1	2	5
Supply type	In-house production	In-house production	Sourcing
Project type	Innovation	Line extension	Introduction of a new category of products to the company
Advertising level	On average company standard	Way above company standard	Below company standard
Actual Sales vs Initial Forecast (first year)	478%	Item 1 (89%) Item 2 (106%)	Item 1 (21%), Item 2 (24%), Item 3 (26%), Item 4 (51%) and Item 5 (54%).
Additional costs in the first year	No	No	3%

As the project B items' actual sales were very close to the initial forecast, lower benefits were perceived for this project. The project's initial sales forecast was maintained for both items until the last sales review of the year, and actual sales were very close to the forecast. However, unexpected orders from three important clients made fulfilling the demand unfeasible without extra hours during the year. Unlike the previous modus operandi of the company, the members of the process first decided to try to negotiate the postponement of those orders by providing partial weekly deliveries for all three clients, which would enable the company to fulfil their needs, as well as other clients' volumes without additional cost.

For project C, the desired results were not obtained either since the entire purchase of the finished product was made during the product development phase (due to a supplier's requirement of a minimum order quantity). Although the members decided during the meetings to reduce the total sales forecast in the eleventh week, the discussions focused first on ways to increase the sales of these products (promotion, advertising, price discount, among others). When the company's attempts showed to be unsuccessful, then the analyses were concentrated on how the exceeding inventory would affect the company's results. The exceeding inventory led to a 3% increase in the costs involving the product throughout the year.

Project A, on the other hand, presented the most significant benefits with the model application. For example, in the first week of the S&OP New Products initiative, the members decided to increase the sales forecast by 100% because of the products initial sales results. Moreover, they also decided to increase production by triggering an additional shift of a specific resource without additional cost, because it was possible to move operators to work during the new shift. The fast alignment between purchasing and production planning (which started at the meeting and was refined during the week) allowed the critical components and raw materials to be delivered in additional quantities and at the time required by production planning without additional costs. All these actions were essential to avoid product shortages or additional costs to fulfil actual sales in the first month after launch, which were three times higher than the forecast.

Throughout the year, the sales performance continued to be better than expected, even in comparison to the revised sales forecast explained in the previous paragraph. Therefore, the S&OP New Products process members decided to trigger one more working shift in the critical production resource and reduce the purchasing lead time with a major supplier from 40 to 10 days by sending a revised raw material forecast every week. With the continuous and intense monitoring and the decisions made during the meetings, there was no stockout of the product of project A through the year, although sales were almost four times higher than expected; there was also no additional cost to fulfil the incremental sales volumes.

4.5 Contribution to design theory

4.5.1 Why the artefact works better for some projects?

To answer this question, we evaluated the characteristics (contextual factors) of each project and how they affected the results obtained with the implementation of the artefact. First, the level of product innovation impacts on how unpredictable its demand can be and, therefore, more frequent alignments should be performed (KAIPIA *et al.*, 2017; NOROOZI; WIKNER, 2017). For example, project B's demand was highly predictable, as it is just a line expansion for the company. On the other hand, the demand for products from project A and C were highly unpredictable, resulting, respectively, in a much higher and much lower actual sales volume than initially expected.

Second, the level of collaboration with suppliers also affects how deeply information can be aligned along the supply chain (MONTOYA-TORRES; ORTIZ-VARGAS, 2014). In Project A, for example, the company could share much information with its two key suppliers, as they do not supply the company's competitors. Therefore, the entire supply chain could move in a joint movement to the subsequent improvement of sales. On the other hand, project C relies on a supplier that is also a competitor of the company (producing another brand for the same category of products). Therefore, with this supplier, almost no information regarding sales performance was shared.

Third, replenishment frequency affects how fast the organization can react to new sales or supply information (KAIPIA *et al.*, 2017). While products from projects A and B were produced at least biweekly, project C's product was pre-purchased in a single lot, which caused the sales week reviews and alignments to have little impact on avoiding additional costs for the product.

Fourth, replenishment lead times impact the model similarly. Items with longer lead times benefit little from frequent sales updates because the production or purchasing is frozen for an extended period of time (KRISTENSEN; JONSSON, 2018; CHANG; LIN, 2019). This was the case for project C, in which the replenishment lead time was 90 days. Therefore, even if the items could be purchased every month, the sales update would impact actions only after 90 days, reducing the benefits of the frequent updates.

Fifth, production restrictions can also negatively affect the process (MARQUES *et al.*, 2014; ALTENDORFER, 2017). If the specific equipment used for project A had no idle capacity at the beginning of the project, there would not be opportunities to increase the sales volumes. Therefore, the company would have no other choice but to try to deflect this demand to other products, which would be unlikely to be successful given that project A aimed at a different audience from the other products of the company.

Sixth, it is essential to analyze the company's power to influence demand (SHEN; QIAN; CHOI, 2017; HUANG *et al.*, 2020). In the focal company, the power was high in its primary product category (projects A and B). Therefore, the company could move the sales of product B in up to three weeks not to use overtime. For product C, on the other hand, the power was low. The company could not increase its sales with advertising strategies, promotions and price discounts.

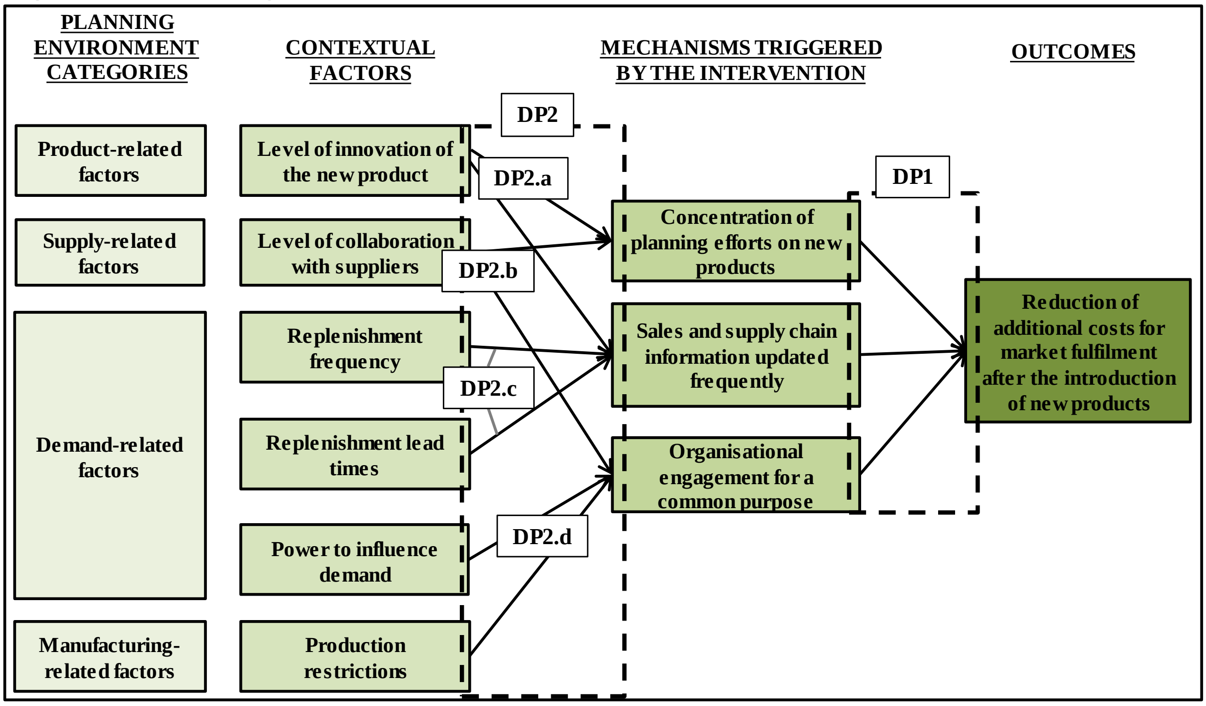
The six contextual factors identified can be classified according to Jonsson and Mattsson’s (2003) proposal. Three of them are related to the demand dimension, while the product's level of innovation is related to the product dimension and production restrictions to the manufacturing process dimension. Collaboration with suppliers could not be classified in any of the dimensions proposed by Jonsson and Mattsson (2003), as it is related to the environment external to the organization facilities, but not to downstream supply chain, as the demand dimension. Therefore, we included a fourth group of factors into our model, called supply dimension, expanding Jonsson and Mattsson’s (2003) model.

Moreover, a significant portion of the outcomes of S&OP New Products is subject to the influence of the external environment (demand and suppliers), even though some of them can be directly (for example, decide to produce an item instead of buying it) or indirectly (influence demand by advertising or price strategies) influenced by the company. This concentration of factors into a few dimensions differs from the relative equal distribution among the three dimensions in a traditional S&OP process, presented by Ivert *et al.* (2015), reinforcing the idea that a separate S&OP process could benefit new products.

4.5.2 Design propositions

Two kinds of design propositions were formulated to summarized the knowledge generated by this study (Figure 12). Design proposition 1 relates the mechanism triggered by the intervention to the outcome. Design proposition 2 shows that contextual factors directly affect the results achieved, as they determine if the three mechanisms will be triggered or not. Design propositions 2.a to 2.d address the main relationships between contextual factors and the mechanisms identified.

Figure 12- CIMO logic for the S&OP New Products process



DP1: The establishment of an S&OP process focused on new products activates three mechanisms (concentration of planning efforts on new products, organisational engagement for a common purpose and frequent updates of sales and supply chain information) that generate the reduction of additional costs for market fulfilment after the introduction of new products.

The activation of the three mechanisms in Project A significantly reduced the additional cost to meet the incremental sales. The concentration of planning efforts on new products in a specific forum was essential to increase the results of those products and was already identified in previous studies (GRIMSON; PYKE, 2007; IVERT *et al.*, 2015; KAIPIA *et al.*, 2017). However, it was not previously clear how to induce this concentration, as now proposed with a parallel S&OP process focus specifically on new products.

A higher information update frequency increases communication effectiveness and reinforces the process members' alignment (OLIVA; WATSON, 2011; TUOMIKANGAS; KAIPIA, 2014; NOROOZI; WIKNER, 2017), especially for new products with significant uncertainties in sales and supply (NEGAHBAN; SMITH, 2016). The weekly meetings enable the organization to take faster and better decisions (e.g., activating sooner an extra shift for Project A), reducing additional cost to meet additional sales.

Finally, the essence of S&OP is to create constructive engagement to generate alignment among the functional areas (OLIVA; WATSON, 2011). The proposed S&OP New Products process has a single and clear objective, i.e., to reduce the additional cost to fulfil the demand for new products, directing all organizations efforts in the same direction (KRISTENSEN; JONSSON, 2018).

DP2: The results generated by the implementation of S&OP New Products depend on six contextual factors.

As we observed in the empirical implementation of the S&OP New Products, the process led to different results for the three projects according to the contextual factors involved. Following the CIMO logic, these factors influence if the three mechanisms will be fully activated or not, and therefore, if the desired outcome will be achieved. In design propositions 2.a to 2.d, the main relationships between contextual factors and the mechanisms identified will be addressed.

DP2.a: The higher the level of innovation of a new product, the greater the potential benefits of concentrating planning efforts on new products and updating sales and supply chain information more frequently and, therefore, the greater the benefits in establishing an S&OP process focused on new products.

Simple extensions of existing products lines (project B) usually have more predictable demands than innovations (projects A and C). Therefore, the S&OP New Products process should concentrate more on planning innovations than simple extensions of existing products (GERMAIN; CLAYCOMB; DRÖGE, 2008; NOROOZI; WIKNER, 2017). Frequent sales updates are more likely to reveal significant changes in demand for products for which sales are more unpredictable, i.e., innovations (KAIPIA *et al.*, 2017). Additionally, innovations are more susceptible to variations in production resources (e.g., new equipment or a new process) and purchasing (e.g., a new supplier).

DP2.b: The more collaborative relationship the company has with its suppliers, the greater the potential benefits of concentrating planning efforts on new products and engaging organization for a common purpose are and, therefore, the greater the benefits in establishing an S&OP process focused on new products are.

In project A, the excellent relationship the company has with its main supplier was essential to significantly increase production in a short time period, as it could dynamically redefine the safety stocks, capacity policies and strategies for raw materials along the supply chain, corroborating with Montoya-Torres and Ortiz-Vargas (2014). The wide possibility of decision making in the supply chain motivates the members of the S&OP New Products process to concentrate planning efforts on new products as well as engages them to follow a common purpose among the functional areas (LIM; APAN; PENZ, 2014; NAGASHIMA *et al.*, 2015).

DP2.c: If replenishment frequency is lower and/or replenishment lead times are higher, the company will obtain little benefits from updating sales and supply chain information more frequently and, therefore, the desired benefits from establishing an S&OP process focused on new products may not be achieved.

The high replenishment frequency of projects A and B enabled the company to make faster decisions that were reflected in the short term. On the other hand, when replenishment frequency is low (as in project C), information update will lead to changes only in the long term, reducing the benefits of increasing the frequency of updating information (KAIPIA *et al.*, 2017). Similarly, the shorter the replenishment lead times are, the greater the benefits of an increase in information updates are, as changes in functional plans could result in short-term benefits (NEGAHBAN; SMITH, 2016; KRISTENSEN; JONSSON, 2018; CHANG; LIN, 2019).

DP2.d: If the company has little power to influence demand and/or significant production restrictions, the company will obtain little benefits from engaging organization for a common purpose and, therefore, the desired benefits from establishing an S&OP process focused on new products may not be achieved.

Production restrictions can negatively affect organizational engagement, as it could be unfeasible to increase production in response to a positive change in sales (ALTENDORFER, 2017; CANNELLA *et al.*, 2018). Therefore, the members of the sales and marketing functions could be demotivated to continue concentrating their efforts on those projects, as no benefits occur with their efforts to update sales forecasts continually, and the classic conflict between sales and supply chain will intensify (THOMÉ *et al.*, 2012; MARQUES *et al.*, 2014). For those cases, an initial alignment could be sufficient to decide the sales and production strategy for the next 6 or 12 months, as incremental demand will not be fulfilled. Similarly, the power of the company to influence demand, i.e., negotiating delivery dates with top clients, can also affect the organizational engagement negatively, as members of production planning, production and purchasing observe no benefits from the S&OP New Products process if the company has no power to influence demand (SHEN; QIAN; CHOI, 2017; HUANG *et al.*, 2020).

4.6 Conclusion

This study aims to contribute to both theory and practice. For the theory, this paper shows that a specific S&OP process focused on new products is a viable solution and could co-exist with a traditional S&OP process. Previous papers have described one or the other process, but it was not clear how those two processes could co-exist. Furthermore, the coexistence of two S&OP processes due to different products characteristics has not yet been explored as a possibility in previous studies.

Moreover, the study identified that the outcome of the proposed S&OP New Products process depends on six contextual factors. When classifying those factors according to Jonsson and Mattsson's (2003) model, we recognized the need to expand the original model to include a fourth dimension (supply). Moreover, we also identified that four of the six contextual factors are related to dimensions that are external to the company (supply and demand). This finding differs from previous studies which have identified that, in traditional S&OP, the contextual factors are more equally distributed among the dimensions. It reinforces the need of an S&OP Process focused specifically on new products.

For the practice, this study presents how to organize an S&O process focused on new products, a point not described in detail in previous papers and that can increase the success of empirical implementations of the S&OP in a NPI context. During the implementation, the six design propositions and the six contextual factors should be used as reference guides by managers, so that they can adapt the S&OP New Products according to the desired outcome and the context, increasing the results obtained with NPI.

The main limitation of this study is that the process was evaluated in a single organization. Therefore, although we evaluated new products with different characteristics, they are all embedded in the same organizational culture. Although this limitation is reduced by analyzing the results using the CIMO logic, it will be interesting to analyze the results of the S&OP New Products in other contexts and with different objectives (not the reduction of additional costs) to further validate the results. Some suggestions are present in Table 19.

Table 19 – Research Agenda

Subject	Potential Research Questions
Evaluation of the S&OP New Products process in different environments	- What are the environments in which the proposed process is useful? - To which additional contextual factors does it need to be adapted? How do the mechanisms work in those environments?
Evaluation of the S&OP New Products for different purposes	- For what other purposes can the process be useful (i.e., to increase service level or to reduce the supply chain inventory)? - How do the contextual factors and mechanisms need to be adapted to achieve those purposes?
Implementation of the S&OP New Products	- In other contexts, what are the main differences in the S&OP New Products? What elements can affect the frequency of meetings, the areas that take part in the process, the KPIs analyzed, among others?

5 CONCLUSION

In the final chapter of this thesis, we started by discussing how the proposed model performed in the S&OP NPI context. Then, we highlighted the main conclusions of the thesis and proposed a research agenda for the further development of the proposed model as well as of DSR as research approach.

5.1 Performance of the model in the S&OP NPI context

The empirical evaluation of the proposed model in Chapter 4 followed all the suggested steps in their order, as specified in the text of that chapter. Compared to previous DSR studies that we have conducted, we observed a much structured path by defining the desired outcome and by identifying the contextual factors. Moreover, the proposal of the artefact was much easier and faster than we expected, as previous artefacts for the same class of problems were adapted for the specific objectives and context of the empirical situation studies. We however, identify two main opportunities of adjustments in the proposed model

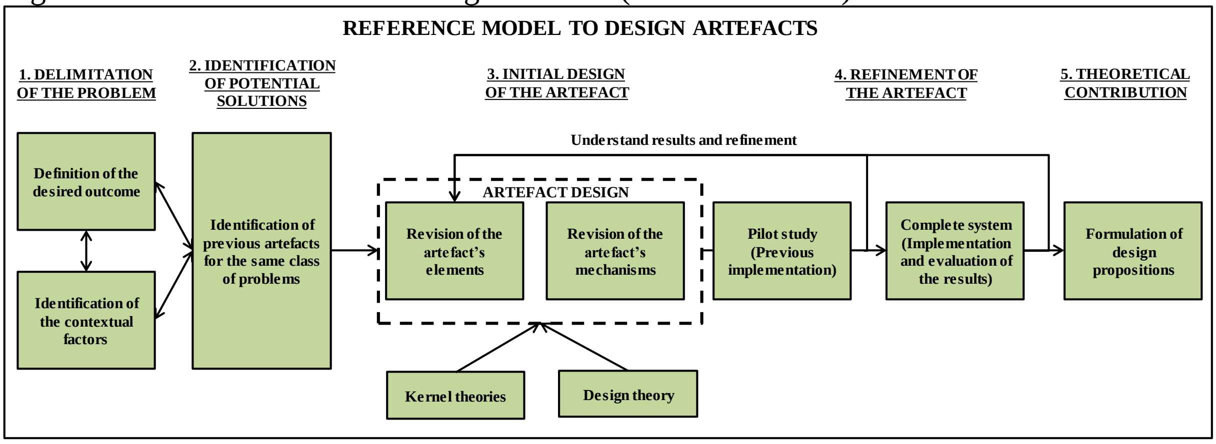
First, we verified the importance that prior knowledge of the theories and concepts involved with the problem being solved (in this case, S&OP and NPI) can provide in directing the questions and answers from the beginning of the process (notably in the definition of the desired outcomes and the identification of the contextual factors). This made us question ourselves the sequence between phases 1 and 2. On the one hand, finding artefacts relevant to the studied problem is more difficult if the objectives and contextual factors are not clearly defined. On the other hand, it is difficult to define the desired outcomes and to identify the relevant contextual factors without knowing other similar cases for the same class of problems.

Among these two possible paths, we understand that the interaction between steps 1 and 2 is an interesting alternative. Therefore, we suggest that, as researchers begin to understand the empirical problem, they already evaluate potential existing solutions, directing the definition of desired outcomes and identifying the contextual factors.

Second, through the empirical implementation, we understood the importance of carrying out a pilot study of the proposed solution before proceeding with an implementation for the entire system. During the pilot, we tested different configurations of the S&OP process, and each week we could introduce a new configuration, based on feedback from the previous week. This process brought speed to the search process for a better solution to the problem and provided great robustness and confidence in the proposed final solution. Based on this learning, we recommend including the pilot version as a formal step in the fourth step of the model.

Both changes are shown in Figure 13, which reflects the final version of the model proposed in this thesis.

Figure 13 - Reference model to design artefacts (Refined Version)



5.2 Thesis main contributions and limitations

This main objective of this thesis was the proposal of a reference model to conduct DSR studies focused on the artefact design. This objective was defined because, although there are several reference models for conducting DSR studies in the OM field, none of them focused specifically on how to design an artefact, a crucial step in DSR given that the artefact is the centrepiece of DSR approach.

Therefore, the proposal of a practical model to propose artefacts is the main contribution of this research both from a theoretical and practical point of view. For practice, the model aims to minimize the unstructured trial and error process used to develop an artefact, reducing development time as well as the resources used in this stage. Moreover, it also aims to help in developing and disseminating DSR as a research approach in the OM field. For theory, the model aims to contribute to the design theory and to facilitate knowledge 2 mode generation. Moreover, the model can also contribute to increase the number of studies published using DSR.

Regarding the research questions formulated in Chapter 1, combining CIMO Logic with DSR since the beginning of the research provided a structured path (on which the proposed model is based) to design and refine artefacts, reducing the cost and time necessary to solve empirical problems. Moreover, it also make it easier to research formulate design propositions, supporting the theoretical contribution of the studies.

Besides the model proposal, other relevant contributions of this thesis are:

1. Mapping the state-of-art of DSR studies in the OM field;

2. Proposal of the existence of two types of DSR in the OM field by a cluster analysis of the studies identified in the SLR;
3. Proposal of a reference model to conduct DSR studies adaptable to both types of DSR;
4. Identification of two barrier (lack of didactic materials and of specific materials to each type of DSR) that DSR need to overcome to increase the number of DSR studies in the OM field;
5. Proposal of two S&OP parallel process, one focused on traditional products and another on new products;
6. Identification in the S&OP NPI context of four contextual variables and three mechanisms that affect the desired outcome (reduction of additional costs for market fulfilment after introducing new products).

The main limitation of this study is that the proposed model was evaluated in a single empirical context (NPI S&OP context, Chapter 4). Because of the in-depth and longitudinal DSR study conducted, it was unfeasible to perform other DSR at the same level of quality to contribute to the design artefact model evaluation. Therefore, the research agenda in the following section suggests the assessment of the proposed model in other empirical contexts to refine it further.

Another limitation of the model is the necessity to find a previous solution to the class of problems studied. If there is not previous solution, even in similar class of problems, researchers will need to project an artefact from zero, not be performing step 2 and facing greater challenges related to the generation of mode 2 knowledge.

Furthermore, it is important to emphasize that there is no consensus in the field of Operations Management on what constitutes a research's theoretical contribution. In the view of this thesis, I understand that it is built from the understanding of why and how the obtained results were generated in opposition to the existing theoretical bases (kernel theory). However, other researchers consider that the construction of artefacts based on theories and the verification of the functioning of these (solving an empirical problem), already constituted a theoretical contribution of the research.

5.3 Thesis research agenda

Aiming to further develop the proposed model as well as of DSR as research approach, in this section we proposed a research agenda (Table 20) for future studies based on the understanding of the state-of-art of DSR studies in the OM field (Chapter 2) and on the limitation of the proposed model and its evaluation (Chapter 3 and 4).

Table 20 – Thesis Research Agenda

Subject	Motivation	Potential research questions
Refinement of the model	In this thesis, the model was evaluated in a single empirical environment. The design of artefacts using this model in other contexts will help to refine it.	What are the adaptations necessary to use the model to design artefacts in different empirical contexts? (inside and outside the OM field) How could each specific model step be conducted? (e.g., which methods and techniques can be used to identified the desired outcome and the contextual factors)
Evolution of DSR as research approach in the OM field	DSR in the OM field are focused on some types of artefacts (models, methods and design propositions) and some types of forms of evaluation (observational and analytical). Moreover, it is still not clear how DSR can be combined with other research methods.	In what situations could studies in OM use constructs and instantiations as artefacts? How can DSR studies benefit from using alternative forms of evaluation to the traditional observational and analytical ones? How can different forms of evaluation be combined to improve the validity of DSR?
Dissemination of DSR	There is a low concentration of studies using DSR even in journals with higher numbers of papers published using this approach	How can DSR be spread among OM researchers? How empirical research can benefit from this method as an alternative to more traditional methods such as action research and case study? What conditions will be necessary for the two different types of DSR to coexist in the future, aiming to serve their different audiences?

The first subject proposed is the refinement of the model proposed in this thesis. Although it is based on previous models widely used in DSR (e.g., (MANSON, 2006; HOLMSTRÖM; KETOKIVI; HAMERI, 2009) and on theoretical studies for designing artefacts (GIBBONS *et al.*, 1994; BUNGE, 2004; HUFF; TRANFIELD; VAN AKEN, 2006), the proposed model was evaluated in only one empirical situation (Chapter 4). In this way, its evaluation in other situations may present adaptations necessary for implementing the model in certain contexts, as well as helping to clarify how to carry out each specific activity.

The second subject is more comprehensive, involving the evolution of DSR as a research approach. From the systematic literature review (Chapter 2), we verified that the DSR in the OM field is still focused on specific types of artefacts and forms of evaluation of these artefacts. However, the use of alternative methods can bring new insights to the field. Another relevant aspect is the combination of DSR with other methods, turning the DSR to be an archetype in which each of its steps can be performed by a specific research method.

Finally, despite the relevant empirical and theoretical contributions that DSR can provide, its dissemination in the OM field is still low. Thus, to understand how researchers can use this approach more frequently in the future, knowing its different approaches, aiming to serve their different audiences, is also a relevant and essential direction.

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APPENDIX A – Papers identified in the SLR of Chapter 2

ID	Authors	Paper Title	Journal	Year of Publication
1	Agostinelli, S., Lupia, M., Marrella, A. and Mecella, M.	Reactive synthesis of software robots in RPA from user interface logs	Computers in Industry	2022
2	Ahlemann, F., Arbi, F.E., Kaiser, M.G. and Heck, A.	A process framework for theoretically grounded prescriptive research in the project management field	International Journal of Project Management	2013
3	Akkermans, H., Oppen, W., Wynstra, F. and Voss, C.	Contracting outsourced services with collaborative key performance indicators	Journal of Operations Management	2019
4	Bagni, G., Sagawa, J.K. and Godinho Filho, M.	Sales and operations planning for new products: a parallel process?	International Journal of Physical Distribution and Logistics Management	2022
5	Bertrand, J.-L., Brusset, X. and Chabot, M.	Protecting franchise chains against weather risk: A design science approach	Journal of Business Research	2021
6	Bodendorf, F., Xie, Q., Merkl, P. and Franke, J.	A multi-perspective approach to support collaborative cost management in supplier-buyer dyads	International Journal of Production Economics	2022
7	Brendel, A.B., Brennecke, J.T., Hillmann, B.M. and Kolbe, L.M.	The Design of a Decision Support System for Computation of Carsharing Pricing Areas and Its Influence on Vehicle Distribution	IEEE Transactions on Engineering Management	2020
8	Broekhuis, M., van Offenbeek, M. and Eissens-van der Laan, M.	What professionals consider when designing a modular service architecture?	International Journal of Operations and Production Management	2017
9	Brusset, X. and Bertrand, J.	Hedging weather risk and coordinating supply chains	Journal of Operations Management	2018
10	Busse, C., Schleper, M.C., Weilenmann, J. and Wagner, S.M.	Extending the supply chain visibility boundary: Utilizing stakeholders for identifying supply chain sustainability risks	International Journal of Physical Distribution and Logistics Management	2017
11	Calabrese, A. and Francesco, F.	A pricing approach for service companies: Service blueprint as a tool of demand-based pricing	Business Process Management Journal	2014
12	Carvalho, L.P., Cappelli, C. and Santoro, F.M.	BPMN pra GERAL: a framework to translate BPMN to a citizen language	Business Process Management Journal	2022
13	Chaudhuri, A., Naseraldin, H., Søberg, P.V., Kroll, E. and Librus, M.	Should hospitals invest in customised on-demand 3D printing for surgeries?	International Journal of Operations and Production Management	2021
14	Chaudhuri, A., Gerlich, H.A., Jayaram, J., Ghadge, A., Shack, J., Brix, B.H., Hoffbeck, L.H. and Ulriksen, N.	Selecting spare parts suitable for additive manufacturing: a design science approach	Production Planning and Control	2020
15	Chuang, H.H.-C., Chou, Y.-C. and Oliva, R.	Cross-item learning for volatile demand forecasting: An intervention with predictive analytics	Journal of Operations Management	2021
16	Drechsler, A. and Breth, S.	How to go global: A transformative process model for the transition towards globally distributed software development projects	International Journal of Project Management	2019
17	Dreyer, S., Egger, A., Püschel, L. and	Prioritising smart factory investments - A project portfolio selection approach	International Journal of Production	2022

ID	Authors	Paper Title	Journal	Year of Publication
	Röglinger, M.		Research	
18	Ebel, M., Jaspert, D. and Poeppelbuss, J.	Smart already at design time – Pattern-based smart service innovation in manufacturing	Computers in Industry	2022
19	Esmeli, R., Bader-El-Den, M. and Abdullahi, H.	An analyses of the effect of using contextual and loyalty features on early purchase prediction of shoppers in e-commerce domain	Journal of Business Research	2022
20	Fahim, P.B.M., An, R., Rezaei, J., Pang, Y., Montreuil, B. and Tavasszy, L.	An information architecture to enable track-and-trace capability in Physical Internet ports	Computers in Industry	2021
21	Fayoumi, A.	Ecosystem-inspired enterprise modelling framework for collaborative and networked manufacturing systems	Computers in Industry	2016
22	Fengel, J.	Semantic technologies for aligning heterogeneous business process models	Business Process Management Journal	2014
23	Finne, M.	Improving university teaching: a professional service operation perspective	International Journal of Operations and Production Management	2018
24	Gauss, L., Lacerda, D.P. and Cauchick Miguel, P.A.	Market-Driven Modularity: Design method developed under a Design Science paradigm	International Journal of Production Economics	2022
25	Gobbo Junior, O. and Borsato, M.	A Method to Support Design for Serviceability in the Early Stages of New Product Development	International Journal of Computer Integrated Manufacturing	2021
26	Gong, Y. and Janssen, M.	An interoperable architecture and principles for implementing strategy and policy in operational processes	Computers in Industry	2013
27	Groop, J., Ketokivi, M., Gupta, M. and Holmström, J.	Improving home care: Knowledge creation through engagement and design	Journal of Operations Management	2017
28	Guggenberger, T., Schweizer, A. and Urbach, N.	Improving Interorganizational Information Sharing for Vendor Managed Inventory: Toward a Decentralized Information Hub Using Blockchain Technology	IEEE Transactions on Engineering Management	2020
29	Healey, M.P., Hodgkinson, G.P., Whittington, R. And Johnson, G.	Off to Plan or Out to Lunch? Relationships between Design Characteristics and Outcomes of Strategy Workshops	British Journal of Management	2015
30	Hedenstierna, C.P.T., Disney, S.M., Eyers, D.R., Holmström, J., Syntetos, A.A. and Wang, X.	Economies of collaboration in build-to-model operations	Journal of Operations Management	2019
31	Hoch, N.B. and Brad, S.	Managing business model innovation: an innovative approach towards designing a digital ecosystem and multi-sided platform	Business Process Management Journal	2021
32	Hoffmann, D., Ahlemann, F. and Reining, S.	Reconciling alignment, efficiency, and agility in IT project portfolio management: Recommendations based on a revelatory case study	International Journal of Project Management	2020
33	Holloway, S.S., Eijnatten, F.M., Romme, A.G.L. and Demerouti, E.	Developing actionable knowledge on value crafting.: A design science approach	Journal of Business Research	2016
34	Ivert, L.K. and Jonsson,	When should advanced planning and	International Journal	2014

ID	Authors	Paper Title	Journal	Year of Publication
	P.	scheduling systems be used in sales and operations planning?	of Operations and Production Management	
35	Jia, Y., Ge, S., Liang, H., Wang, N., Wang, Z. and Shu, J.	Incorporating Use History in Information System Remodularization	IEEE Transactions on Engineering Management	2022
36	Johnson, M., Burgess, N. and Sethi, S.	Temporal pacing of outcomes for improving patient flow: Design science research in a National Health Service hospital	Journal of Operations Management	2020
37	Kaipia, R.; Holmström, J.; Småros, J. and Rajala, R.	Information sharing for sales and operations planning: Contextualized solutions and mechanisms	Journal of Operations Management	2017
38	Kalaiarasan, R., Agrawal, T.K., Olhager, J., Wiktorsson, M. and Hauge, J.B.	Supply chain visibility for improving inbound logistics: a design science approach	International Journal of Production Research	2022
39	Kinra, A., Hald, K.S., Mukkamala, R.R. and Vatrapu, R.	An unstructured big data approach for country logistics performance assessment in global supply chains	International Journal of Operations and Production Management	2020
40	Kregel, I., Stemann, D., Koch, J. and Coners, A.	Process Mining for Six Sigma: Utilising Digital Traces	Computers and Industrial Engineering	2021
41	Kunz, N. and Wassenhove, L.N.	Fleet sizing for UNHCR country offices	Journal of Operations Management	2019
42	Land, M.J., Thürer, M., Stevenson, M., Fredendall, L.D. and Scholten, K.	Inventory diagnosis for flow improvement—A design science approach	Journal of Operations Management	2021
43	Lerche, J., Enevoldsen, P. and Seppänen, O.	Application of Takt and Kanban to Modular Wind Turbine Construction	Journal of Construction Engineering and Management	2022
44	Lerche, J., Neve, H.H., Ballard, G., Teizer, J., Wandahl, S. and Gross, A.	Application of Last Planner System to Modular Offshore Wind Construction	Journal of Construction Engineering and Management	2020
45	Lin, X., Ho, C.M.-F. and Shen, G.Q.	For the balance of stakeholders' power and responsibility A collaborative framework for implementing social responsibility issues in construction projects	Management Decision	2018
46	Liutkevičienė, I., Rytter, N.G.M. and Hansen, D.	Leveraging capabilities for digitally supported process improvement: a framework for combining Lean and ERP	Business Process Management Journal	2022
47	Lockl, J., Schlatt, V., Schweizer, A., Urbach, N. and Harth, N.	Toward Trust in Internet of Things Ecosystems: Design Principles for Blockchain-Based IoT Applications	IEEE Transactions on Engineering Management	2020
48	Lopes, C.S., da Silveira, D.S. and Araujo, J.	Business processes fragments to promote information quality	International Journal of Quality and Reliability Management	2021
49	Lu, W., Wu, L., Zhao, R., Li, X. and Xue, F.	Blockchain Technology for Governmental Supervision of Construction Work: Learning from Digital Currency Electronic Payment Systems	Journal of Construction Engineering and Management	2021
50	Luís-Pereira, J., Varajão, J. and Uahi, R.	A new approach for improving work distribution in business processes supported by BPMS	Business Process Management Journal	2020

ID	Authors	Paper Title	Journal	Year of Publication
51	Mamoghli, S., Cassivi, L. and Trudel, S.	Supporting business processes through human and IT factors: a maturity model	Business Process Management Journal	2018
52	Martins, J., Parente, M., Amorim-Lopes, M., Amaral, L., Figueira, G., Rocha, P. and Amorim, P.	Fostering Customer Bargaining and E-Procurement Through a Decentralised Marketplace on the Blockchain	IEEE Transactions on Engineering Management	2022
53	Matana, G., Simon, A. Godinho Filho, M. And Helleno, A.	Method to assess the adherence of internal logistics equipment to the concept of CPS for industry 4.0	International Journal of Production Economics	2020
54	Mattila, J., Seppälä, T., Valkama, P., Hukkinen, T., Främling, K. and Holmström, J.	Blockchain-based deployment of product-centric information systems	Computers in Industry	2021
55	Mazhar, S., Wu, P.P.-Y. and Rosemann, M.	Designing complex socio-technical process systems - the airport example	Business Process Management Journal	2019
56	Meyer, G.G., Buijs, P., Szirbik, N.B. and Wortmann, J.C.H.	Intelligent products for enhancing the utilization of tracking technology in transportation	International Journal of Operations and Production Management	2014
57	Moerchel, A., Tietze, F., Aristodemou, L. and Vimalnath, P.	A Novel Method for Visually Mapping Intellectual Property Risks and Uncertainties in Evolving Innovation Ecosystems: A Design Science Research Approach for the COVID-19 Pandemic	IEEE Transactions on Engineering Management	2022
58	Morenza-Cinos, M., Casamayor-Pujol, V. and Pous, R.	Stock visibility for retail using an RFID robot	International Journal of Physical Distribution and Logistics Management	2019
59	Mturi, E. and Johannesson, P.	A context-based process semantic annotation model for a process model repository	Business Process Management Journal	2013
60	Myrodia, A., Randrup, T. and Hvam L.	Configuration lifecycle management maturity model	Computers in Industry	2019
61	Nogueira, C.A., Pádua, S.I.D. and Bernardo, R.	A map for the holistic BPM diagnosis	Business Process Management Journal	2022
62	Oberdorf, F., Stein, N. and Flath, C.M.	Analytics-enabled escalation management: System development and business value assessment	Computers in Industry	2021
63	Oesterreich, T.D. and Teuteberg F.	Looking at the big picture of IS investment appraisal through the lens of systems theory: A System Dynamics approach for understanding the economic impact of BIM	Computers in Industry	2018
64	Offenbeek, M.A.G. and Vos, J.F.J.	An integrative framework for managing project issues across stakeholder groups	International Journal of Project Management	2016
65	Öhman, M., Finne, M. and Holmström, J.	Measuring service outcomes for adaptive preventive maintenance	International Journal of Production Economics	2015
66	Öhman, M., Hiltunen, M., Virtanen, K. and Holmström, J.	Frontlog scheduling in aircraft line maintenance: From explorative solution design to theoretical insight into buffer management	Journal of Operations Management	2020
67	Oppong-Tawiah, D.,Webster, J., Staples, S., Cameron, A., Guinea, A.O. and Hung, T.Y.	Developing a gamified mobile application to encourage sustainable energy use in the office	Journal of Business Research	2020
68	Otto, B., Ebner, V.,	Toward a business model reference for	Computers in	2013

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	Baghi, E. and Bittmann, R.M.	interoperability services	Industry	
69	Ozkan, B.Y., Spruit, M., Wondolleck, R. and Coll, V.B.	Modelling adaptive information security for SMEs in a cluster	Journal of Intellectual Capital	2020
70	Polančič, G.	BPMN-L: A BPMN extension for modeling of process landscapes	Computers in Industry	2020
71	Pournader, M., Tabassi, A.A. and Baloh, P.	A three-step design science approach to develop a novel human resource-planning framework in projects: the cases of construction projects in USA, Europe, and Iran	International Journal of Project Management	2015
72	Reich, J., Kinra, A., Kotzab, H. and Brusset, X.	Strategic global supply chain network design–how decision analysis combining MILP and AHP on a Pareto front can improve decision-making	International Journal of Production Research	2021
73	Reinerth, D., Busse, C., and Wagner, S.M.	Using Country Sustainability Risk to Inform Sustainable Supply Chain Management: A Design Science Study	Journal of Business Logistics	2019
74	Rocha, R.S., Fantinato, M., Thom, L.H. and Eler, M.M.	Dynamic product line for Business Process Management	Business Process Management Journal	2015
75	Sanches, C., Meireles, M. and Silva, O.R.	Framework for the generic process of diagnosis in quality problem solving	Total Quality Management & Business Excellence	2015
76	Santharm, B.A. and Ramanathan, U.	Supply chain transparency for sustainability – an intervention-based research approach	International Journal of Operations and Production Management	2022
77	Santos, F., Pereira, R. and Vasconcelos J.B.	Toward robotic process automation implementation: an end-to-end perspective	Business Process Management Journal	2020
78	Santos, J.C. and Silva, M.M.	Price management in IT outsourcing contracts. The path to flexibility	Journal of Revenue and Pricing Management	2015
79	Song, R., Cui, W., Vanthienen, J., Huang, L. and Wang, Y.	Business process redesign towards IoT-enabled context-awareness: the case of a Chinese bulk port	Business Process Management Journal	2022
80	Sonnenberg, C. and vom Brocke, J.	The missing link between BPM and accounting: Using event data for accounting in process-oriented organizations	Business Process Management Journal	2014
81	Spanaki, K., Karafili, E., Sivarajah, U., Despoudi, S. and Irani, Z.	Artificial intelligence and food security: swarm intelligence of AgriTech drones for smart AgriFood operations	Production Planning and Control	2021
82	Spenhoff, P., Wortmann, J.C. and Semini, M.	EPEC 4.0: an Industry 4.0-supported lean production control concept for the semi-process industry	Production Planning and Control	2020
83	Srai, S. J. and Lorentza, H.	Developing design principles for the digitalisation of purchasing and supply management	Journal of Purchasing and Supply Management	2019
84	Su, S.-L.I., Fan, X. and Shou, Y.	A design science-based case study of retail chain delivery operations and its implications	International Journal of Physical Distribution and Logistics Management	2021
85	Suzic, N. and Forza, C.	Development of mass customization implementation guidelines for small and medium enterprises (SMEs)	Production Planning and Control	2021
86	Takagi, N. and Varajão,	ISO 21500 and success management: an	International Journal	2022

ID	Authors	Paper Title	Journal	Year of Publication
	J.	integrated model for project management	of Quality and Reliability Management	
87	Tarpey, R. and Mullarkey, M.	Engineering Innovative Clinical Resource Management By Design: A guided Emergent Search Through a Complex Adaptive System of Systems	IEEE Transactions on Engineering Management	2021
88	Teixeira, E.L.S., Tjahjono, B., Alfaro, S.C.A. and Wilding, R.	Extending the decision-making capabilities in remanufacturing service contracts by using symbiotic simulation	Computers in Industry	2019
89	Torre, M.L., Valentinetti , D., Dumay, J. and Rea, M.A.	Improving corporate disclosure through XBRL: An evidence-based taxonomy structure for integrated reporting	Journal of Intellectual Capital	2018
90	Venter, S. and Grobbelaar, S.	A Technology Management Capabilities Framework for Technology Platforms	IEEE Transactions on Engineering Management	2022
91	Verdouw, C.N., Beulens, A.J.M., Reijers, H.A. and van der Vorst, J.G.A.	A control model for object virtualization in supply chain management	Computers in Industry	2015
92	Wagner, S.M. and Thakur-Weigold, B.	Supporting collaboration in humanitarian supply chains–insights from a design science project	Production Planning and Control	2018
93	Wang, Y., Chen, C.H., and Zghari-Sales, A.	Designing a blockchain enabled supply chain	International Journal of Production Research	2021
94	Winkler, R., Briggs , R.O., Vreede, G.-J., Leimeister, J.M., Oeste-Reiss, S. and Söllner, M.	Modeling Support for Mass Collaboration in Open Innovation Initiatives: The Facilitation Process Model 2.0	IEEE Transactions on Engineering Management	2020
95	Wu, L., Lu, W., Xue, F., Li, X., Zhao, R. and Tang, M.	Linking permissioned blockchain to Internet of Things (IoT)-BIM platform for off-site production management in modular construction	Computers in Industry	2022
96	Xu, H.	Minimizing the ripple effect caused by operational risks in a make-to-order supply chain	International Journal of Physical Distribution and Logistics Management	2020
97	Zellner, G.	Towards a framework for identifying business process redesign patterns	Business Process Management Journal	2013
98	Zhong, B., Wu, H., Xiang, R. and Guo, J.	Automatic Information Extraction from Construction Quality Inspection Regulations: A Knowledge Pattern-Based Ontological Method	Journal of Construction Engineering and Management	2022