

DESIGN SCIENCE IN OPERATIONS MANAGEMENT: CONCEPTUAL FOUNDATIONS AND LITERATURE ANALYSIS

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ABSTRACT

Goal: The aim of this paper is to show that design science and design science research may contribute as a methodological approach in the context of operations management. **Design/methodology/approach:** A systematic literature review was conducted to identify articles that have applied design science and design science research in operations management studies.

Results: The findings show that the concepts of design science and design science research are relevant and can be applied to conduct more relevant research. Moreover, this paper presents appropriate steps for conducting design science research and provides a summary of the main studies conducted in operations management until the present time. Some drivers are also suggested for advancing research in design science and design science research in operations management.

Limitations of the investigation: The main limitation of this paper is the lack of an empirical approach.

Practical implication: This paper can contribute to other researchers in the sense of presenting a methodological approach that can help reducing the gap that exists between the research that is developed by academics and what is necessary to support practitioners in organizations, mainly in operations management problems.

Originality/value: Publications that discuss research in the area of operations management generally consider the aims and practices determined by traditional sciences (natural and social) as a reference. Thus, it is important to explain the core concepts and foundations, as well as presenting the papers, which have already been developed using design science research in operations management, is necessary for advancing the discussion regarding the use of this method in this area.

Keywords: Operations Management; Design Science Research; Design Science; Research.

1. INTRODUCTION

The growing concern about the relevance of research carried out in the area of management has been the subject of discussion in a number of scientific communities. Among these communities, the Production and Operations Management Society in the USA, the British Academy of Management in the United Kingdom, and the Academy of Management in the USA stand out, among others. There has been increasing attention paid to the relevance of scientific studies published in journals, particularly those who address the topic of operations management, and which have been discussed by various authors (e.g. Van Aken, 2005; Pandza and Thorpe, 2010; Singhal et al., 2014).

Worry regarding the relevance of research is revealed in concern about the fact that the results from studies are rarely applied in organizations (Singhal et al., 2014). This lack of relevance entails a gap between what is developed in academia (theory) and what is, in fact, applied in practice in organizations (Slack et al., 2004).

Indeed, although relevance is fundamental for research in operations management, it is not the only factor to be considered by researchers in the area. In addition to being relevant to organizations, research should be recognized by the academic community, in order to guarantee the advancement of knowledge (Daft and Lewin, 2008). Therefore, rigor is another aspect that should be present from the research development process to the presentation of the results (Van Aken, 2005; Hatchuel, 2009).

This paper concentrates on research carried out in the area of operations management and is concerned with characterizing the appropriate research methods for carrying out relevant investigations, as well as conducting studies rigorously. Furthermore, there is a need to investigate how to bring practitioners closer to the academics. Some initiatives have been undertaken aimed at bringing the two together, such as a number of initiatives to increase the relevance of publications (Singhal et al., 2014).

Publications that discuss research in the area of operations management generally consider the aims and practices determined by traditional sciences (natural and social) as a reference. This occurs because research in operations management is founded on the notion that the aim of science is to explore, describe, explain, and occasionally predict (Romme, 2003; Van Aken, 2004). Consequently, this research concentrates on the construction of theories that explore, describe, explain, or predict reality and how organizational processes work (Taylor and Taylor, 2009).

However, this view regarding the way of constructing applied scientific knowledge in the field of management has

received a significant number of criticisms. The excessive focus on research based on traditional science makes it difficult to develop papers that can present new perspectives in terms of future research (Van Aken, 2004). Besides that, organizations need to improve their processes, but the results from academic research, via traditional methods, do not always make an adequate contribution (Platts, 1993).

Faced with the challenge of producing relevant research that maintains the necessary rigor for scientific advancement, this article aims to focus on the terms of these questions in another way. It argues for the possibility of using design science concepts (Simon, 1996) and the method that operationalizes this design science research. Moreover, it analyses publications involving design science in operations management, conducting a systematic literature review. To present the core concepts and foundations as well as presenting the papers already developed using design science research in operations management is necessary for advancing the discussion regarding the use of this method in this area. Some drivers are also suggested for advancing research in design science and design science research, contributing to the generation of innovations in the context of operations management research.

This paper is organized as follows: Section 2 describes the principles and foundations of design science a design science research; subsequently, a discussion about the importance of defining the classes of problems and the general types of artefact is made, as these are core elements for design science. Section 3 describes the research procedures used to conduct the literature review. Section 4 presents the main results of the literature review regarding design science and design science research in operations management and drivers for the advancement of research on this theme. Finally, section 5 makes some concluding remarks and suggests further work.

2. DESIGN SCIENCE FOUNDATIONS

Based on the design science approach, the problem of relevance and the theory-practice relationship assumes new forms. This problem is not about the transposition of scientific knowledge to the organizational environment. The question of the relevance of the knowledge produced and the tension in the theory-practice relationship require, in fact, new research logic (Lanamäki et al., 2011), in which research is effectively directed towards the design of artefacts that offer better solutions to existing problems (Van Aken, 2004). Thus, studies related to organizations should include design science and design science research as one of the main ways of conceiving knowledge and of conducting scientific research (Romme, 2003).



At this point it is worth making some distinctions between two scientific paradigms: (i) traditional science (natural and social); and (ii) design science. Traditional science “helps to understand the organizational phenomenon, discovering laws and forces that determine its characteristics, functioning and results” (Romme, 2003, p. 558). Design science is responsible for conceiving and validating systems that do not yet exist, whether by creating, recombining, or altering products/processes/software/methods, in order to improve existing situations.

The research conducted in the operations management area is based on both traditional science (natural and social) and design science. Table 1 presents some aspects that contextualize the research developed in the operations management area based on the distinct scientific paradigm.

For the production of knowledge about operations management it is necessary to develop research from the different scientific paradigms that exist. Traditionally, the operations management research has been developed based on natural science (Holmström et al., 2006). Such development has been important to generate and expand a base of knowledge with less dependence on the context in which it was generated (Van Aken, 2005). Consequently, its generalization capacity allows greater reach of the research results, the capacity of testing and refuting theories, and makes the existing theoretical gaps explicit.

At the same time, it's inherent to a productive system, internally and externally, to influence and be influenced by human and social factors (Wilkinson, 1983). This dynamic cannot always be properly captured from the point of view of natural science. In this sense, social science can generate knowledge in terms of how human and social aspects influence productive systems and management in general (Hatchuel, 2009). Thus, the knowledge generated from social science deepens and approximate the knowledge gener-

ated by natural science in the sphere of operations management. The integration between natural and social science reduces the gaps of the knowledge existing in operations management, regarding the phenomena that exist in the productive systems.

The knowledge about what already exists in operations management, generated from natural and social sciences is necessary (Huff et al, 2006), but not enough to create and to design new artefacts that can change the reality. These changes encompass both the reality improvement and, also, the generation of innovations.

To generate knowledge about what does not yet exist, developing artefacts that help solving problems and improving production systems, design science is the appropriate scientific paradigm. Furthermore, design science not only generates knowledge on how to design, but also uses the knowledge of natural and social science (Walls et al., 1992), as well as contributes in the development of artefacts that allow new research to be carried out both in the scope of natural science and social science.

To conduct an investigation in design science paradigm, it's recommended the use of adequate research methods (Takeda et al., 1990; Vaishnavi and Kuechler, 2009). One of these methods is the design science research (DSR). Then, while design science is the epistemological base, DSR is the method that operationalizes knowledge constructed in this context.

In this sense, DSR is a research method that aims to allow research to be conducted in various areas that focus on projecting and designing artefacts (Vaishnavi and Kuechler, 2009). DSR constitutes a rigorous research method for projecting artefacts, evaluating what was projected, and communicating the results reached (Çağdaş and Stubkjær, 2011).

Table 1. Operations management research based on natural, social and design science

Aspects	Traditional Science		Design Science
	Natural Science	Social Science	
Aim of the research	Identify patterns and establish laws that explain and predict the functioning of productive systems	Analyze how people behave and how their attitudes can interfere in productive systems	Design artefacts that generate satisfactory solutions to innovate or improve production systems
Outcomes	Propositions, construction and testing of theories and elaboration of explanatory and predictive models	Propositions, construction and testing of theories from human aspects inherent of productive systems	Artefacts (constructs, models, methods, instantiations and design propositions)
Research extent	Formal theory	Formal theory	Mid-range theories or generalization to a class of problems
Paper example	Of physics and factory physics (Spearman, 2014)	The moderation of lean manufacturing effectiveness by dimensions of national culture: Testing practice-culture congruence hypotheses (Kull et al., 2014)	Peer-to-peer inventory management of returnable transport items: A design science approach (Mason et al., 2012)

Generally, it is worth highlighting that DSR recognizes that the problems that exist in organizations are usually specific (Van Aken et al., 2012) and this specificity can, on some occasions, result in generalization of a piece of an unfeasible knowledge. In fact, Van Aken (2004) indicates that the generalization of the prescriptions extended to the artefacts need to be generalizable for a particular “class of problems”.

Classes of problems constitute an organization for the trajectory towards and development of knowledge generated within the paradigm of design science (Dresch et al., 2015). Classes of problems allow artifacts and hence their solutions to be not only a specific response to a problem in a context. It should be stressed that design science is not concerned with a solution in itself, but rather with the knowledge generated during the process of constructing the solution and which can be used to design new solutions (Van Aken, 2004).

Structuring the classes of problems is also a way of organizing the knowledge produced in the field of design science. Veit et al. (2017) present a structure that organizes the classes of problems related to the area of business process management. This structure contributes both to organizing knowledge and relating artefacts developed to solve each of the classes of problems identified in the business process management.

Based on the concept of class of problems, it is possible to address theoretical problems based on design science, since a problem can even be a way of testing a theory in the organizational reality. The use of this logic also becomes possible for formalizing the existing artifacts in organizations, and which need evaluations in other environments or contexts. This aspect also allows traditional research methods (e.g. action research, case study, and modelling) to be used for formalizing these existing artifacts (Van Aken, 2004).

An artifact can be considered as the organization of components of the internal environment to achieve objectives in a particular external environment (Van Aken, 2004, 2005). Artifacts can be defined as: constructs, models, methods, instantiations, or design propositions (March and Smith, 1995; Venable, 2006; Gregor, 2009; Van Aken, 2011).

Constructs, also known as conceptual elements, can be understood in the context of design science research as the vocabulary of a certain domain. Models are a set of propositions

that express the relationships between constructs (Venable, 2006). The third type of artefact is methods, which can be characterized as a set of steps that are necessary to perform a given task. They can be represented graphically, or even in the form of heuristics and algorithms. The fourth type of artefact is instantiations, which can be defined as the realization of the artefact in its real environment (March and Smith, 1995).

The fifth and last type of artefact refers to theoretical contributions that can originate from the application of various DSR applications. These artefacts, known as design propositions, correspond to a generic template that can be applied for the design of solutions of a particular class of problems (Van Aken, 2011). Thus, an artefact that generates a theoretic contribution originating from design science research is presented as a generalization of a solution for a particular class of problems. The logic that can be used to represent a design proposition is: “If you want to achieve Y in situation Z, then you must carry out action X” (Van Aken, 2004, p. 227).

The development of theories within the paradigm of design science can be divided into four main stages (Holmström et al., 2009), as shown in Figure 1. These stages represent the process of constructing a theory from its origin until the test stage, transforming fledgling ideas into simplified theories, and finally into formal and more robust theories.

The first stage to ensure the development of a theory based on design science is called incubation of the solution. It aims to create frameworks that can adequately represent the problem that is being studied. By using on a framework that best represents the problem, the researcher can suggest possible solutions to the problem in question (Holmström et al., 2009).

The second stage for the development of theories is called refinement of the solution in which the solutions developed are tested in a real environment, with the aim of examining whether the solution initially proposed is able to solve the problem in question (Holmström et al., 2009). These first two stages that support the construction of a theory usually occur in organizations when research in operations management is concerned. The contribution from professionals in organizations in the first two stages is important for the construction of theories based on design science; however, it should be noted that this contribution alone cannot be considered a scientific contribution (Dresch et al., 2015).



Figure 1. Stages in constructing a theory

Source: Adapted from Holmström et al. (2009)



The third stage is called mid-range theories. This stage seeks relevance that is not only practical but also academic for the knowledge initially generated in stages 1 and 2. It is worth noting that mid-range theories are dependent on the context in which the solutions were conceived and cannot be considered as general theories. That is, mid-range theories do not aim to generalize solutions for all contexts, but rather aim to generalize theoretical concepts that can contribute to the theme within a particular scientific community (Holmström et al., 2009).

Thus, it is necessary to define the limits for applying the artefact or solution developed in stages 1 and 2, since the theory will not work in the same way in other contexts. The core aim of mid-range theories is precisely to develop a deeper understanding of a theory in a particular application context, having been derived from the integration of a set of empirical studies that help to explain relationships between various concepts (Haynes et al., 2015).

The last stage, for constructing theories, corresponds to formal theories. Formal theories address the development of theories that can be applied independently of the context (Glaser and Strauss, 2012), thus differing from mid-range theories. With this last type of theory, scientific contribution becomes more important than practical relevance. Moreover, formal theories are usually subject to generalization. In the context of operations management, scientists should address stages 3 and 4, the third being the main one (Holmström et al., 2009).

3. RESEARCH DESIGN

To achieve the objective of this work, a systematic literature review was conducted based on the steps proposed by Morandi and Camargo (2015). The first step consists in the definition of the question addressed by the work. In the second step, it is necessary to define the work team, in this case, the authors of the paper. The third step is the definition of the search strategy.

The search strategy was based on international and national studies collected from the databases EBSCOhost, Web of Science, Scopus, and Emerald. These databases were selected due to its large coverage, especially in the subject of operations management. The search terms used were: (i) "operations management" combined with "design science" or "design science research"; (ii) "operations" combined with "management" and "design science" or "design science research". These terms were searched in texts as a whole and without setting a timeframe.

Then, in the fourth step, the search, eligibility and coding of the papers was performed. To make the eligibility of the papers, an inspectional reading was conducted among each of the studies found. During the inspectional reading process, titles and abstracts were read. The inclusion and exclusion criteria used to this paper are presented on Table 2.

The search resulted in 94 peer-reviewed publications (peer review papers on journals) that address design science or design science research together with operations management. While analyzing each of the 94 articles resulting from the literature review, it was found that most of the studies did not refer to the area of operations management itself. The terms "operations management" or "operations" and "management" appear throughout the texts, but not as the purpose of the publications. In many articles, those previous terms appear only in the references for the article and not in the body of the text. The same happened to the terms "design science" and "design science research".

After the reading, 18 publications were selected because they answered the review criteria, i.e. those papers considered operations management and design science (or design science research) as the study object.

To ensure the quality assessment, all the steps were carefully conducted and evaluated by the authors involved. After that, the synthesis of results was made, based on qualitative analysis, and was presented in Section 4.

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> text in English or Portuguese; publications that have been peer reviewed; papers that had design science or design science research as a methodology approach to operations management problems; papers that addressed conceptual issues concerning design science and design science research in operations management. 	<ul style="list-style-type: none"> papers that just cite the terms "design science" or "design science research" but not applied it; papers that just cite the terms "design science" or "design science research" but do not focus on this approach; papers that just cite the terms "operations" and "management" or "operations management" but not have this area as a study object.

4. DESIGN SCIENCE AND DESIGN SCIENCE RESEARCH IN OPERATIONS MANAGEMENT

The foundations of design science and DSR have still barely been explored and applied in the context of operations management research (Silva and Proença, 2015). Nevertheless, it is a topic that has been receiving attention from researchers, mainly due to the fact that it seeks greater relevance in the research carried out in the area of operations management (Proença, 2015; Holmström et al., 2009).

From the 18 publications, half of the articles deal with empirical studies, while the other half develops theoretical studies. The first publication addressing design science or design science research in operations management context was published in 2004. In the next sections, the analyzes performed in both theoretical and empirical articles will be presented.

4.1 Analysis of the theoretical articles that emerged from systematic literature review

The categories used to analyze the theoretical articles emerged during the reading of the articles, that is, *a posteriori*. Thereby, four categories were defined: (i) purpose of the paper; (ii) argumentative aspects of the article to use design science or design science research in the operations management area; (iii) contributions of the paper to design science or design science research in the operations management context; (iv) distinction between the knowledge produced in design science from the traditional science; and (v) presentation of some aspects related to the knowledge production in design science.

The first category (purpose of the paper) was analyzed considering the main objective of the papers, which can be, in this case: (i) presenting concepts of design science and/or design science research; (ii) criticizing the design science and/or design science research; (iii) theorizing from design science; (iv) discussing methodological issues; and, (v) systematic literature reviews. In the second category, the argumentative aspects that authors used, were analyzed. On the argumentative line employed by the authors, it is possible to highlight the rigor/relevance debate, the theory and practice gap, type of knowledge produced, among others.

The third category presents the main contributions that the paper adds to design science and DSR. The fourth category seeks to identify whether there are papers that address issues related to the distinction between the knowledge produced in design science and in traditional science. Finally, the fifth category analyzes whether the papers present some kind of issue or structure related with the knowledge production in design science (epistemological structure).

Table 3 presents a summary of the theoretical papers analyzed. The papers are organized according to the year of publication (from the oldest to the most recent).

Based on Table 3, it is possible to realize that, of the nine analyzed papers, four of them are concerned with the presentation of the concepts of design science and design science research in management (Van Aken, 2004; 2005; Huff et al., 2006; Van Aken and Romme, 2009). Two articles discuss methodological aspects of design science and design science research in operations management concepts (Dresch et al., 2015; Van Aken et al., 2016). One article addresses the theorizing aspects of design science (Holmström et al., 2009) and one paper presents a systematic literature review based on the publications that used design science or design science research in management context (Sordi et al., 2011). Finally, only one paper criticizes and makes explicit the limitations of the use of design science and design science research in the management area (Pandza and Thorpe, 2010).

All papers presented arguments to use design science or DSR in operations or management context. These arguments expose, for example, the advantages of design science or design science research use. The main arguments are related to the need to conduct a research based on relevance and rigor at the same time. Another argument is based on the demand to conduct research that bridge the gap between theory and practice in operations management.

Furthermore, it was possible to observe that most articles present an additional contribution to design science or DSR knowledge *corpus*. Van Aken (2004), as they present, for example, the concept of technological rules.

Besides, Huff et al. (2006) contribute by presenting another concept of design science and design science research in management, with a vision about the role of theory in these approaches. Van Aken and Romme (2009) contribute in the sense that they have the purpose of joint application of the evidence-based management (EBM) concepts and design science. In this case, evidence based management could be a good way to consolidate the currently dispersed and defragmented knowledge design science in management context.

Conceptual questions regarding design science in the field of operations management are broadly discussed by Holmström et al. (2009). The main contribution of these authors is the suggestion that the management research has four main phases: solution incubation, solution refinement, substantive theory, and formal theory. These phases can be understood as a macro framework that represents the logical process to produce knowledge in design science, namely, an epistemology.

Table 3. Summary of the theoretical papers

Reference	Purpose of the paper	Arguments to use DS/DSR in OM	Additional contributions to DS/DSR in OM	DS knowledge production (distinction with traditional science)	DS knowledge production (epistemology)
Van Aken (2004)	Presenting concepts of design science and/or design science research	Rigor-relevance problem in management research; Theory-practice gap; Prescriptive research;	DS producing technological rules to management context.	Traditional science produces descriptive knowledge and DS produces prescriptive;	Not mentioned
Van Aken (2005)	Presenting concepts of design science and/or design science research	Rigor-relevance problem in management research; Theory-practice gap; Prescriptive research;	Technological rules as products of Mode 2 knowledge production.	Traditional science produces descriptive knowledge and DS produces prescriptive; Mode 1 knowledge production is academic and Mode 2 is useful to problem-solving researches;	Not mentioned
Huff et al. (2006)	Presenting concepts of design science and/or design science research	Rigor-relevance problem in management research; Theory-practice gap; Prescriptive research;	The role of theory in design science.	Traditional science produces descriptive knowledge and DS produces prescriptive; Mode 1 knowledge production is academic and Mode 2 is useful to problem-solving researches;	Not mentioned
Van Aken and Romme (2009)	Presenting concepts of design science and/or design science research	Rigor-relevance problem in management research; Theory-practice gap;	DS combined with the EBM concept.	Explanatory research produces knowledge searching for the truth and design science research through improving the human condition;	Not mentioned
Holmström et al. (2009)	Theorizing from design science	Rigor-relevance problem in operations management research; Theory-practice gap;	Four phases of research (solution incubation, solution refinement, substantive theory, formal theory).	Traditional science produces an explanatory knowledge and design science produces an exploratory knowledge;	The knowledge can be produced from the practice (solution incubation) through theory (formal theory).
Pandza and Thorpe (2010)	Criticize the design science and/or design science research	Rigor-relevance problem in management research; Theory-practice gap; Explanatory or prescriptive research;	Types of design in management (deterministic, path-dependent and path-creation design).	Traditional science produces explanatory knowledge and DS produces prescriptive knowledge;	Not mentioned
Sordi et al. (2001)	Systematic literature review	Rigor-relevance problem in management research; Theory-practice gap;	Not identified	Not mentioned	Not mentioned
Dresch et al. (2015)	Discuss methodological issues	Rigor-relevance problem in operations management research; Theory-practice gap; Prescriptive research;	Distinguish the design science research from two other approaches (case study and action research)	The knowledge produced in traditional science describes and analyzes what already exists; in design science, the knowledge produced is prescriptive and problem-solving is oriented.	Not mentioned
Van Aken et al. (2016)	Discuss methodological issues	Rigor-relevance problem in operations management research; Theory-practice gap;	Explicit how to conduct and publish a design science research	Explanatory research produces knowledge searching for the truth and design science research through improving human condition;	Not mentioned

It should be noted that only one of the analyzed papers, criticize the use of design science or DSR in the management context (Pandza and Thorpe, 2010) and the contribution of this article lies precisely in the criticism made. Thus, in an attempt to overcome the limits of design science, Pandza and Thorpe (2010) propose that, in management, there are three types of design: deterministic, path-dependent, and path-creation; understanding and recognizing this design types can help the researcher understand how artefacts emerge.

Still, some contributions were identified in papers that discuss methodological aspects in DSR. Dresch et al. (2015) made a contribution since they distinguished the design science research from two other methodological approaches commonly applied in the operations management research: case study and action research. In this sense, it was possible to affirm that design science research can expand the methodological repertoire in operations management studies.

Likewise in terms of the methodological issues, Van Aken et al. (2016) offers guidelines for conducting studies that employ design science research. This paper is the inaugural essay of the design science department of the Journal of Operations Management. In addition to the guidelines on how to conduct and publish a DSR, Van Aken et al. (2016) present the main aspects that a good study must present in this context: practice relevance and pragmatic validity, which is related to the arguments of all the authors analyzed in this section: rigor-relevance to conduct the research and search to reduce the gap between theory and practice.

Some points can be observed from the analysis of the articles that emerged from the systematic literature review. Firstly, it was possible to notice that not all articles discuss or distinguish the knowledge produced in design science from the one produced by traditional science. Moreover, even when the authors seek to make a brief distinction among design science and the traditional science, there is no agreement between them. None of the analyzed papers, present criteria to distinguish the knowledge produced in design science from the one produced in natural and social science.

Second, it can be observed that there is no clarity, in the analyzed papers, about the distinction between design science and design science research. It is worth highlighting that design science is the epistemological paradigm that grounds the research that has focus on prescription and in problem solving. The DSR, in turn, is the methodology that can be used to operationalize the research based on the paradigm of design science. Not understanding or distinguishing it properly may hinder the distinction between design science paradigm and the natural and social science, for example, or between design science research and other methodological approaches (case study, action research,

grounded theory, etc.). Besides that, not distinguishing between design science and DSR may compromise the use of traditional research approaches, such as case study and action research, in the design science paradigm. To elucidate this issue, new works could be made in the sense of distinguishing DSR from other methodological approaches, allowing the advancement of the work of Dresch et al. (2015).

Finally, it is possible to perceive that it lacks a logic that establishes the knowledge production process. This is an epistemology that clearly details the knowledge production in the design science paradigm.

4.2 Analysis of the empirical articles that emerged from systematic literature review

Regarding the empirical articles, nine were analyzed because they used DSR or the paradigm of design science to conduct research in the operations management area. The categories used to analyze the empirical articles were based on the guidelines of Hevner et al. (2004) and in the framework of March and Smith (1995), who distinguish between research outputs and research activities. The definition of these criteria to guide the analysis of the empirical articles is based on the fact that most of these papers cite the work of Hevner et al. (2004) and March and Smith (1995). Table 4 presents the articles analyzed, as well as the purpose of each research, the artefact developed/evaluated and whether they considered the seven guidelines proposed by Hevner et al. (2004) to support an effective design science research.

As can be seen in Table 4, all the articles clearly explain the purpose of the research developed in operations management, applying the DSR approach. These studies were conducted in industries all around the world. Most of these articles present clearly the seven guidelines proposed by Hevner et al. (2004): (i) design as an artefact; (ii) problem relevance; (iii) design evaluation; (iv) research contribution; (v) research rigor; (vi) design as a search process; (vii) communication of research. The cell is gray when the article meets the guideline.

Smart et al. (2007), for example, developed an artefact to guide the process of network design for innovation in pharmaceutical companies in the UK. However, the problem relevance and the design evaluation is not evidenced in the article, that is, the way the artefact was evaluated in order to analyze this effectiveness and utility. The work of Mason et al. (2012), which was also developed in the UK, presents, throughout the paper, an evident concern about attending all the Hevner et al. (2004) guidelines. In this way, the authors presented all the process of development and evaluation of a relevant artefact to assist in the inventory management of returnable items in a package gas industry.

Table 4. Summary of the empirical articles analyzed with the guidelines of Hevner et al. (2004)

#	Reference	Purpose of the research	Artefact	Design science research guidelines (Hevner et al. 2004)						
				Design as an artefact	Problem relevance	Design evaluation	Re-search contributions	Re-search rigor	Design as a search process	Communications of research
1	Smart et al. (2007)	To propose an artefact to guide the process of network design for innovation in pharmaceutical companies	Framework architecture of design rules							
2	Moon and Ngai (2010)	To present an intelligent system for the management of fabric samples for the textile industry in Asia	R&D Framework							
3	Mason et al. (2012)	To present an artefact to assist in the inventory management of returnable items in a gas industry in UK	Inventory management system							
4	Soinio et al. (2012)	To propose a framework for categorizing logistics services to SMEs in Finland.	Framework for categorizing logistics services							
5	Baloh et al. (2012)	To present an artefact that shows how the individual knowledge of the workers interferes in the company knowledge itself	Knowledge management system							
6	Kanjana-ootra et al. (2013)	To evaluate the efficiency and effectiveness of knowledge management system developed by a manufacturing company	Knowledge management system							
7	Saraswat et al. (2014)	To develop and evaluate a graduate level Business Process Management (BPM) course with process modelling and simulation as its integral component	BPM course							
8	António and Serra (2015)	To develop a performance management system for the hotel sector in Portugal	Performance management system							
9	Leite et al. (2016)	To develop an artefact to support transparency on construction workers attributions and performance	Gamified System							



A second point is the lack of explanation of some of the empirical papers in highlighting the relevance and the pragmatic validity of the studies conducted in the operations management area. According to Van Aken et al. (2016), the practical relevance and the pragmatic validity should be clearly evidenced in studies that apply the DSR, because these aspects are fundamental to bridge the theory and practice gap.

Finally, most of the empirical papers do not characterize, in detail, the internal and external environments of the developed artefacts. In addition, they do not present the class of problems that the artefact is addressing. This lack of detail hinders the advancement of knowledge on how to design. It should be noted that some studies (Baloh et al., 2012; Mason et al., 2012; Kanjanabootra et al., 2013) stand out positively and can be used as a source in order to establish the logic of development and evaluation of artifacts, among other things.

4.3 Contributions of design science and design science research to operations management

Although the operations management area is significantly close to the context of the organizations, by the nature of its study object, the research-oriented paradigm is based on the traditional sciences. The researchers in the operations management field, guided under this paradigm, are important for expanding knowledge about production systems and their changes over time.

Nevertheless, design science and DSR may contribute to conduct research in operations management. The contributions of design science and DSR are evidenced at different levels of analysis. From the point of view of the research paradigm, it is necessary to extend valid and generalizable knowledge that can be used to design and implement artefacts to create or improve productive systems and the management itself.

The prescriptive knowledge generated from a specific and generalizable situation expands and complements the body of knowledge that is produced in the area of operations management. Therefore, the design science paradigm contribute to guide the knowledge production about how to design better solutions, implement them in organizations and evaluate existing solutions. In this sense, it is necessary to develop studies that are specifically concerned with the knowledge produced on how to design, that is, to deepen discussions on design theory (Hatchuel et al., 2018).

The development of artefacts, itself, can contribute to the expansion of knowledge in terms of traditional sciences. There are examples in this sense reported by the literature

in other fields of study (e. g. Lenoir, 2005). An example of an artefact that is contributing to the traditional science is the particle accelerators, which allow man to understand more and more the universe and its laws.

The systematic literature review has shown a small number of studies associated with design science in the operations management field. One possible implication of the reduced attention to prescriptive knowledge concerns the distance between researchers and managers or practitioners.

From the point of view of the research method, DSR can contribute to guiding the conduction of studies aimed at generating satisfactory solutions to the problems associated with productive systems. The portfolio of research methods for conducting research in the operations management area has been restricted to action research and case study and, in some situations, modeling (generation of optimization models and algorithms). However, the set of concepts (classes of problems, artefacts, and satisfactory solutions) and methodological steps (Figure 1) can contribute to increase the usefulness of the prescriptions (solutions) originated from these studies. For example, the class of problems concept could support the operations management area to select existing artefacts for a given situation and help comparing the proposal to be made with the existing set of solutions (artefacts).

At the same time, classes of problems expose the extent (generalization possibility) of the proposed solution and its capacity to be used in other contexts. The conduction of case studies or action research does not explicit methodologically this kind of concern.

The artefact concept also induces operations management investigators to conduct prescriptive research to make explicit the key elements for problem-solving. The use of the artefact concept indicates the need to expose the external environment (context and the exposed conditions in which the artifact will be implanted), implying in limits or preconditions for the success of the development of the artefact. In turn, the exposure of the internal environment invites the exposure of which mechanisms and/or elements were used and articulated for the construction of the artefact itself.

The exposure of the external and internal environment sediments the contingency and constructive heuristics, respectively (Dresch et al., 2015). The contingency and constructive heuristics constitute the knowledge generated by the research and, over time, can be consolidated as design propositions. These aspects are not observed in the studies that aim to produce solutions when conducted by the paradigm of the traditional sciences and by the research methods currently used.

5. CONCLUSIONS

This paper has attempted to present design science in general, and particularly DSR, presenting this method and its innovative aspect to contribute to research conducted in the operations management field. For this, the main concepts were outlined, presenting the main distinctions between design science and traditional science (natural and social).

In this sense, it is possible to observe that there are efforts to apply design science and DSR in the operations management field. Nevertheless, the studies have been produced in a dispersed way.

This involves an important discussion regarding research conducted in the field of operations management, using approaches such as design science (as a scientific paradigm) and design science research (as a research method). However, it is known that this discussion is not limited to this article. Moreover, this article can contribute by presenting a methodological approach that can help reducing the gap that exists between the research that is developed by academics and what is necessary to support practitioners in organizations, mainly in the problems of operations management.

Moreover, the aim of this paper was to highlight the particular need to broaden the discussion regarding research methods that can be used with the aim of making contributions to the base of knowledge in a particular area, but which are not only concerned with rigor, but also with the relevance of what is studied. Another important contribution of this paper consists in a presentation of a set of articles that addressed design science and DSR in operations management.

However, various aspects were not addressed and deserve attention in future research. These aspects could constitute a research agenda that addresses design science or DSR in operations management. Firstly, it would be interesting to analyze the research that has applied DSR as a method, in order to verify its adequacy for the needs of research in the operations management area, verifying whether this method, in fact, helps reducing the existing gap between academia and organizations. Secondly, studies could make advancements in the sense of applying traditional research methods in the context of design science paradigm. Thirdly, other research could be conducted with the aim of evaluating the real nature of knowledge generated on design science paradigm.

Finally, it can also be highlighted that a set of journals that consolidated classes of problems and the artefacts developed by the scientific community would be necessary. These consolidations could constitute a relevant mechanism

for interaction between what is produced in academia and the practitioners in organizations.

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