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ORIGINAL ARTICLE

Design Science Research in practice: review of applications in Industrial Engineering

Design Science Research na prática: revisão sobre as aplicações na Engenharia de Produção

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Abstract: The present study analyzes aspects of the application of the Design Science Research (DSR), identifies the problem classes, as well as the contributions and limitations in the implementation of the method in the various areas and subareas of Industrial Engineering. The research uses the method of systematic literature review through a review of articles using the Atlas.ti 8 software, it performs network analysis for classification by area and grouping by similarities, analyzing the aspects proposed in the objective of the study. Through investigation, it offers theoretical and practical contributions. First, it provides a comprehensive view of how DSR has been applied in research, identifying problem classes, artifacts, and classification areas in Industrial Engineering. Similarly, it contributes to a research agenda to replicate the method in emerging areas.

Keywords: Design Science Research; Research method; Industrial Engineering; Improving process; Problem classes; Emergent topics.

Resumo: O presente estudo analisa aspectos da aplicação da Design Science Research (DSR), identifica as classes de problemas, bem como as contribuições e limitações na aplicação do método nas diversas áreas e subáreas da Engenharia de Produção. A pesquisa utiliza o método de revisão sistemática da literatura. Por meio da uma revisão de artigos com o uso do software Atlas.ti 8, efetua análises de redes para classificação por áreas e agrupamento por similaridades, analisando os aspectos propostos no objetivo do estudo. Através da análise, oferece contribuições teóricas e práticas. Primeiro, fornece uma visão abrangente de como a DSR vem sendo aplicada nas pesquisas, identificando as classes de problemas, os artefatos e a área de classificação na Engenharia de Produção. Da mesma forma, contribui com agenda de pesquisas para replicação do método em áreas emergentes.

Palavras-chave: *Design Science Research*; Método de pesquisa; Engenharia de Produção; Melhoria de processo; Classe de problemas; Tópicos emergentes.

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1 Introduction

In recent years, the Design Science Research (DSR) methodology has stood out as an adequate research method in the scientific area. DSR is an artifact-oriented discipline that aims to solve known problems or design something that does not yet exist (Simon, 1996; Van Aken, 2004). Also, DSR focuses on achieving the intended objectives. Such objectives may be related to organizational contexts, machines, economics, and society (Dresch et al., 2015; Hevner et al., 2019). The project comprises an understanding of the studied context and the application of relevant technical and scientific knowledge. The construction involves developing an artifact based on experience and its demonstration (Doyle et al., 2016). For this reason, the DSR has been gaining notoriety among research methods (Van Aken, 2004; Van Aken et al., 2016).

The literature indicates that such fame occurs due to the following aspects: 1) The DSR focuses on eliminating the distance between theory and practice; 2) Explains a science that aims to prescribe the solution to specific problems (Van Aken, 2004; Tuunanen et al., 2010). The information systems area was a pioneer in the application of DSR (Peffers et al., 2007). However, DSR is used with the research method in several areas of knowledge. In addition to applications in engineering (Lacerda et al., 2013; Dresch et al., 2019), other applications, such as, for example, in health (Ngai et al., 2009), public management (Nfuka & Rusu, 2013), accounting (Chiu et al., 2019), logistics (Matana et al., 2020), business (Costa et al., 2020), education (Heathcote et al., 2020) and quality management (Castillo-Martinez et al., 2021) has been reported in the literature. In addition to the diversification of application areas, the scientific community's interest in the topic has also increased, as shown in Figure 1.

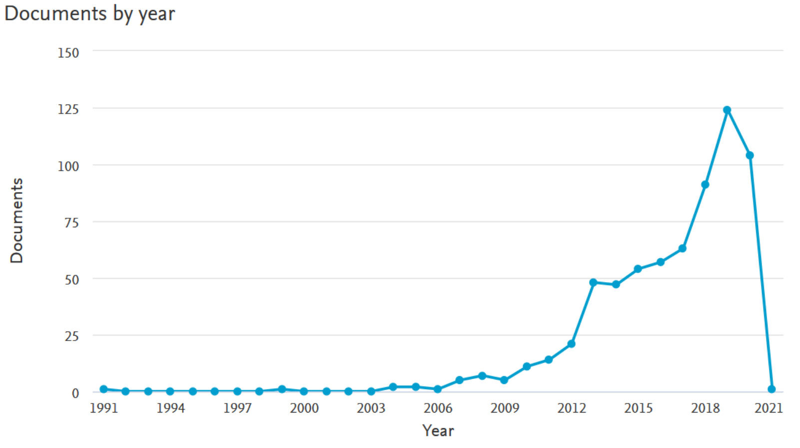

Figure 1. Cientometria – evolução da publicação anual. Source: SCOPUS, 2020.

Figure 1 presents the scientometric data of a quick search in the SCOPUS database, using "design science research" as a search term, with no time limit and considering publications in engineering and business areas until October 2020. The data indicate that the number of published studies increases, reinforcing the academic community's interest and the importance of the subject in focus.

Despite the growing number of publications, some questions on the topic remain. Öhman (2019) argues that the need to expand practical relevance in operations management suggests that research based on Design Science should base its discussion around how theory is translated into practice. However, no relevant aspects of the application of DSR were identified in the literature consulted about the contributions and limitations of artifacts created from the application of the method. There were also no studies that recognized the classes of problems for which the artifacts created from the DSR can indicate solutions. For Lacerda et al. (2013), this recognition is essential for establishing a framework of known empirical solutions. Such a condition still potentially reduces the possibility of generalizing the results. However, a survey of the application of the DSR in the engineering area, sub-area of production, was also not found in the consulted literature. Thus, this research proposes to investigate how DSR can contribute to problems and consequent improvement of processes in Production Engineering. Thus, this study aims to review the literature to identify and analyze such aspects systematically.

Consistent with the research question's breadth, this research takes an inductive approach to grounded theory, according to Wolfswinkel et al. (2013). Reviewed 122 articles that used the DSR search method. After the researchers (the authors of this article) reached a 68 papers corpus and considered only the method's articles. In the end, the corpus of 12 articles was used for in-depth analysis. This analysis focused on identifying aspects related to the application of the DSR, recognizing the problem classes, and the contributions and limitations in the application of the method. Figure 2 summarizes the article review and selection process. The research focuses on analyzing articles related to Industrial Engineering that mention: Organizational Performance Management; Production and Operations Systems Management, Project Management; Production Engineer Training Study; Information management, and technology management. According to the Brazilian Association of Industrial Engineering (ABEPRO), the areas of application in Industrial Engineering were classified. According to de Lima et al. (2019), the ABEPRO classification is the most comprehensive and generic Industrial Engineering.

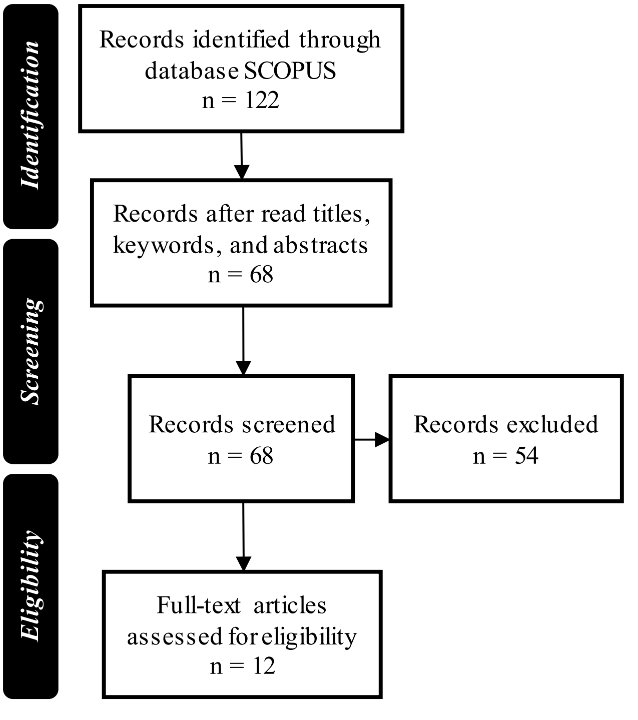

Figure 2. Article review and selection process. Source: Prepared by the authors of the research.

This research offers theoretical and practical contributions. First, it provides a comprehensive view of how DSR has been applied to research in various areas, identifying problem classes, artifacts, and classification areas in Industrial Engineering, according to ABEPRO. Similarly, it contributes to the practice, that is, by presenting research that can be replicated in other organizations. Also, the study aims to indicate DSR contributions and limitations reported in the investigated articles. Network analyses were performed to classify according to the area as well as grouping by similarities. All analyses were performed with the aid of software, providing greater credibility to the data investigated.

DSR is concerned with the knowledge to generate solutions (Van Aken, 2004), generating knowledge intentionally and contingently (Simon, 1996) without losing sight of generalization (Dresch et al., 2015). A study conducted by DSR follows a set of defined steps. Based on the refinement of several proposals for conducting DSR, Dresch et al. (2015) propose a method composed of 12 degrees, presented in Figure 3.

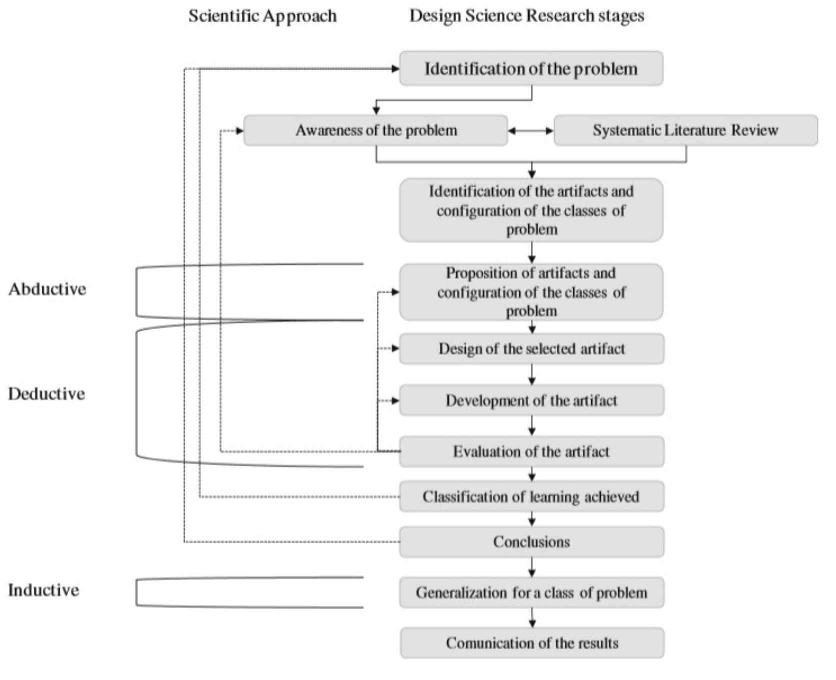

Figure 3. Main steps to conduct a design science research. Source: Dresch et al., 2015, p. 125.

The first step is problem identification, followed by problem awareness and systematic literature review (Peffers et al., 2007; Kuechler & Vaishnavi, 2008). These first three steps are called problem definition. The problem to be investigated arises mainly through the investigator's interest, who must clearly and objectively justify the problem's importance. The output of these steps is the question of formalized research. As much information as possible should be sought, including facets, causes, and interrelationships of the problem with the context in question, as well as consulting pre-existing knowledge databases (Dresch et al., 2015). The fourth step is the identification of artifacts and problem class configuration. Once the problem is understood, the researcher should identify previously developed artifacts to address such issues and possible problem classes (Dresch et al., 2015).

The generalization of knowledge generated from Design Science Research can be framed in a particular case class (Van Aken, 2004) or problem classes. There is no universal definition of problem classes. Takeda et al. (1990) suggested the need for enumeration of problems, while Dresch et al. (2015) define as the organization of a set of practical or theoretical issues that contain useful artifacts for action in organizations. Table 1 shows examples of problem classes.

Table 1. Examples of problem classes.

Problem classes		
Strategic Alignment	Project management	Process modeling and improvement
Problem analysis and decision support	Knowledge management	Motivation
Process automation and standardization	Governance	Production Organization
Supply Chain	Implementation of systems	Planning and production control
Skills	Performance indicators and measures	Relationship with customers and services
Organizational culture	Innovation	Relationship and process integration
Costs and Investments	Process Mapping	Risks
Information flow and management	Best practices	Information systems
Change management	Cost Measurement	Outsourcing
Processes management	BPM Methodologies	

Source: Prepared by the authors of the research.

The class of problems can be broad or specific. The framing of the solution generated by the DSR for a type of questions, as exemplified in Table 1, contributes to the research's generalization, which consequently allows the artifact to be applied to similar problems later (Dresch et al., 2015).

The next step is to propose artifacts to solve the problem in focus. Therefore, most creative and abductive (Dresch et al., 2015), at this stage, the researcher will use the previous knowledge to propose robust solutions that can be used to improve the current situation (Dresch et al., 2015). One or more alternative artifacts to solve a problem must be explicit (Manson, 2006). The researchers can propose suggestions for future artifacts.

The next step is the artifact design. From the previous steps, an artifact must be selected to go through the following steps. The procedures for constructing and evaluating the artifact should be described. The seventh step is the development of the artifact itself. The literature indicates different approaches to designing artifacts, such as algorithms, graphics, prototypes, among others (Dresch et al., 2015). Table 2 presents the classification of artifact types.

Table 2. Artifact types.

Algorithm	An approach, method, or process described mostly by a set of formal logical instructions.
Construct	Concept, assertion, or syntax that has been constructed from a set of statements, assertions, or other concepts.
Framework	Meta-model.
Instantiation	The structure and organization of a system's hardware or system software or part thereof.
Method	Actionable instructions that are conceptual (not algorithmic).
Model	Simplified representation of reality documented using formal notation or language.

Source: Prepared by the authors of the research.

According to Table 2, artifacts can be classified into algorithms, constructs, models, instantiations, methods, and models (Peffers et al., 2012). At the end of this stage are the artifact itself in a functional state (Manson, 2006) and the construction heuristic, which is one of the contributions of DSR.

The next step is the evaluation, which analyzes the artifact’s behavior in solving the problem for which it was designed. Van Aken et al. (2016) see testing as a prerequisite for understanding the mechanisms that produce the intended results through design. Different authors have identified several methods, which can be used in combination or not, to evaluate DSR. One form of assessment is observational to observe the artifact in detail in the real business environment (Dresch et al., 2015). The evaluation can also be carried out with the support of case studies, action research, focus groups, experiments, and simulations (Venable et al., 2012).

Steps nine and ten spells out learning and completion. The purpose of these steps is to ensure that the research can serve as a reference for knowledge generation in both the practical and theoretical fields (Dresch et al., 2015), exposing the success and failure points and their decisions (Manson, 2006). The final stages of the method are associated with class generalization and problems and communication of results. Conception allows the generated knowledge to be applied to other similar situations later. Finally, communication of results can occur through publication, seminars, and congresses. (Dresch et al., 2015).

2 Research Design

This research method can be divided into three essential phases: definitions of the research and data collection method and analysis of results, as shown in Figure 4.

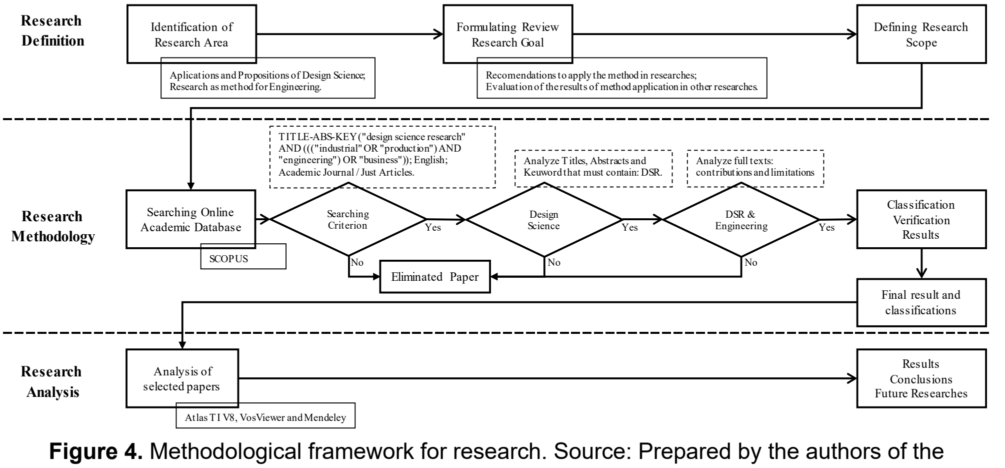

Figure 4. Methodological framework for research. Source: Prepared by the authors of the research.

This paper aims to systematically review the literature on DSR application aspects, problem classes, contributions, and limitations of artifacts created from applying the method. In line with the research question’s breadth, the inductive approach was adopted to review the literature on DSR. The method includes the guidelines reported by Wolfswinkel et al. (2013) and followed the steps mentioned: 1) definition of the scope of the literature review, 2) literature search in the online databases; 3) selection of the corpus of articles; 4) corpus analysis; and finally, 5) presentation of the findings.

According to Figure 2, initially, queries were made to the SCOPUS database to obtain an understanding provided by the literature on DSR in various areas. The choice was restricted to this database because it contains more influential journals than the Web of Science - WoS (Falagas et al., 2008; Vieira & Gomes, 2009). In fact, according to Vieira & Gomes (2009), SCOPUS has a coverage of 110% greater than WoS, and 2/3 of the total documents searched are on both bases. The SCOPUS database (developed by Elsevier) combines characteristics of PubMed and Web of Science (Falagas et al., 2008). The terms were searched ("design science research"); ("Industrial" OR "production"), AND ("engineering" or "business"). These classifications indicate that the literature guide that the development of industrial transformation may involve new business opportunities (Schneider, 2018). The consultation was limited to English studies and resulted in 122 articles. The 122 articles were read in the titles, keywords, and abstracts, resulting in 68 articles that demonstrated the artifacts created from applying the method, applying the DSR method. The DSR method application studies' concentration focused on engineering areas was established to ensure that the review sample size remained viable. In the end, 12 articles were selected for analysis of the aspects of the research objectives.

These articles were imported and coded using Atlas.ti 8 software, following the coding procedures described in the literature (Corbin & Strauss, 1990). The researchers established three codes: 1) Artifacts, 2) Contributions, and 3) Limitations. For each code, the categories were defined as follows: 1) Artifacts - framework, modeling, artifact/method, algorithm, instantiation; 2) Contributions - production/industry, customer, software, simulation, relationships, business/simulations, supplier, project, finance, learning, and knowledge; 3) Limitations - participants, learning, support tools, vendor, simulation, generalization, credibility, production/industry, business/simulation, and knowledge.

Finally, integrations and analysis of relationships were performed using groups and categories. These integrations and analyzes resulted in the study's contributions. Articles were collected from the SCOPUS database on 07/17/2019, and no period restriction was required. The return of 122 articles was obtained, to which the exclusion criteria were applied (as shown in Figure 3), which involved the analysis of titles, abstracts, and keywords. These articles were imported into Mendeley to separate articles to be read by the researchers. After reading the titles, abstracts, and keywords, a balance of 68 articles was obtained for a detailed reading. Of the 68 resulting articles (read in detail), we excluded 54 papers because they did not contribute to the research theme and do not be according to the ABEPRO classification, leaving 12 articles for insertion Atlas.ti 8 software (systematically reviewed through content analysis).

The data analysis process occurred through the triangulation of information, according to Bardin's Content Analysis (Bardin, 2011). This method analyzes a set of information based on objective and systematic procedures, structured in three specific and complementary phases: (i) pre-analysis, which consists of reading the documents; (ii) exploration of the material, that is, the elaboration of compilation units with decoding, classification and categorization techniques; and, (iii) treatment of the results, which in turn, consists of the elaboration of categories and explanations concerning the information obtained. Thus, for such categorization, the ABEPRO classification was used.

3 Results

According to the "Research Analysis," the 12 selected articles are presented in Table 3.

Table 3. Selected articles.

Author	***Journal***	***Problem class***	***Application Subarea***
Dresch et al. (2019)	International Journal of Productivity and Performance Management	Process Improvement	1.1. Production Systems and Operations Management
Sanches et al. (2015)	Total Quality Management & Business Excellence	Process modeling and improvement	4.1. Quality Systems Management
Anke (2019)	Electronic Markets	Process modeling and improvement	5.3. Product Planning and Design
Saraswat et al. (2014)	Journal of Information Systems Education	Process modeling and improvement	10.1. Production Engineer Training Study
Amrollahi & Rowlands (2018)	Information & Management	Processes management	6.1. Strategic and Organizational Management
Mamoghli et al. (2018)	Business Process Management Journal	BPM Methodologies	6.1. Strategic and Organizational Management
Krawatzeck et al. (2013)	Conference: ICDSRIS	Project management	6.2. Project management
Manfio & Lacerda (2016)	Gestão & Produção	Project management	6.2. Project management
Lehnert et al. (2016)	Business Research	Project management	6.2. Project management
Hao et al. (2015)	Tourism Management	Relationship with customers and services	6.3. Organizational Performance Management
Wu (2009)	Information & Management	Knowledge management	6.4. Information management
Wang et al. (2011)	Information & Management	Knowledge management	6.7. Technology Management

Source: Prepared by the authors of the research.

As for the problem class "process improvement," Dresch et al. (2019) present an article focusing on demonstrating a method to assist micro and small enterprises in the industrial sector in adopting Lean Manufacturing practices. Thus, according to this class and research objective, it was classified as Management of Production and Operations Systems.

Relating to the problem class "modeling and process improvement," he classified the articles by Sanches et al. (2015); Anke (2019); Saraswat et al. (2014). Sanches et al. (2015) analyze a problem to determine the root causes, presenting an artifact composed of procedures and algorithms (coded in software), aiming to identify the potentially most important cause for a given effect. Already, in Anke's research (2018), he proposes a method for the integrated financial evaluation of intelligent design services. Saraswat et al. (2014) describe the development and evaluation of a postgraduate level Business Process Management (BPM) course with process modeling and simulation. Thus, referring to the areas of ABEPRO, these articles were classified as quality system management, product planning, and design and production engineer training study, respectively.

Amrollahi & Rowlands (2018) employ a design science perspective on the process management problem class to propose a methodology for open strategic planning (OSP), classifying it as strategic and organizational management. In this same subarea of ABEPRO, Mamoghli et al. (2018) present an article focusing on assisting organizations in assessing both information technology (IT) and human factors, their business processes (BPs), taking into account the interdependence and alignment of these factors rather than to consider them independently. Thus, the latest research falls into the problem class, “BPM methodologies.”

Concerning the problem class “project management,” Krawatzeck et al. (2013), Manfio & Lacerda (2016), Lehnert et al. (2016) address this. Krawatzeck et al. (2013) develop a DSR process that enables the construction of so-called software-intensive methods, which considers the interdependencies of two artifacts and optimizes conventional DSR processes, including initial feedback loops, allowing the identification of initial project weaknesses. Manfio & Lacerda (2016) investigate the scope of product development projects for food industry companies, proposing an artifact that best addresses the research object. Finally, Lehnert et al. (2016) present a planning model to assist organizations in determining which projects, at the process and BPM level, should be implemented, the sequence of which maximizes business value. These three surveys qualify at ABEPRO as project management.

About the class of problems “customer relationship and services,” Hao et al. (2015) follow a design science research paradigm to develop a learning approach based on genetic algorithms to understand customer satisfaction and its psychometric reasons. Thus, this is classified as, according to ABEPRO, organizational performance management.

Finally, about the problem class “knowledge management,” Wu (2009); Wang et al. (2011) present a methodology for organizations. Wu (2009) develops a methodology based on improved cognitive adjustment theory to synthesize knowledge in forms. While Wang et al. (2011) demonstrate a performance-oriented approach, clarifying organizational goals and individual learning needs linked to e-learning applications. As for the ABEPRO subareas, these surveys are classified as information management and technology management, respectively.

Like any other study, this research has some limitations, which may serve as opportunities for future studies. First, the study focuses on the literature review of the use of DSR in the industrial engineering segment. As such, the results cannot be generalized outside the context of this segment. Second, the research agenda opportunities dealt with emerging topics in this segment. Researchers developing artifacts may contribute to many other research gaps using DSR. Future research may deepen the research agenda for other areas of engineering and management. We also believe that further research can contribute to disseminating, strengthening, and enhancing DSR use in the most diverse realms of scientific research.

3.1 Research artifacts

For the classification of research, the article by Peffers et al. (2007), in which the authors present the types of artifacts used in DSR. Figure 5 presents a network analysis, made in Atlas.ti 8, about the artifacts identified in the 12 articles. These artifacts were identified according to the complete reading of the text.

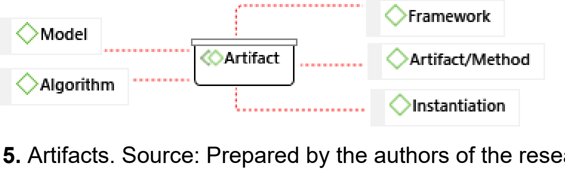

Figure 5. Artifacts. Source: Prepared by the authors of the research.

In the research by Sanches et al. (2015), the authors present a framework as an artifact for developing a meta-model. It aims to determine the root cause of a particular effect ("relevant problem"), with a rigorous assessment of the usefulness of the artifact ("design assessment"), assisting in model preparation and system dynamics.

For a simplified representation of documented reality using formal notation or language, Anke (2019); Saraswat et al. (2014); Lehnert et al. (2016); Mamoghli et al. (2018) use modeling as an artifact. In Anke's research (2018), the authors develop a model for financial services and business while Saraswat et al. (2014); Lehnert et al. (2016); Mamoghli et al. (2018) apply BPM as an artifact in undergraduate disciplines, in the implementation of individual processes and for maturity models, respectively.

Regarding conceptual instructions, the method is artifacts. Corroborating this, Wu (2009) presents a method for sharing knowledge across sectors, while Wang et al. (2011) expand this concept by demonstrating an artifact for self-learning by electronic means. Manfio & Lacerda (2016) created the artifact that aims to serve the food industries, regardless of size, product to be developed, or even the company's structure and can be adapted to other sectors. Along the same lines, Dresch et al. (2019) develop a method for implementing Lean Manufacturing tools in micro and small companies in the industrial sector. Finally, Amrollahi & Rowlands (2018) present a method of relating different strategic plan components.

An approach, method, or process mainly described by a set of formal logical instructions represents an algorithm as an artifact. Thus, Hao et al. (2015) are structured in genetic algorithms to understand customer satisfaction and psychometric reasons. It can be interpreted as a heuristic or evolutionary algorithm. When it comes to structuring and organizing a system or part of it, instantiation is an artifact. Thus, the research by (Krawatzeck et al., 2013) considers interdependencies and optimizes conventional DSR processes, including new feedback loops for intermediate outcomes, allowing identifying initial project weaknesses.

3.2 Research contributions

The grouping of contributions has been classified by keywords (codes) that represent their purpose. The codes that represent them are presented in Figure 6. Similar to the previous subsection, these data were analyzed in Atlas.ti 8 software.

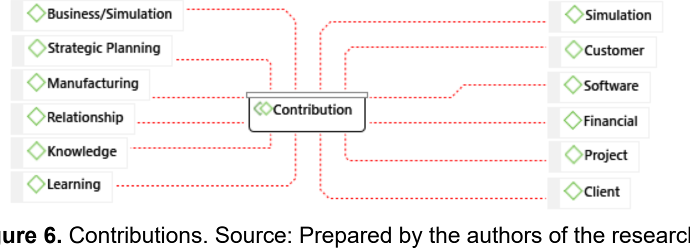

Figure 6. Contributions. Source: Prepared by the authors of the research.

Beginning the analysis of contributions, the research by Manfio & Lacerda (2016); Dresch et al. (2019) serves researchers in the industrial sector, that is, production/industry. Thus, Manfio & Lacerda (2016) highlight that the presented method offers a systematization establishes the procedures to define the scope of food product development projects, assists in the construction, and ensures that all stages are analyzed evaluated, and evaluated. Including contributing to and supporting future research in finding solutions to new problems. In contrast, Dresch et al. (2019) contribute a method for incorporating Lean Manufacturing practices into micro and small enterprises; consequently, contributions to the process and the implementation of productive systems.

From the client's point of view, there is research by Hao et al. (2015). This shows that different customer segments have different opinions about the importance of different evaluation criteria, including constructive suggestions for developing marketing campaigns and improving online travel agency services.

Concerning software, Sanches et al. (2015) demonstrate the practical benefits of using the artifact proposed by the research. The research contributions were perceived and identified by the users, who highlighted the practical nature of the method and the ability to identify the root cause of a given problem by the software (based on the prioritization matrix) as a logical and consistent result for predictive purposes. Consequently, the software assists in problem identification and enables effective decision making.

Focusing on strategic planning, the study developed by Amrollahi & Rowlands (2018) successfully evaluated the feasibility and effectiveness of the methodology proposed by the authors. Also, it achieved its goal by proposing a methodology based on Open Strategic Planning (OSP) theory in organizations. Empirical results indicate that the proposed methodology can improve the effectiveness of strategic planning. About business/simulation, Saraswat et al. (2014), Lehnert et al. (2016), Mamoghli et al. (2018) contribute to their research. Compared to competing artifacts, the planning model proposed by Lehnert et al. (2016) is the first approach to integrating an organization's BPM resource development with individual process improvement to help organizations determine which projects to implement to maximize their value. Mamoghli et al. (2018) contribute from a theoretical point of view, where the presented maturity model makes progress in understanding the success factors in BPM.

Regarding the supplier, Hao et al. (2015) contribute to the practice and research of hospitality in the tourism industries, proposing an approach for psychometric reasons. Similarly, Sanches et al. (2015) contribute an artifact to identifying cause and effect relationships for a given problem and can be used for predictive purposes.

Equitably, regarding learning, Wang et al. (2011) present a performance-oriented e-learning mechanism, modeling and implementing the KPI framework and streamlining and guiding individual and social learning processes. As to the project, the model by Mamoghli et al. (2018) assists in identifying opportunities for improvement, either by improving the sophistication and integration of software technologies or by enhancing the capabilities of existing resources while the study presented by Krawatzeck et al. (2013) suggest a DSR process for building engineering software, contributing to research in information systems, allowing useful feedback within the early stages of development, thus avoiding possible design errors that can be corrected.

Anke (2019) introduces the concept of design-integrated financial valuation for smart services, which addresses the research gap identified from the lack of concrete financial valuation methods in product-service systems engineering. Wu (2009) research results indicate that knowledge contributes as follows: (i) the methodology can alleviate the difficulty in reusing and representing knowledge; (II) the method allows a knowledge form skeleton and its associated knowledge objects to be managed separately; (III) a general model for knowledge creation. The author also presents a design methodology for reuse and knowledge representation based on knowledge management systems (KMS) forms and prototype. Such a prototype supports form-based knowledge generation.

3.3 Research limitations

In addition to each research's contributions, this work also sought to identify the limitations of each. Following the same process, the limitations were coded by keywords that represented the subject matter. It can identify similarities in content analysis in the Atlas.ti 8 software. The network analysis of limitations is represented in Figure 7.

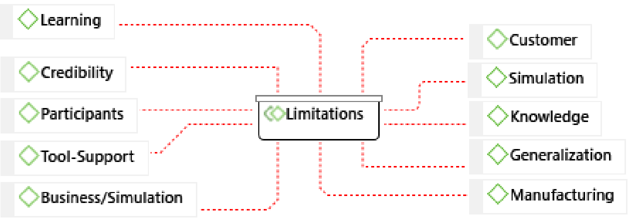

Figure 7. Limitations. Source: Prepared by the authors of the research.

Concerning limitations, Wang et al. (2011), Manfio & Lacerda (2016) present their research disadvantages pertinent to participants. For Wang et al. (2011), the system's evaluation was mainly about the perception of users about the system based on research and interviews, and it was used in a single case, limiting the research, making generalizations difficult. Manfio & Lacerda (2016) work are limited as to the lack of knowledge of the population of specialists who worked with product development projects, making it difficult to perform a more relevant sampling; that is, it was conveniently done due to the character itself. Food product development sector, which is restricted. Thus, in these two cases, participants affect the research outcome.

Respecting learning, although the competency-based method is being introduced in e-learning system applications, the work of Wang et al. (2011) merely organized learning content around competencies that are generally specified on an ad hoc basis, without considering performance as its outcome. The work also underestimated the complexity of interactions between employees and organizations in learning.

About support tools, Anke (2019); Sanches et al. (2015) have limitations in their research. The metamodel presented by Anke (2019) was limited in its use, where it is not enough to analyze all aspects of smart services since the factors interfere in the development, such as the user's qualification, the complexity of the problem. And the ease of use of the tool. On vendor limitations, the research by Hao et al. (2015) is restricted when it focuses on only two distinct customer segments, including the Likert scale that is presented and is a typically fuzzy language with certain limitations. Also, no "one size fits all" rule can serve as a metric for measuring customer satisfaction for all online travel agency websites. Customers have varying preferences, including different psychometric properties, to consolidate their assessment criteria and determine their satisfaction levels.

Lehnert et al. (2016) limit their research regarding Simulation. The planning model is only for deterministic interactions between projects, where stochastic interactions are possible only from a theoretical perspective. The planning model treats the processes under investigation as independent. However, they are often interconnected. A knowledge base should be built to institutionalize data collection routines and collect best practices, which the authors did not explore.

Regarding generalization, Amrollahi & Rowlands (2018); Mamoghli et al. (2018) have disadvantages in their research. Amrollahi & Rowlands (2018) limited the study to only two cases, making it difficult to interpret whether they are generalizable, which is proven by them. The model presented by Mamoghli et al. (2018) is limited to use in larger organizations, making it challenging to develop and evaluate at different levels, referring to case studies that refer only to small and medium enterprises with specific characteristics. That is, researches are replicable in specific groups.

According to the research by Amrollahi & Rowlands (2018), credibility and reliability in DSR, using a qualitative approach, is undermined due to the subjectivity of data collection, as the researcher is responsible for collecting and analyzing them. Therefore, if it is not capable of this, data may be impaired. Consequently, impacting the result of the research.

About the limitations related to production/industry, Dresch et al. (2019) do not consider the presented method appropriate for continuous process companies. Concerning business/simulation, Saraswat et al. (2014) highlight that the means for student responses are not high, which implies modeling and simulation, hindering teaching BPM concepts at the postgraduate level. Finally, regarding the limitation on knowledge creation (Wu, 2009) highlight that this is a human activity, often poorly structured and neglected by researchers.

4 Conclusions

This article provides a conceptual foundation for further theoretical and empirical research in the emerging DSR. The literature review indicates that the focus of DSR researchers is on “organizational engineering.” (Amrollahi & Rowlands, 2018; Mamoghli et al., 2018; Krawatzeck et al., 2013; Manfio & Lacerda, 2016; Lehnert et al., 2016; Hao et al., 2015; Wu, 2009; Wang et al., 2011). The main classes of problems addressed in the publication are “project management” (Krawatzeck et al., 2013; Manfio & Lacerda, 2016; Lehnert et al., 2016) and “knowledge management” (Wu, 2009; Wang et al., 2011). Also, many publications dealing with “process modeling and improvement” (Sanches et al., 2015; Anke, 2019; Saraswat et al., 2014). The analysis of research artifacts indicates that publications fulfill virtually all classifications except “construct” (Peffers et al., 2012). Publications were obtained focusing on structure, modeling, method, algorithm, and instantiation. Modeling and design can be highlighted. On modeling, the research of Saraswat et al. (2014); Lehnert et al. (2016); Mamoghli et al. (2018) use the BPM methodology. Regarding the method, Wu (2009); Wang et al. (2011) develop a structure centered on knowledge and learning, while Manfio & Lacerda (2016); Dresch et al. (2019) apply it in processes. The research contributions have been codified by focusing on the application. It was observed that the application areas of the DSR have a prevalence in production/industry, business/simulation, and design. On production/industry, Dresch et al. (2019), Manfio & Lacerda (2016) contribute to the food industry and Lean practices, respectively. On business/simulation, Saraswat et al. (2014), Lehnert et al. (2016), Mamoghli et al. (2018) use the BPM methodology. Finally, Mamoghli et al. (2018); Krawatzeck et al. (2013) contribute to the project area. In the same way, research is limited to “participants” (Wang et al., 2011; Manfio & Lacerda, 2016) and “generalization” (Amrollahi & Rowlands, 2018; Mamoghli et al., 2018). Wang et al. (2011) point out that the limited number of participants makes it difficult to generalize the research, while Amrollahi & Rowlands (2018) argue that lack of knowledge of the expert population can impair sampling. In the case of generalization, Mamoghli et al. (2018) limited their research to only two instances, and Mamoghli et al. (2018) applied the study to small and medium-sized companies, disregarding larger organizations.

DSR has been increasing the interest of the community of researchers from various fields of industrial engineering. According to the literature, this method consists of the project’s science, which sheds light on the need, meaning, and, essentially, how to operationalize it (Lacerda et al., 2013). Furthermore, DSR stands out from the literature in that it can significantly increase the understanding of learning in technical subjects such as engineering (Carstensen & Bernhard, 2019). However, we believe that DSR can provide answers and artifacts to the most diverse research gaps in emerging topics. Below, our article intends to present some research agenda aiming to increase the interest in DSR.

4.1 Wider areas for future research

The application of the DSR, despite presenting a considerable number of results in the SCOPUS database, still shows few discoveries regarding Industrial Engineering. Most of the research refers to information systems problems, which are related to the computing area in many cases. This study indicates that the DSR may become relevant in scientific research to address emerging literature gaps. The literature contributes by indicating that the strength of the DSR lies in the scientific rigor to build and evaluate artifacts (Lacerda et al., 2013). The essential goal of the DSR is to develop artifacts to address complex problem solutions (Lacerda et al., 2013). The DSR research method is distinguished by its ability to combine the three logical formalisms (see Figure 3): abductive, proposing artifacts and configuring classes of problems; deductive, designing, developing and evaluating artifacts; and inductive, generalizing to a class of problems (Lacerda et al., 2013). This research indicates that these abilities can enhance solutions to emerging literature (Carstensen & Bernhard, 2019).

Aiming to stimulate the DSR application, this research contributes by suggesting a series of research gaps in industrial management's organizational, informational, and human areas. We trust that a positive research agenda using DSR maybe shed light on critical emerging issues in organizations. For instance, among the class of emerging problems in Industry is the lack of a digital strategy for Industry 4.0 (Raj et al., 2020). On the other hand, the DSR has the potential to develop artifacts to support the decision system (Goecks et al., 2020), optimize resources to reduce time in hospitals (Flórez et al., 2020), decentralize production control through autonomous, intelligent and interconnected devices (Guirro et al., 2020). Finally, we are very confident that the RSD can forward artifacts that resolve conflicts in human relations within organizations. Research using the DSR can develop artifacts that facilitate the discussion between top managers and sales key account managers (Pereira et al., 2019). Another emerging topic is the lack of internal capacity for Industry 4.0 (Raj et al., 2020). Moreover, the methodology can provide tools to understand the use and potential purchase of consumers (Wu et al., 2015). Below, we developed a table to organize some examples to show how researchers may use the DSR (Table 4).

Table 4. DSR research agenda examples.

DSR Areas	Research Agenda	Class of problems	Artifacts
Organizational	Industry 4.0	Lack of a digital strategy (Cavata et al., 2020; Raj et al., 2020).	Strategic Road Map, Simulations, Artificial Intelligence, Big Data, Machine Learning.
		Integration and digitalization of the quality management system (Goecks et al., 2020; Korzenowski et al., 2020).	Big Data, Decision-Making Models, Machine Learning, Neural Networks, Cyber-Physical Systems, Automated Process Control.
	Business model	It requires in-depth knowledge of customer needs and the technological and organizational resources that might meet those needs (Sousa & Barros, 2020; Teece, 2018).	Customer Relational Management (CRM), Enterprise Resource Planning (ERP), Big Data, Artificial Intelligence, Machine Learning.
	Dynamic Capabilities	How dynamic capabilities contribute to digital transformation (Vial, 2019).	Sensing: assessment of technological opportunities in relationship to customer needs; Seizing: address needs and opportunities, and to capture value; Transformation: continued renewal.

Table 4. Continued...

DSR Areas	Research Agenda	Class of problems	Artifacts
Informational	Supply Chain Management	Lack of specification can affect coordination (Vosooghidizaji et al., 2020).	Simulations, Artificial Intelligence, Big Data, Machine Learning, Blockchain, IoT.
		Consideration of supply chain data analytic approaches (Kakhki & Gargeya, 2019).	Machine learning technique, neural networks and data-driven approaches to integrate the production and distribution planning in the supply chain.
	Industry 4.0	Fashion manufacturing companies and their Industry 4.0 strategies to extract potential success factors (Braglia et al., 2020).	Artificial Intelligence, Big Data, Machine Learning.
		Support the production strategy using data processing aspects (Campos & Alves, 2020). Intelligent hospitals are optimizing the use of resources and reducing hospital stay (Flórez et al., 2020).	Big Data and IoT (Flórez et al., 2020; Campos & Alves, 2020)
		Decentralization of the productive system's control by autonomous and intelligent devices interconnected by a communication system (Guirro et al., 2020).	Enterprise Resource Planning (ERP); Big Data, Artificial Intelligence, Machine Learning (Guirro et al., 2020).
Humans	Management	Investigate how Top Managers stimulate internal/external debate without generating conflicts (Pereira et al., 2019).	Big data insights for more effective relational selling; Leverage artificial. intelligence for relational selling (Arli et al., 2018).
	Industry 4.0	Lack of firms' internal capabilities in order to overcome the challenges of implementing Industry 4.0 (Raj et al., 2020).	Building roadmaps and planning strategically to invest in suitable resources. Framework to prioritize their allocation of resources.
	Consumers Intentions	Factors such as price and time might influence their actual behavior. Future research might be able to measure subjects actual usage and purchasing behavior (Wu et al., 2015).	Software's for decision-making in properties portfolio (Baierle et al., 2020). Customer Relational Management (CRM), Big Data, Artificial Intelligence, Machine Learning.

Source: Prepared by the authors of the research.

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