A Review of Design Science Research in Information Systems: Concept, Process, Outcome, and Evaluation

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Abstract

Design science research is a research paradigm focusing on problem-solving. It is increasingly accepted and adopted by Information Systems (IS) researchers as a legitimate research paradigm because of its capability in balancing research relevance and rigor. In the last fifteen years, many design science research has been published in top IS journals and has received a lot of attentions from IS researchers. However, current confusion and misunderstandings of DSR's central ideas (e.g., definition, philosophical foundation, research outcomes, etc.) are obstructing it from having a more striking influence on the IS field. The purpose of this paper is to present a comprehensive and critical review of existing DSR literature. In total, 119 papers, published in top IS journals and conference proceedings, were included in the review. The results of this study portray a big picture of current DSR in IS field and build a comprehensive theoretical knowledge base in terms of DSR-related issues. This study also identifies many research issues which can be examined by future DSR.

Keywords: design science research, Information Systems, artifact, theory, knowledge, concept, process

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Introduction

Design science research (DSR) is a research paradigm that focuses on problem-solving (March and Storey, 2008). It aims to create and evaluate artifacts that are designed to solve identified organizational problems by enabling the transformation from the "present situation" to the "desired situation" (Hevner et al., 2004; March and Smith, 1995; March and Storey, 2008). According to Simon (1996, p. 130), "*everyone designs who devises courses of action aimed at changing existing situations into preferred ones.*" As such, management can be viewed as design (Boland, 2002; Simon, 1996). Rooted in engineering and the sciences of the artificial (Simon, 1996), design science was first introduced to address the inability of traditional sciences, i.e., natural science and social science, in dealing with the objectives of prescribing solutions and methods or designing new artifacts for solving given problems. This inability arises mainly because the objectives of traditional sciences are to explore, to describe, to explain and, when possible, to predict (Van Aken, 2004; Romme, 2003). Whereas traditional science aims to understand reality, design science endeavors to build artifacts that serve human purposes (March and Smith, 1995). Given its focus on problem-solving, the application of DSR can potentially reduce the existing gap between theory and practice (Van Aken, 2004, 2005; Romme, 2003). Occupying a middle ground between traditional scientific approaches and practical business problems, DSR helps researchers address the low level of professional relevance of many IS studies while maintaining the rigor of research (Benbasat and Zmud, 1999; Hevner et al., 2004). It has been viewed as a procedure of knowledge creation for achieving two different purposes in one research project at the same time: producing scientific knowledge and solving real organizational problems (Dresch et al., 2014).

Among other resources, Information Technology (IT) is used within organizations to define work systems through which organizational goals are accomplished (Alter, 2003). Similar to the aim of design science research, the development, implementation, use, and management of information systems within organizations are rooted in changing existing situations into preferred ones. Thus, Information Systems (IS) research could benefit from adopting design science paradigm (Arnott and Pervan, 2008; Goes, 2014). Information Systems is one area that exhibits increasing adoption of Design Science as an epistemological paradigm for the advancement of knowledge (Arnott and Pervan, 2008; Goes, 2014; March and Smith, 1995; Nunamaker et al., 1991; Takeda et al., 1990; Walls et al., 1992). According to Hevner et al. (2004), the seminal work on DSR widely cited in IS field, design science and behavioral science are two paradigms that characterize most of the research in the IS field. Focusing on the analysis, design, adoption, and management of information systems at individual, group and organizational levels, IS research adopting design science paradigm aims to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts, while IS research that has adopted the behavioral science paradigm seeks to develop and verify theories that explain and predict human and organizational behavior (Hevner et al., 2004). They further proposed that IS research could make significant contributions by complementarily employ design science and behavioral science. In IS field, DSR has become an important research paradigm, and its general acceptance as a legitimate approach is being increasingly recognized (Hevner and Chatterjee, 2010; Kuechler and Vaishnavi, 2008). In the last fifteen years, many design science research has been published in top IS journals (Deng et al., 2017) and has received a lot of attentions from IS researchers. However, the current confusion and misunderstandings of its

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central ideas and objectives are hindering DSR from having a further profound influence on the IS field (Gregor and Hevner, 2013). Therefore, in this paper, we present a critical literature review of previous DSR in the IS field (ISDSR) with the aim of clarifying the current understandings of DSR and identifying some issues for future research.

To identify related research, we first conducted a search within the nine top IS journals (i.e., *MIS Quarterly*, *Information Systems Research*, *Information Systems Journal*, *Journal of the Association for Information Systems*, *Journal of Management Information Systems*, *Journal of Strategic Information Systems*, *Journal of Information Technology*, *European Journal of Information Systems*, and *Decision Support Systems*) and the proceedings of four top IS conferences (i.e., *International Conference on Information Systems*, *Americas Conference on Information Systems*, *European Conference on Information Systems*, and *Hawaii International Conference on System Sciences*). Specifically, we search papers of which the title, abstract, or keyword include "*design science*", "*design research*", or "*design science research*" and were published *between 2001 and 2015*. This step resulted in 435 papers. After de-duplication and removing papers that are not full research (e.g., editor's commentary, research-in-process, and introduction to a special issue or conference mini-tracks), we got 351 papers. Since our aim of this paper is mainly focusing on the theoretical perspective of ISDSR, we read through the titles and abstracts of the 351 papers and remove both unrelated papers and empirical papers. This step resulted in 78 theoretical papers that directly addressed DSR-related issues. To further extend our review sample, we adopted a snowball sampling method and identified related research cited by the 78 papers. We also did a further title search in Google Scholar using the same search keywords. Similar screening method was used, and this step resulted in 41 papers (or books). Our final review sample included 119 papers (or books).

After collecting the review sample, we conducted a thematic analysis of the 119 publications to develop a general framework to guide this review. Thematic analysis is one common qualitative analysis method that can be used to identify patterns (or "themes") within a set of data (Braun and Clarke, 2006; Guest et al., 2011). Following this method, we coded the 119 publications in terms of their research topics. Then we adopted an inductive consensus-building approach (similar method was also used in Peffers et al., 2007) and synthesize the coding results. This step resulted in four common research topics regarding ISDSR, namely, concept, process, outcome, and evaluation. Thus, the following of this study will present a critical literature review of ISDSR from these four common perspectives. By doing that, this paper aims to explore the following research questions (listed in Table 1).

The results of this study have two implications. First, reviewing ISDSR from the four common perspectives can help researchers better understand the basic concepts of DSR and provide a knowledge base that informs researchers how to conceptualize, conduct, and evaluate DSR. Second, based on the review of extant ISDSR, this paper reveals many research gaps and identifies several research opportunities for future research.

Table 1 - The Guiding Research Questions

Perspective	Research Question
Concept	What is DSR (e.g., definition, terminology)? Philosophically, where should we position DSR?
Process	How to do DSR?
Outcome	What to expect from DSR?
Evaluation	How to evaluate DSR?

Concept

What Is Design Science Research?

Historically practiced under a number of labels, such as "sciences of the artificial" (Simon, 1969), "systemeering" (Iivari, 1983), "a constructive approach" (Iivari, 2007), "systems development" (Nunamaker et al., 1991), "design science research" has recently become an umbrella name used to represent any scientific research involves with design activities. However, to now, no unified definition of DSR has been formed. For researchers, it is clear what DSR is not (see Baskerville, 2008), but not well clarified what DSR is. Despite the definition of DSR, the conceptualization of other related terminologies (e.g., design science, design research, science of design) and the concept demarcation between these terminologies are not clear as well. Such ambiguity has caused researchers great inconvenience in communication (Baskerville, 2008). Table 2 shows a summary of the definitions of DSR and related terminologies.

Table 2 reveals two features of the extant state of definitions of DSR related terminologies. First, there is no consensus on the definitions of DSR and related terminologies. For example, for the term, "design science", there are six different definitions, with wide or narrow scopes. Second, at a general level, the terminologies have been used indiscriminately and, sometimes, even inappropriately.

To reveal the arbitrary use of DSR related terminologies, we categorize the terminologies listed in Table 2 based on the similarity of their definitions (see Figure 1). Figure 1 shows that the DSR-related terminologies have been used arbitrarily. First, different researchers used different terminologies to represent same concepts. For example, to communicate a concept with a focus on knowledge creation, four terminologies (i.e., science of design, design research, design science and design science research) have been used by different researchers. Second, different researchers used the same terminologies in different ways. For example, "design science" has been used to represent concepts, such as knowledge creation, artifact creation & problem-solving, and design process & design method. It might be such arbitrariness that caused current confusion in the definitions of DSR related terminologies. Despite the arbitrary use, the disagreement on the scope of the DSR related terminologies might be another reason for current confusion. For example, Winter (2008) proposed that IS design science research includes both (IS) design science and (IS) design research; while Vaishnavi and Kuechler (2015) stated that DSR includes design science but is primarily differentiated from DR by involving the defining feature of learning through building, or artifact creation. In the IS area, DSR has been used in both broad and narrow ways. We propose that the commonly-accepted definitions and scopes of DSR and related terminologies are still needed to improve the communication of DSR.

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Table 2 - Definitions of Design Science Research and Related Terminologies

Source	Terminologies and Definitions
Walls et al. (1992)	**Design (#1)** is "the use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency." (p. 36) A **design theory (#2)** is "a prescriptive theory based on theoretical underpinnings which says how a design process can be carried out in a way which is both effective and feasible." (p. 37)
Cross (1993)	**Scientific Design (#3)** "refers to modern, industrialised design - as distinct from pre-industrial, craft-oriented design - based on scientific knowledge but utilising a mix of both intuitive and non-intuitive design methods." (p. 65) **Design Science (#4)** "refers to an explicitly organised, rational and wholly systematic approach to design: not just the utilisation of scientific knowledge of artefacts, but design also in some sense as a scientific activity itself." (p. 66) **Science of Design (#5)** "refers to that body of work which attempts to improve our understanding of design through 'scientific' (i.e. systematic, reliable) methods of investigation." (p. 67)
Bayazit (2004)	**Design Research (#6)** is "systematic inquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value, and meaning in man-made things and systems." (p. 16)
Hevner et al. (2004)	**Design Science (#7)** is "fundamentally a problem solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished." (p. 76)
Birkhofer (2006)	**Design (#8) "**is the (mostly complex) process of consciously creating models of artefacts (products of processes) which may be produced for use by customers." (p. 2) **Design Methodology (#9) "**is a body of knowledge (like a repository), which comprises all rules, methods, tools, working aids, etc. to support the improvement of efficiency and effectiveness in professional design." (p. 2) **Design Science (#10) "**is the scientific fundament of Design Research (procedures, products and all related models)." (p. 2) **Design Research (#11) "**comprises all processes that produce knowledge, method, tools, models, characteristics, etc. by scientifically performed research work." (p. 2)
Baskerville (2008)	**Design Science (#12)** "has to do with the systematic creation of knowledge about, and with, design. It extends to the scientific study of design and the use of design processes in the scientific creation of knowledge. At its core, design science is directed toward understanding and improving the search among potential components in order to construct an artifact that is intended to solve a problem." (p. 441)
Winter (2008)	"An analysis of **IS design science research (#13)** exhibits two different types of contributions: On the one hand, artefact construction and artefact evaluation are reflected on a generic level. The majority of contributions, on the other hand, describe the construction and evaluation of specific artefacts." (p. 471) "While Cross (2001) designates these two categories as 'science of design' and 'design science', respectively, we prefer the designations '**(IS) design science**' **(#14)** vs '**(IS) design research**' **(#15)**. While design research is aimed at creating solutions to specific classes of relevant problems by using a rigorous construction and evaluation process, design science reflects the design research process and aims at creating standards for its rigour." (p. 471) "Not every artefact construction, however, is **design research**. 'Research' implies that problem solutions should be generic to some extent, i.e., applicable to a set of problem situations." (p. 471)
Vaishnavi and Kuechler (2015)	**Design (#16)** means "'to invent and bring into being'. Thus, design deals with creating some new artifact that does not exist." **Design Science (#17)** then "is knowledge in the form of constructs, techniques and methods, models, well-developed theory for performing this mapping – the know-how for creating artifacts that satisfy given sets of functional requirements. **Design Science Research (#18)** is research that creates this type of missing knowledge using design, analysis, reflection, and abstraction." "The term '**design research**' **(#19)** had a long prior history as the study of design itself and designers – their methods, cognition, and education. **DR** is a broad area spanning all design fields, but importantly, does not have the defining feature of **DSR**: learning through building – artifact creation… The distinction frequently expressed is that **DR** is research *into or about* design whereas **DSR** is primarily research *using design as a research method* or technique."

Knowledge Creation	**Artifact creation & Problem solving**
#5 (science of design) #6 (design research) #12 (design science) #18 (design science research)	#7 (design science) #15 (IS design research) #17 (design science)
Design Activity	**Design Process & Design Method**
#1 (design) #3 (scientific design) #8 (design) #16 (design)	#2 (design theory) #4 (design science) #9 (design methodology) #11 (design research) #14 (IS design science) #19 (design research)

Figure 1 - The Categorization of DSR-related Terminologies

Philosophical Foundation of Design Science Research

Recently, there is a call for more inquiry of the philosophical foundations (i.e., ontology, epistemology, methodology, and axiology) of DSR (Owen, 1998; Niehaves and Bernd, 2006; Niehaves, 2007; Levy and Hirschheim, 2012; Purao, 2013). Researchers address the importance of philosophical investigation from three standpoints. First, the clarification of the philosophical foundation is important for design science researchers because it can legitimize and communicate how knowledge may be created following a mode of research, especially in an area like IS, in which there are multiple research paradigms, and the comparisons between the established paradigms are inevitable (Purao, 2013; Vaishnavi and Kuechler, 2015). Second, the current dominant philosophical assumptions are inadequate for design science research. Inherited from the disciplines of management and social sciences, the major paradigms of interest for IS researchers have been Positivist/ Postpositivist and the Interpretive/ Constructivist since the conception of the field (Gregg et al., 2001). While the paradigms provide a good basis for most of the IS research, they do not fully address the unique requirements of DSR, which focuses on creation. Such limitation has somewhat prevented design science researchers from providing convergent answers for research questions, such as what is the knowledge contribution of DSR? How can DSR be conducted? How to evaluate the DSR? We believe that, without a consistent philosophical assumption of DSR, it might be impossible for design science researchers to reach consensus on the aforementioned questions. Third, and on a general level, knowledge of philosophical foundations can serve as a base, improve our understanding of DSR per se, and facilitate the pragmatic DSR.

In spite of the importance, the philosophical foundation of DSR has rarely been explored. Indeed, none of the major influential DSR (such as Weber, 1987; Nunamaker et al., 1991; Walls et al., 1992; March and Smith, 1995; Hevner et al., 2004) in IS field has provided systematic and clear articulations of the philosophical foundation of DSR (Levy and Hirschheim, 2012; Purao, 2013). In this sense, the work by Vaishnavi and Kuechler (2015), which is closely based on the major influential IS design science studies, can be viewed as the “representative” philosophical view of

ISDSR. According to Vaishnavi and Kuechler's (2015), DSR is a paradigm parallel to the positivism and interpretivism. Design science researchers believe in the multiple world-states. DSR changes world-state through creating and implementing novel artifacts. Thus, for design science researchers, reality is technologically created, and alternative world-states are not unacceptable. However, notably, multiple world-states believed by design science researchers are not the same as the multiple realities embraced by interpretive researchers. Many, if not most, design science researchers believe in a single, stable underlying physical reality that constrains the multiple world-states. In other words, the world-states is technically changeable, however, at every moment, there is one and only one world-states. Epistemologically, the design science researcher is a pragmatist who believes in "knowing through making". The methodology of DSR is primarily constructive, starting from problem identification to the artifact description or formal implementation. Axiologically, design science researchers value creative manipulation and control of the environment in addition to (if not over) more traditional research values such as the pursuit of truth or understanding. Products of DSR are assessed against criteria of value or utility – does it work? Is it an improvement?

Although Vaishnavi and Kuechler (2015) embraced an evolutionary view and did not limit DSR into one specific philosophical assumption, the current philosophical assumptions of major DSR works are still facing many challenges. Criticism mainly focuses on the inextricable link to positivism of major influential ISDSR (Niehaves and Bernd, 2006; Niehaves, 2007; Levy and Hirschheim, 2012). Although the major design science researchers advocate that DSR is a third paradigm, which is different from positivism and interpretivism, an in-depth examination of their works (i.e., Hevner et al., 2004; March and Smith, 1995) indicates that the "dominate" design science researchers implicitly have a positivist epistemological assumption (McKay and Marshall, 2005; Niehaves, 2007). A summary of the critical discussion on the philosophical foundation of DSR is shown in Table 3.

Two major propositions can be summarized from Table 3. First, DSR is not necessarily chained from the positivist domain; instead, it should subscribe to the philosophy of pragmatism as an alternative to the philosophy of logical positivism, and should be applied using a variety of research paradigms, approaches, methods, and techniques (Lee and Nickerson, 2010; Levy and Hirschheim, 2012; Niehaves and Bernd, 2006). Pragmatism is the doctrine that an idea can be understood in terms of its practical consequences (Lee and Nickerson, 2010). It can serve DSR better than positivism for two reasons. On the one hand, according to the pragmatism, the evaluation of the truth or validity of a concept or hypothesis is dependent on not only the truthfulness, but also the usefulness or moral rightness of its practical consequences (Lee and Nickerson, 2010; Levy and Hirschheim, 2012). Such focus on usefulness is parallel to the central belief of design activity. On the other hand, different from positivism, pragmatism recognizes the constructive and indispensable roles that researchers play in the research process. Such recognition is similar to the design science recognizing the value of designer's in the design process (Simon, 1971). Second, during the iterative design process, the philosophical assumptions of one design science researcher continues changing among constructivist, positivist, and interpretivist (Gregg et al., 2001; Purao, 2013; Vaishnavi and Kuechler, 2015). For example, Gregg et al. (2001) propose that the three paradigms (positivist, interpretive and design science, which they called "socio-technologist/developmentalist") are intrinsically interdependent. Purao (2013) also indicates that design science requires an evolutionary ontology, and the convergence between artifact and problem, which is achieved through the research process, characterizes the epistemological stance for DSR. Vaishnavi and Kuechler (2015) proposed that the ontological and epistemological viewpoints shift through the DSR cycle. Therefore, based on previous discussions, we can develop a model to depict the iterations of the philosophical foundations during the DSR process (see Figure 2).

Table 3 - Current Discussions on Philosophical Foundations of DSR

Reference	Philosophical Foundations Discussed				Key Statement
	O	E	M	A	
Gregg et al. (2001)	X	X	X		• The positivist and interpretive paradigms do not fully address the unique requirements of software engineering. • The three paradigms (positivist/postpositivist, interpretive/constructivist, and socio-technologist/developmentalist) are intrinsically interdependent.
Niehaves and Bernd (2006)	X	X			• It is possible to concentrate on design from an interpretivist or a positivist position.
Niehaves (2007)		X			• DSR is not only a positivist domain but is also open to alternative epistemologies, such as interpretivism.
Lee and Nickerson (2010)					• Design research in information systems should consider subscribing to the philosophy of pragmatism as an alternative to the philosophy of logical positivism.
Levy and Hirschheim (2012)	X	X			• Through the lens of pragmatism, DSR should be applied using various research paradigms, approaches, methods, and techniques.
Purao (2013)	X	X			• DSR requires an evolutionary ontology towards both the problem and the artifact. • DSR has an epistemology that recognizes the convergence between the problem and the artifact.
Vaishnavi and Kuechler (2015)	X	X	X	X	• Neither the ontology, the epistemology, nor the axiology of the paradigm is derivable from any other. • Ontological and epistemological viewpoints shift through the design science research cycle.
Note: O – Ontology; E – Epistemology; M – Methodology; A – Axiology.					

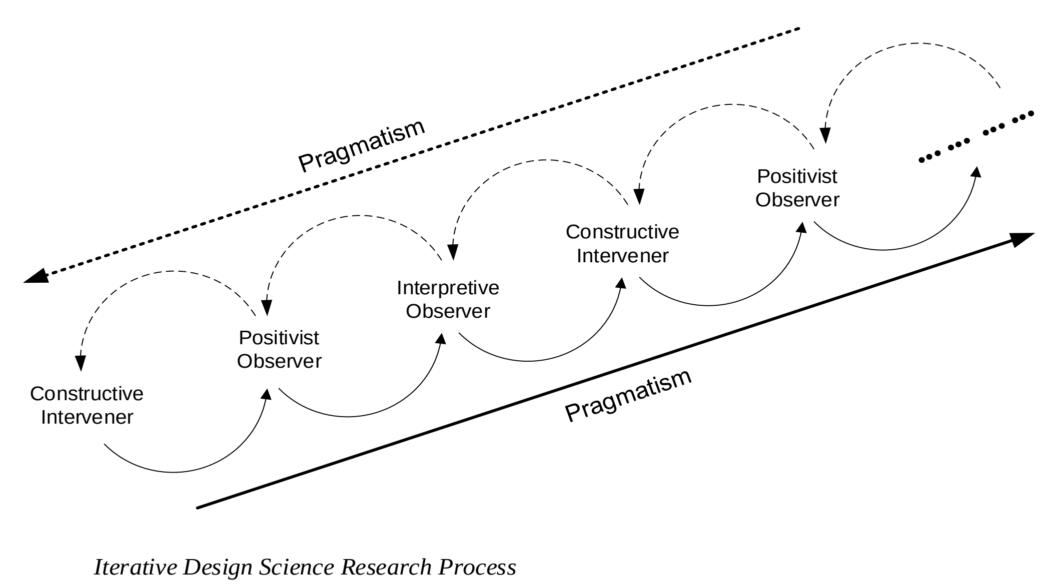

Figure 2 - Iteration of Philosophical Perspective during DSR Process

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As discussed above, it is not hard to see that the exploration of the philosophical foundation of DSR is still in its early stage. More research is needed before design science researchers can eventually clarify their philosophical assumptions with confidence. Although currently, DSR lands on the domain of logical positivism, it is still unknown where the destination is. Pragmatism might be a useful lens for DSR, especially when it is applied as a treatment to the ontological and epistemological debate. If that turns out to be the right direction, a way of balancing and integrating three paradigms might be carved out and greatly promote our philosophical understanding of DSR and paradigm per se.

Process

The research process, according to Blalock and Blalock (1982), is the application of scientific approaches to complex tasks of discovering solutions to problems. There has been a concern on DSR process since the emergence of the field. Previous research has proposed DSR processes that are widely cited by IS design science researchers (i.e., Takeda et al., 1990; Eekels and Roozenburg, 1991; Nunamaker et al., 1991; March and Smith, 1995; Cole et al., 2005; Peffers et al., 2007; Offermann et al., 2009; Gleasure et al., 2012; Alter, 2013; Vaishnavi and Kuechler, 2015). In this section, we provide a review of the existing DSR process models with a focus on the specificity of each model. The summary of the DSR processes proposed in these papers is shown in Appendix 1. To uncover the evolutionary picture of these process models, a citation map is built (Figure 3). Citation map is a commonly used bibliometric method to explore the evolution of a research field (Garfield, 1972; Moed, 2005). In the citation map, the arrow from paper A to paper B in the roadmap represents that *paper A is cited by paper B* and *paper B is conducted based on paper A*.

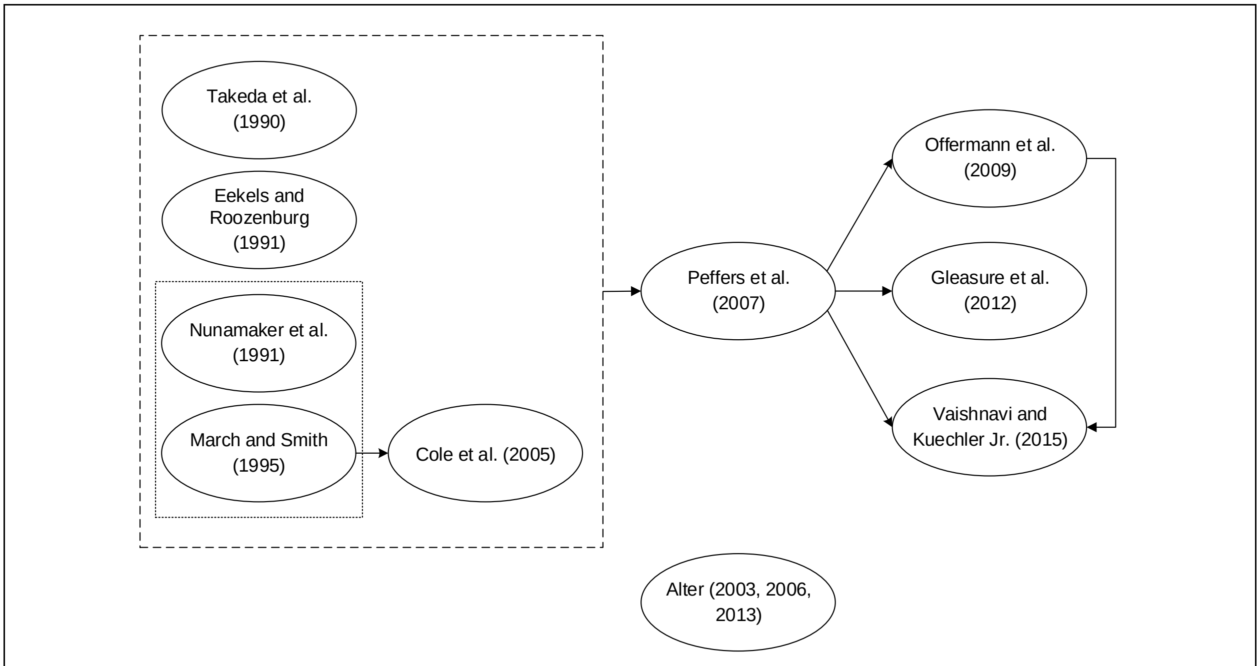

Figure 3 - Citation Map of DSR Process Studies

DSR was introduced to the IS community in the early 1990s by three seminal papers, namely, Nunamaker et al. (1991), Walls et al. (1992), and March and Smith (1995) (Peffers et al., 2007). Among the three papers, Walls et al. (1992) has a focus on building and testing information systems design theory. March and Smith (1995), while directly rooted in Simon's (1969) work, emphasizes the comparison between natural science and design science, the categorization of design artifact, and the activities of DSR. Although March and Smith (1995) address the basic DSR activities, which, according to them, are build and evaluate, they do not propose a systematic DSR process model. Instead, they compare the design science activities (build and evaluate) with natural science activities (discovery and justification) to signify the difference. In the IS field, Nunamaker et al. (1991) might be the first to propose a systematic DSR process model, despite the model being named as "system development". Rooted in software engineering, Nunamaker et al. (1991) propose a multi-methodological approach on IS research. According to them, there are four research strategies in IS research: theory building, experimentation, observation, and systems development, among which, systems development is the hub of research that interacts with other research methodologies to form an integrated and dynamic research program. They further explain the five activities in the system development research process and provide a list of the potential research issues for each activity. Although they only focus on the design of one type of artifact (i.e., system) and omit other types of artifacts (e.g., construct, model, and method), Nunamaker et al. (1991)'s work is possibly the first effort on integrating system development into the IS research process and is widely cited by IS design science researchers.

Efforts on developing DSR process model were also made in other research fields at the same time. However, since these efforts were made by scholars with very different backgrounds and focuses, there is no dependent relationship among early works on developing DSR process (see Figure 3). Another two works that are widely cited by IS researchers are Takeda et al. (1990), and Eekels and Roozenburg (1991). Takeda et al. (1990) introduce their general design theory and discuss a descriptive model, a cognitive model, and a computable model of the design process. An interesting point of their work is that they distinguish two levels in the cognitive design process model. First is the object level, where designer thinks about design objects themselves, that is what properties the design object has and how it behaves in a certain condition. Second is action level, where designer thinks about how to proceed with the design, that is, what s/he should do next. They propose that designer's (mental) activities constantly change between the two levels through the design cycle. Eekels and Roozenburg (1991) conduct a methodological comparison between the research cycle in science and the design cycle in engineering. According to them, the scientific research cycle and engineering design cycle are seemingly isomorphic but essentially different.

Embracing the premise that design research and action research methods are closely related and can offer unique strengths to the IS research community, Cole et al. (2005) examine the similarities between two methods and propose a synthesized research process that fully integrates design research and action research. Based on a cross application of research criteria, they state that design research and action research share important assumptions regarding ontology, epistemology, and axiology. Their views on DSR mainly come from March and Smith (1995), and Hevner et al. (2004).

Despite the different emphases, Peffers et al. (2007), Offermann et al. (2009), Gleasure et al. (2012), and Vaishnavi and Kuechler (2015) are all developed from the five papers discussed above and have a

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common aim of developing a general DSR process model. Building upon Takeda et al. (1990), Eekels and Roozenburg (1991), Nunamaker et al. (1991), March and Smith (1995), Cole et al. (2005) and other ISDSR literature and reference disciplines and using a consensus-building approach, Peffers et al. (2007) propose a general process for DSR, and explain and justify the process using four case studies. Peffers et al. (2007) is the most widely cited (if not the first) paper which systematically compares the similarities among prior DSR process models and proposes a general process. As shown in Figure 3, it is a connecting link between the preceding research and the subsequent research. With an emphasis on the importance of relevance of problem, Offermann et al. (2009) propose a general design science process model. Different from Peffers et al. (2007), Offermann et al. (2009) also address the publication opportunities and the self-contained work packages during the DSR process. From the standpoint of publication, they recommend three subparts of the DSR process. They further divide the research process into four self-contained work packages (i.e., problem identification, artifact design, laboratory experiment, case study/action research) and suggest that these work packages should/could be distributed among research participants. Gleasure et al.'s (2012) work aim to identify significant aspects of the design process that are not commonly documented and to increase the perceived rigor of a study by increasing the visibility of aspects of the design process. They present a DSR process model for increased procedural transparency. A feature of the model presented is that it emphasizes the significance of evaluation of design process. Although they do not state explicitly, it is implied from their paper that they take their model as a complementary (and somewhat improved) model of Peffers et al.'s model. Vaishnavi and Kuechler (2015) proposed a general methodology of DSR and justified the methodology using a case study. The feature of this model is that they clearly specify the research output(s) of each activity.

Compared to Peffers et al. (2007), Offermann et al. (2009), Gleasure et al. (2012), and Vaishnavi and Kuechler (2015), Alter's work (2003, 2006, and 2013) seems to be self-contained. Alter names his work "Work System Theory" which includes work system definition and special cases, work system method, work system life cycle model, work system framework, work system metamodel, etc. Work System Theory proposes that, a natural unit of analysis for thinking about systems in organizations is work system, which "*is a system in which human participants and/or machines perform work (processes and activities) using information, technology, and other resources to produce specific products/services for specific internal and/or external customers*" (Alter, 2013, p. 75). In Work System Theory, work system life cycle (WSLC) addresses the design process. A detailed introduction of Alter's work (see http://www.stevenalter.com/) will be beyond the scope of this paper. However, it is still necessary to explain the specificity of WSLC. As far as we can see, work system life cycle has three important features. First, while other DSR process models seem to view design as a project, WSLC is applicable at an organizational level. The former views the system in DSR as a technical artifact, while, the latter takes the whole organization as a work system which is consist of several independent and interdependent sub-work systems. From this point, it is fair to say that WSLC has more broad application than other design science process models. Second, while other DSR process models are control-oriented, the WSLC embraces unanticipated opportunities and adaptations and treats unplanned changes as part of a work system's natural evolution. From this point, the WSLC is agiler than other DSR process models. Third, while other DSR process models are introduced at purely conceptual and general level, WSLC provides several useful tools (for example, work system snapshot) to help researchers (and practitioners) identify problems and establish the analysis. From this point, WSLC is more practical than other DSR process models.

Outcome

Having discussed the process of DSR, it is essential to turn attention to the question of what are the outcomes of DSR. A general answer to this question would be "design science knowledge" (Vaishnavi and Kuechler, 2015). However, even though the contribution to knowledge is seen as the most significant criterion for publishing research (Straub et al., 1994), the answer like "design science knowledge" still seems to be too general to provide effective guidelines for researchers to expect, identify, and report their research outcomes. In the IS field, there is recently an increasing interest in DSR outcomes. Researchers have addressed DSR outcomes from different perspectives (see Walls et al., 1992; March and Smith, 1995; Gregor and Jones, 2007; Gregor and Hevner, 2013).

Generally speaking, the DSR paradigm in IS field has emerged into two camps, namely, a pragmatic-design camp (represented by Hevner et al., 2004; March and Smith, 1995; Nunamaker et al., 1991) and a design-theory camp (represented by Gregor and Jones, 2007; Markus et al., 2002; Walls et al., 1992, 2004), with each of them placing comparatively more emphasis on artifacts or design theory, respectively, as research outcome (Gregor and Hevner, 2013). The pragmatic-design camp believes that artifact (i.e., constructs, model, methods, and instantiations) is the core outcome of DSR. This camp does not view design theory as a necessary outcome of DSR; to them, design theory is at most one type of artifact. The design-theory camp takes design theory (including both nascent design theory and well-developed design theory) as the core product of DSR and only view instantiation (a material artifact) as the artifact. This camp calls the abstract artifacts (constructs, models, methods, design principles, technical rules) nascent design theory.

The Pragmatic-Design Camp

The most representative work of pragmatic-design camp is March and Smith (1995). According to them, artifacts are the outputs of design science, and there are four types of artifacts, namely, construct, model, method, instantiation. A c*onstruct* consists of the concepts that form the vocabulary used to describe problems and to specify their solutions within a domain. It may be either highly formalized or very informal. Kuhn's notion of paradigm is based on the existence of a set of consistent constructs for a domain (Kuhn, 1970). A *model* is a set of propositions or statements describing relationships among constructs, which, in design science activities, represents both problem situations and solution statements. Although models can be viewed simply as descriptions of how things are, the concern of models is utility, not truth, the concern of theories. A *method* is a set of steps used to perform a task. Methods are usually based on a set of underlying constructs and models. They are human-created artifacts that have value insofar as they address their tasks. An *instantiation* is the realization of an artifact in its environment. Instantiations operationalize constructs, models, and methods, and demonstrate and validate their feasibility and effectiveness. However, it is also possible that an instantiation precedes the complete articulation of its underlying constructs, models, and methods. For example, aircraft flew decades before a full understanding of how such flight was accomplished.

Notably, an absent from this list are theories, which, according to March and Smith (1995), are the ultimate products of natural science research. Design scientists, as they propose, rather than posing theories, should focus on creating constructs, models, methods, and instantiations that are innovative and valuable. These ideas are further developed in Hevner et al. (2004), where the "artifact

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itself" is emphasized as the prime or only contribution of design science. Hevner et al. (2004) contrast design-science paradigm (rooted in engineering and the science of the artificial) with behavioral-science paradigm (rooted in natural science), and propose that the goals of these two paradigms are, respectively, utility and truth. While March and Smith (1995) and Hevner et al. (2004) preserve the word, "theory", for natural science and behavioral science, and leave it out from the outcomes of DSR, the design-theory camp seems to be more inclusive.

The Design-Theory Camp

The design-theory camp's work began with stating the need for design theory (Walls et al., 1992; Gregor, 2006) and proposing the components of design theory (Walls et al., 1992; Gregor and Jones, 2007), and then extended to incorporating design theory as major outcomes of DSR (Walls et al., 1992; Vaishnavi and Kuechler, 2015).

In one of her well-known works, Gregor (2006) examined the structural nature of theory in the discipline of Information Systems. She addressed issues of causality, explanation, prediction, and generalization that underlie an understanding of theory and proposed a taxonomy that classifies IS theories into five interrelated types: 1) theory for analyzing, 2) theory for explaining, 3) theory for predicting, 4) theory for explaining and predicting, and 5) theory for design and action (Gregor, 2006). According to her, theory for design and action says how to do something. It gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact. Although the formalization did not happen until the early 2000s, the discussion on the need and components of design theory had arisen for many years. Of the early works of design-theory camp, the most representative and widely cited one possibly comes from Walls et al. (1992). Walls et al. formalized the need of design theory in IS discipline and, for the first time, proposed the basic components of design theory based on their study on Executive Information Systems. According to them, a design theory must have two aspects, one dealing with the product and one dealing with the process of design. The product component is a set of meta-requirements, meta-design, kernel theories and testable design process hypotheses, while the process component includes design method, kernel theories, and testable design process hypotheses. The primary contribution of Walls et al.'s work is to formalize, justify, and extend the traditional IS practice of labeling system types, describing their characteristic features, and prescribing an effective development approach (Markus et al., 2002).

Gregor and Jones (2007) critically examined and further extended Walls et al.'s (1992) work. They re-specified the IS design theory and proposed a revised framework for IS design theory. They also clarified the range of artifact based on Dubin (1978) and Nagel (1979). According to them, artifacts can be categorized into two types, material artifacts and abstract artifacts. The major difference between the two types of artifacts is whether the artifact has a physical existence. Based on this categorization, instantiations will be material artifacts and theories (including constructs, methods, and models) will be abstract artifacts. Gregor and Jones's (2007) work extends Walls et al. (1992) by incorporating the potential importance of an instantiation in an ISDT. Moreover, they implicitly recognize that both artifact and theory (regardless of the ranges) are important outcomes of DSR. Gregor and Jones (2007) is not the only work of design-theory camp which incorporates artifacts as necessary parts of ISDT and important outcomes of DSR. In fact, there is a long tradition in design-theory camp to view both artifact and theory as outcomes of DSR. Such opinion can be found in both the very early work like Purao (2002) and the most recent work like Gregor and Hevner (2013). Purao (2002) distinguished DSR outcomes into three types, namely, artifact as situated implementation, knowledge as operational principles, and emergent theory about supporting a phenomenon. According to him, the situated implementation is a software or a system, which serves to instantiate the artifact to ensure that the design is feasible. The operational principle is a symbolic and manipulable representation of concepts and abstractions, which ensures that the intended behavior of the artifact is explicated in accepted forms. The emergent theory is a metaphorical understanding of how the artifact supports or controls the phenomenon of interest, which ensures that the expected behavior of the phenomenon, in conjunction with the artifact, is articulated. His core idea is that DSR produces more than just artifacts. According to Purao (2002), the situated implementation is the most visible output of DSR, but also are less important than the other two kinds of outputs. Gregor and Hevner (2013) further developed the framework proposed by Purao (2002). Based on the knowledge's abstraction level and maturity level, they categorized the outcomes of DSR into three levels: 1) situated implementation of artifact (e.g., instantiations, such as software products or implemented processes); 2) nascent design theory (e.g., constructs, methods, models, design principles, technological rules); 3) well-developed design theory about embedded phenomenon (e.g., mid-range and grand theories). More importantly, their work formally proposed the significance and necessity of viewing both artifact and theory as outcomes of DSR.

One interesting fact about Gregor and Hevner (2013) is that it is conducted by two authors, one comes from early design-theory camp, and the other comes from early pragmatic-design camp. Such fact can possibly be viewed as a recent trend of convergence between the two camps. Similar opinion can also be found in other fields (see Van Aken, 2004, 2005). Although at first glance, the two camps are exclusive from each other, the fact is that the seeming dichotomy only comes from different opinions on the scopes of artifact and theory and, possibly, different emphases put on long-term and short-term outcomes. In essence, both of the camps admit that artifact and theory are important knowledge contribution of DSR. Therefore, a proper belief for future should be that artifact and theory are complementary rather than opposing perspectives of DSR knowledge contribution (Gregor and Hevner, 2013). Furthermore, given that the ambiguity on the boundary between design artifact and design theory has caused many inconveniences in terms of research communication and has inhibited the integration of the two camps, future study should also aim to develop a widely accepted conceptual boundary between artifact and theory and pay more attention to how to merge the two camps and take advantage of both of the camps to make knowledge contribution to DSR.

Evaluation

Evaluation in DSR is concerned with the evaluation of outcomes, including theory and artifact[1]. It is a crucial component of the DSR process. The basic question addressed by evaluation of DSR is "how well does the artifact (or theory) work". Simon (1996) views the evaluation of artifact as one of the three fundamental aspects of DSR. According to Simon (1996), the design guided by only the most general heuristics of "interestingness" or novelty is a fully realizable activity, and design should be conducted without final goals. Although providing some general discussions on evaluation, Simon (1996) more-or-less left it open for future development (Pries-Heje et al., 2008). In the IS field, many researchers have addressed the evaluation of DSR from different perspectives and have developed many evaluation criteria, frameworks and taxonomies with wide or narrow applicability

[1] Here, following *Gregor & Hevner (2013)*, artifact is used to refer to a thing that has, or can be transformed into, a material existence as an artificially made object or process.

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(see March and Smith, 1995; Hevner et al., 2004; Pries-Heje et al., 2008; Gregor and Hevner, 2013; Venable et al., 2016; Baskerville et al., 2015; Prat et al., 2015). A summary of these works is shown in Table 4. As Table 4 shows, some of the works can be used to evaluate both artifact and theory, while some are only applicable in evaluating artifacts.

Table 4 - Design Science Research Evaluation: A Summary of Extant Studies

Citation	Applicability	Core Content
Simon (1996)	Artifact	Proposal of replacing “optimizing” using “satisficing”.
March and Smith (1995)	Artifact	Corresponding evaluation contents for each of the four types of the artifacts: constructs, models, methods, and instantiations.
Hevner et al. (2004)	Artifact	A summary of evaluation methodologies of designed artifacts available in the knowledge base.
Pries-Heje et al. (2008)	Artifact, Theory	A strategic DSR evaluation framework which includes two dimensions: 1) ex-ante vs. ex-post; 2) naturalistic vs. artificial. It can be used descriptively to analyze the evaluation strategy of DSR.
Gregor and Hevner (2013)	Artifact, Theory	A DSR knowledge contribution framework with two dimensions based on the existing state of knowledge in both the problem and solution domains for research opportunity under study.
Baskerville et al. (2015)	Artifact, Theory	A framework which categorizes the knowledge contribution of DSR into four genres of inquiry, and evaluation and justification criteria for each of the genres.
Prat et al. (2015)	Artifact	Seven typical evaluation patterns and a hierarchy of evaluation criteria, which includes five perspectives: 1) goal; 2) environment; 3) structure; 4) activity; 5) evolution.
Venable et al. (2016)	Artifact	A framework for evaluation in design science (FEDS) together with a process to guide design science researchers in developing a strategy for evaluating the artifacts; four DSR evaluation strategies.

Evaluation of Design Artifact

The evaluation of design artifact has been addressed since the emergence of DSR. According to March and Smith (1995), design science consists of two basic activities, build and evaluate. They further proposed four types of artifacts (constructs, models, methods, and instantiations) resulting in building and corresponding evaluation contents for each type of the artifacts. For example, “*evaluation of constructs tends to involve completeness, simplicity, elegance, understandability, and ease of use... models are evaluated in terms of their fidelity with real world phenomena, completeness, level of detail, robustness, and internal consistency…. evaluation of methods considers operationality (the ability to perform the intended task or the ability of humans to effectively use the method if it is not algorithmic), efficiency, generality, and ease of use…. evaluation of instantiations considers the efficiency and effectiveness of the artifact and its impacts on the environment and its users.*” (March and Smith, 1995, p. 261). Although March and Smith (1995) discussed the question of “what to evaluate”, they did not address the question of “how to evaluate”. Hevner et al. (2004) answered the “how” question by summarizing the evaluation methodologies of designed artifacts available in the knowledge base. They categorized the evaluation methods into five categories and proposed that the selection of evaluation methods must be appropriately matched with the designed artifact. However, they did not clarify how to decide the match. Venable et al.'s (2016) work partly addressed this. They developed a framework for evaluation in design science (FEDS) together with a process to guide design science researchers in developing a strategy for evaluating the artifacts. According to them, the FEDS evaluation design process consists of four steps: 1) explicate the goals of the evaluation, 2) choose the evaluation strategy or strategies, 3) determine the properties to evaluate, and 4) design the individual evaluation episode(s). Another work on the evaluation of design artifact is Prat et al. (2015). Based on a taxonomy of evaluation methods for IS artifacts, they analyzed ten years of DSR publications in the basket of journals of the Association for Information Systems (AIS) in terms of their artifact evaluation practices. The analysis resulted in seven typical evaluation patterns: 1) demonstration; 2) simulation- and metric-based benchmarking of artifacts; 3) practice-based evaluation of effectiveness; 4) simulation- and metric- based absolute evaluation of artifacts; 5) practice-based evaluation of usefulness or ease of use; 6) laboratory, student-based evaluation of usefulness; and 7) algorithmic complexity analysis.

Evaluation of Design Theory

Unlike evaluation methods of the artifact, the proposed evaluation methods of design theory are at a general level with a focus on knowledge contribution and can be used to evaluate both design theory and artifact. For example, Gregor and Hevner (2013) proposed a DSR knowledge contribution framework, based on which, the DSR knowledge can be categorized into four types: 1) invention (new solutions for new problems); 2) improvement (new solutions for known problems); 3) exaptation (known solutions extended to new problems); 4) routine design (known solutions for known problems). This framework was adopted by Goes (2014) to explain DSR's publication opportunity in MIS Quarterly. According to Goes (2014), all of the first three DSR knowledge contributions are valuable and have the opportunity to be published in MIS Quarterly. Another example is Baskerville et al. (2015), in which, the knowledge contribution of DSR was categorized into four genres of inquiry based on two dimensions: 1) knowledge goal (the design-science duality); 2) knowledge scope (the idiographic-nomothetic duality). According to Baskerville et al. (2015), the knowledge goal of DSR can be either design or science, while the knowledge scope can be either nomothetic or idiographic. Based on the dualities, knowledge contribution of DSR can be categorized into four genres: 1) nomothetic design; 2) nomothetic science; 3) idiographic design; 4) idiographic science. They further proposed corresponding evaluation criteria for each genre. Pries-Heje et al. (2008) also proposed a framework for DSR evaluation. The framework encompasses both ex-ante and ex-post orientations as well as naturalistic settings (e.g., case studies) and artificial settings (e.g., lab experiments) for DSR evaluation. However, the framework is mainly used descriptively to offer a strategic view of DSR evaluation and, therefore, is not discussed in detail here.

Design Science Research Evaluation Guidelines

From the descriptions abovementioned we can see, there is still no consensus on the evaluation method of DSR. Although many efforts have been put on developing the DSR evaluation frameworks, most of the studies are on a general knowledge contribution level and, thus, can only be used to guide design science researchers in the evaluation practice in a very limited way. Besides, the related results are scattered and DSR still lacks commonly accepted, specific evaluation methods for the different artifact types. All of these indicate that evaluation of DSR has not reached maturity yet (Pries-Heje et al., 2008; Venable et al., 2016; Prat et al., 2015). Despite the fragmentation, it is still valuable to summarize several common guidelines from previous research on DSR evaluation.

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Based on an inductive consensus-building approach, we reviewed the eight papers that provide detailed discussions on DSR evaluation at a general level. Four general guidelines regarding DSR evaluation are formed. The summary of the sources of the guidelines are shown in Table 5, and the detailed coded supportive contents for each guideline can be found in Appendix 2. Note that Appendix 2 only aims to provide some quoted contents that support the development of the guidelines, therefore, the contents listed in it are not exhaustive.

Table 5 - The Summary of the Sources of the DSR Evaluation Guidelines

Citation	Guideline			
	G1	G2	G3	G4
Simon (1996)	X		X	
March and Smith (1995)	X	X		
Hevner et al. (2004)	X	X	X	
Pries-Heje et al. (2008)	X	X		
Gregor and Hevner (2013)	X			
Baskerville et al. (2015)		X		
Prat et al. (2015)		X		X
Venable et al. (2016)	X	X	X	X

Guideline 1: The evaluation of artifact should involve the intended use and the context in which the artifact operates. Artifacts are built to fulfill some purposes (e.g., solving problems). Such fulfillment involves a relation among three terms: the purpose, the artifact, and the context in which the artifact performs (Simon, 1996). Whether the artifact works well is not only decided by artifact itself, but also decided by the purpose of design and the operation context. Only when the inner context is appropriate to the outer context, or vice versa, will the artifact serve its intended purpose. Many similar examples can be found in the aeronautics and astronautics engineering. Here, an example from Simon (1996) is inferred to demonstrate the guideline. Think about a clock, in terms of its purpose of telling time, the effectiveness and usefulness of the clock are related to the context in which it is to be used. Sundials perform as clocks in sunny climates. Therefore, they are more useful in Phoenix than in Boston and of no use at all during the Arctic winter. To make a clock perform in this difficult context, the clock had to be endowed with many delicate properties, some of which are largely irrelevant to the performance of a landlubber's clock.

Guideline 2: The evaluation methods should be matched appropriately with the designed outcomes. To evaluate the outcomes of DSR appropriately, researchers should carefully select the evaluation methods. Different evaluation methods might be needed to evaluate different design outcomes. For example, the observational methods are useful to evaluate methods while the experimental or testing methods are useful to evaluate instantiations (Deng et al., 2017). Although possibly not clearly stated, this guideline is possible the most widely held opinion among the studies on DSR evaluation. For example, some studies firstly categorize the artifacts or knowledge into different types, then propose different evaluation criteria for each type. Such studies are essentially implying that evaluate methods should match the specific artifact. Notably, this guideline does not mean that for each artifact, we need to develop a new evaluation method. One evaluation method can be used to evaluate different types of artifacts. For example, Prat et al. (2015) identified seven common IS artifact evaluation patterns, of which, most can be used in evaluations of different types of artifacts.

Guideline 3: The evaluation of artifact should include a consideration of the artifact's style. The style was possibly first introduced into DSR by Simon (1969). According to Simon (1971, p. 1), "*a style is some one way of doing things, chosen from a number of alternative ways.*" The concept of style comes from Simon's proposal of satisficing. According to Simon (1971), optimizing techniques generally produce unique solutions or small sets of similar solutions. Therefore, an optimizer faces no question of style, but simply a question of finding the best solution. However, for the satisficer, the unique solution is the exception rather than the rule. Therefore, satisficer is free to make choice of style. Simon (1971) further proposed that style of design (artifact) mainly arises from the processes used to design it. In design, since, generally, there are not unique optimal solutions, designer introduce style into his/her design by choosing any one of many satisfactory solutions during the process of design. For example, an architect who designs buildings from the outside in will arrive at quite different buildings from one who designs from the inside out, even though both of them might agree on the characteristics that a satisfactory building should possess (Simon, 1996). Simon addressed the concept of style in design mainly from analyzing its source. He implied the importance of style in design which was later emphasized by Hevner et al. (2004). Style is important in the evaluation of design because it provides a robust criterion to make a choice among alternative designs while other evaluation metrics are inappropriate or insufficient to guide decision making (Simon, 1996). Often, evaluation of design involves making a choice among alternative artifacts. But comparison among alternatives does not always result in artifacts being evaluated as "better" or "worse". Making choices among different artifacts usually comes with trade-off. In this case, style comes out and plays an important role in evaluation. The style is not value free; instead, it is attached with designers' value preferences (Simon, 1996). Considering style in evaluation implies that designer should consider his/her axiology while evaluating the artifact he/she designs.

Guideline 4: The evaluation of DSR should include long-term organizational impact and the societal impact of artifacts. Prat et al.'s (2015) review indicates that while most artifact evaluations focus on the individual impact, both organizational and societal impacts of IS artifacts have been overlooked in the evaluation. However, such impacts are important. Especially in the evaluation of safety critical systems and technologies, the evaluation should address potential impacts on animals, people, organizations, or the public, including future generations. It has been indicated that DSR has far overemphasized immediate utility, at the expense of sustainable impact (Gill and Hevner, 2013). While science studies the world to create new knowledge, the design uses knowledge to create a new world (Verkerke et al., 2013). In essence, the real result of our design is to establish initial conditions for the next succeeding stage of action (Simon, 1996). So the question becomes, what are good initial conditions for the future world? Such question should be considered when evaluating artifacts. Only by thinking about that, can we offer as many alternatives as possible to future decision makers and perhaps avoid irreversible commitments that they can do.

The four guidelines aim to provide researchers with some general thinking when conduct evaluation in DSR. All of the guidelines are suggestive, not normative, and they should be used based on the specific features of one DSR project.

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Discussion

A Roadmap for Design Science Research Publications

After reviewing the ISDSR in terms of concept, process, outcome, and evaluation, in this section, we develop an integrated roadmap for ISDSR. The roadmap is shown in Figure 4. In the roadmap, the basic unit of relationship is represented by arrows, of which, the underlying meaning is same as the arrows in Figure 3. As Figure 4 shows, the dotted line divides the roadmap into five parts. Papers are posited in different parts according to their main topics. The middle part includes three seminal papers of ISDSR. The three papers are put in the middle of the roadmap because all the other papers cite as well as are inspired by at least one of them, and based on my review, they are indeed the most important cornerstones of ISDSR. The other four parts are corresponding to the structure of the review in this study. Each part covers several studies. Notably, three papers are exactly posited on the dotted lines; that means that each of the three papers has carefully addressed two topics. For example, Nunamaker et al. (1991) address both the design science research concept and the DSR process.

The design science research roadmap shows that the four topics reviewed in this study are, in essence, a whole. Although they have different emphases, they are interdependent with each other. The roadmap is not without limitations. First, because it is two-dimensional, it is hard to show all connections, especially, the connections between “process” and “evaluation” papers and between “concept” and “outcome” papers. Second due to the space limitation, only the most cited papers are included in the roadmap. However, despite the limitations, the roadmap has many implications for IS design science researchers. First, it provides a good guideline for new design science researchers to find the “must-read” papers of ISDSR. Second, it depicts the inherited relationship among those papers, which, combined with the publication date, reveals an evolution history of ISDSR concisely and explicitly. Last, but not least, the ISDSR roadmap can be viewed as one single part of the roadmap of general DSR, and, in future, maybe we could draw the roadmaps of DSR in other areas and connect them together. In that way, we can generate a big picture of the status quo of DSR.

Issues for Future Design Science Research

The review of DSR in IS field reveals many research issues for future research. A list of the issues is shown in Table 6, following which is the discussion of each issue.

Research Issues regarding Concept

What is DS? What is DR? What is DSR? How to distinguish them?

As indicated in Section 2, there is no consensus on the definitions of design science, design research, and design science research. Researchers tend to use different terms to represent the similar meaning, which reflects an existing confusion on how to choose right terms in ISDSR area. The concern here is not that ISDSR needs more arguments on the definitions and scopes of basic concepts. Basic concepts should be used to support research. More specifically, support the communications between researchers in one area, rather than trigger debates. As we see, the DSR-related definitions are not as diversified as the defining activities (see Figure 1). For the long-term development of ISDSR, researchers should possibly stop assigning more terms for the similar meaning and focus on clarifying the existing concepts with the aim of achieving a consensus on the definitions and scopes of DS, DR, and DSR. So what is DSR? To us, DSR is a research paradigm that includes both the research on solving problems by building artifacts and the research on understanding design through scientific methods.

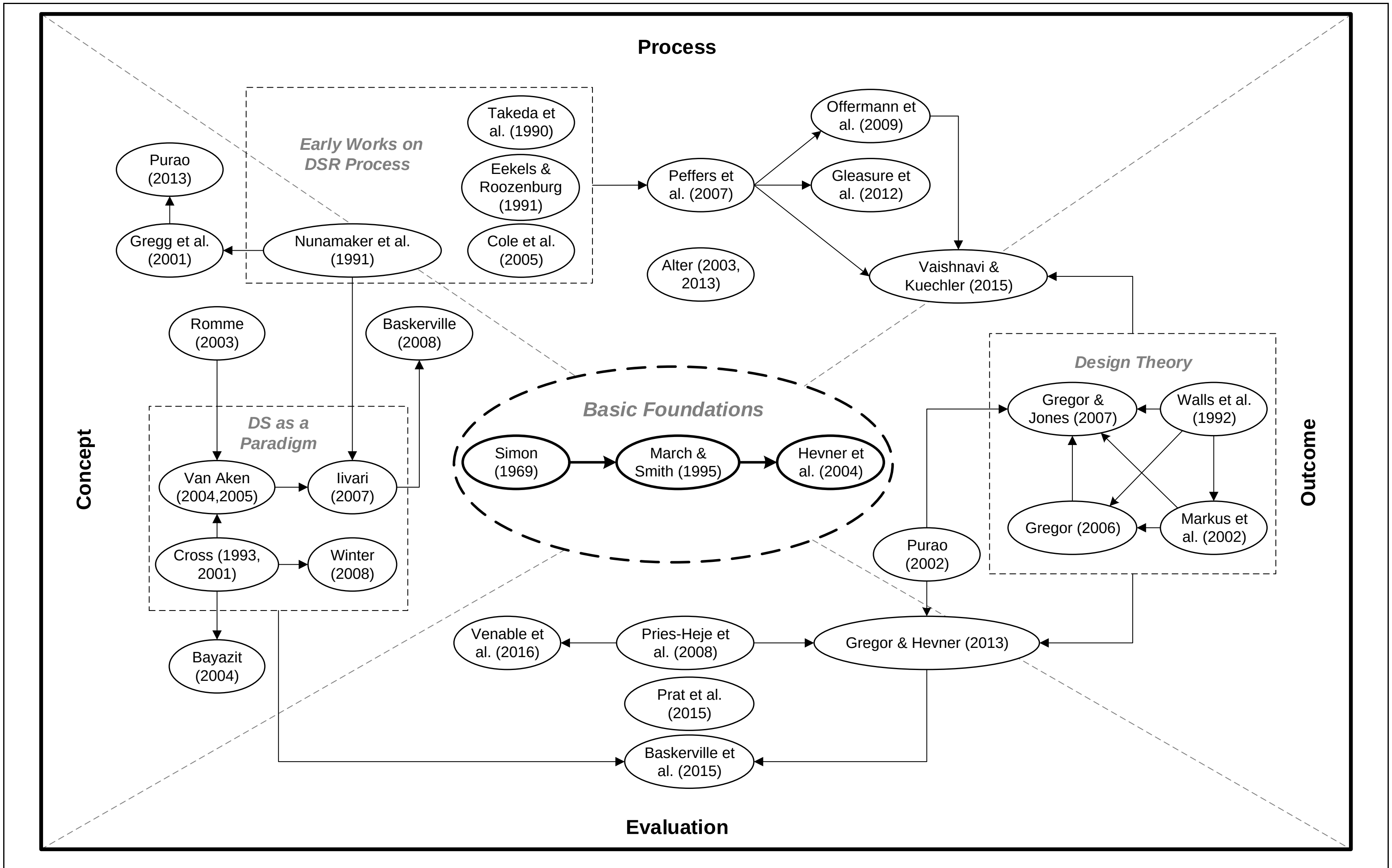

Figure 4 - Design Science Research in Information Systems: An Integrated Roadmap

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Table 6 - Issues for Future IS Design Science Research

Topic	Research Issues
Concept	• What is DS? What is DR? What is DSR? How to distinguish them? • What is the philosophical foundation of current dominant ISDSR? Is it appropriate? What should it be?
Process	• Developing new design process model • Examining different design modes • Research on designers
Outcome	• Developing a new taxonomy of artifact. • Re-defining the concept of design theory
Evaluation	• Identifying the artifact-evaluation match • Broaden the view of evaluation • What is design style? How can design benefit from style?

What is the philosophical foundation of current dominant ISDSR? Is it appropriate? What should it be?

While current ISDSR is dominated by a considerably small number of seminal studies, none of them has systematically examined the philosophical foundation of DSR. A critical examination reveals an inextricable link between these seminal works and positivism. However, it is proposed that DSR is not necessarily chained from the positivist domain. Limited and narrow philosophical foundations could possibly bound the diversity of DSR in terms of method, evaluation, outcome, etc. One proposal is that design science researchers could consider subscribing to the philosophy of pragmatism as an alternative to the philosophy of logical positivism. However, more research is needed to find how to incorporate current philosophical foundations into pragmatism. To find a solution for that question, several complementary questions should be answered first, such as, what is the philosophical foundation of current dominant ISDSR? Is it appropriate? What should the philosophical foundation of ISDSR be? The current subscription to positivism could possibly be traced back to a partially subscription of Simon's philosophical assumption. However, as we see, although most of Simon's works show a philosophical assumption of logical positivism, his original work, *The Sciences of the Artificial*, shows a very open attitude to the philosophical foundation of design science. While the current dominating ISDSR works assert that they are rooted in Simon's original work, there might be a retrenchment during the proliferation of Simon's work in IS field. Therefore, future research might be able to benefit from a systematic examination of Simon's view of DS in terms of the philosophical foundation.

Research Issues regarding Process

Developing new design process model

Several studies have developed design process models as shown in Section 3. With regard to the extant process models, three problems should be addressed in future ISDSR. First, most of the extant process models are rational waterfall models. As Appendix 1 shows, despite the retrospect relationship, most of the models imply that DSR starts from the problem identification and ends with evaluation or implementation decision. However, this is not always true in real design cases, where the designer often has a vague, incompletely specified goal or primary objective and sometimes the problem is to discover what the problem is (Glegg, 1969; Dorst and Cross, 2001).

The step-by-step rational model does not accurately reflect what real designers do, or what the best design thinkers identify as the essence of the design process (Brooks, 2010). Although the rational model has persisted in practice because of its seductive logical simplicity, and because builders and clients need "contracts", new alternative process models which can provide more accurate descriptions of real design processes should be proposed and developed in future ISDSR. Second, extant design process models are at a very general level, and more detailed process model or sub-process model for each design step should be developed in future. As the review in Section 3 shows, extant design process models only separate the whole design process into several general steps without providing a sub-process model for each step (e.g., problem identification, artifact design, artifact evaluation, etc.). However, in design, each step includes much decision-making and problem solving which need guidelines (e.g., how to identify design problems, how to design an artifact, etc.) from the process model. The extant process models seem to provide inadequate guidelines for such activities. Future DSR should possibly address this problem by providing process models for each step of design. Third, the extant design process models seem to embrace the cybernetic view and take design as an activity completely under the control of designer and the design plan. These models fail to incorporate constraints and unexpected opportunities from the context. Designers should take constraints and opportunities from the context into consideration, as well as realize that the constraints and opportunities are changing constantly. Therefore, more open and flexible process model should be developed in future research.

Examining different collaboration modes of design

Since 1900, two major changes in design have taken place: 1) design is now done mostly by teams, rather than individuals; 2) design teams now often collaborate by using telecommunications, rather than by being collocated (Brooks, 2010). As a result, the design community is abuzz with several hot topics, such as Tele-collaboration, “virtual teams” of designers, “virtual design studios”. However, ISDSR seems to have overlooked the topics addressing different collaboration modes of design, which is surprising because IS has a long tradition in examining research topics like telecommunication and virtual team. One possible explanation is that ISDSR is still in the early stage and research efforts have been mainly put in answering the elementary design-related questions (Goes, 2014; Gregor & Hevner, 2013). Given that real design is always more complex than we tend to imagine (Brooks, 2010), future DSR could examine the different collaboration modes of design to reflect the real design context.

Research on designers

One thing should be noticed by IS design science researchers is that great designs come from great designers, not from great design processes (Brooks, 2010). Many designs in the world are produced either naturally or intentionally set apart from normal design processes, such as the atomic bomb, the nuclear submarine, the ballistic missile, the stealth airplane, the Spitfire, penicillin, and so on. This fact raises an important question: why do many great designs arise outside design process? One major concern of this question is why different designers, even though they follow the same design process, come up with different designs? For example, not every composer can write music as great as Mozart, even if they follow exactly the same writing process. This leads to another topic overlooked by ISDSR, ‘designer’. Compared to ISDSR treating ‘designer’ as a black box, traditional design research has a long history of examining the designer-related issues in design activity. For example, Cross (1990) examined the role of designers in design from the perspectives of intuition and experience and emphasized the importance of designers in design activities. Therefore, future research should probably pay more attention to designers and explore the role that designers play in the design process and its impacts on design outcomes.

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Research Issues regarding Outcome

Developing new taxonomy of artifact

So far, in ISDSR, the dominant categorization of artifact is still the one proposed by March and Smith (1995), that is, the one categorizing artifact into four types, construct, model, method, instantiation. However, sometimes, this taxonomy is too general to be used for explicitly assigning artifacts into clearly defined and well-structured categorizations (Deng et al., 2017). For example, in a systematic literature review of ISDSR (i.e., Deng et al., 2017), due to the limited choice of artifact types, algorithms, frameworks, mechanisms, architectures, approaches and processes are all coded as method. However, the difference can be found among these artifacts. Our point here is that, if the taxonomy cannot ensure the homogeneity within one category and the heterogeneity between different categories, then the taxonomy should probably be replaced by a new one. Future DSR probably needs to build a new taxonomy for design artifact based on March and Smith's (1995).

Re-defining the concept of design theory

In ISDSR field, "what is design theory" is one of the most important research questions and has been addressed by researchers from many perspectives. Perhaps, the most widely accepted work on design theory is Walls et al. (1992); according to which, design theory includes seven components (i.e., kernel theories governing design requirements, mete-requirements, meta-design, testable design product hypotheses, kernel theories governing design process, design method, and testable design process hypotheses), covering both design product and design process. If examining the seven components carefully, it would be easy to find that the design theory proposed by Walls et al. (1992) is itself the DSR. In this case, it seems that current conceptualization of design theory is too general to clarify what design theory is. Therefore, a question arises, that is, "what design theory should be". Unfortunately, considering that the definition of theory is not that clear, maybe, it would be more applicable to figure out what design theory is not (Sutton and Staw, 1995; Weick, 1995). Future research could pay attention to answer the question "what design theory is not" and then provide a concise conceptualization of design theory.

Research Issues regarding Evaluation

Identifying the artifact-evaluation match

The need of match between artifact and evaluation method has been discussed in Section 5. Different evaluation methods might be needed to evaluate different artifacts. For example, evaluation of artificial intelligence might be different from the evaluation of FinTech. A recent systematic review of ISDSR has identified some popular match patterns between artifact type and evaluation method (Deng et al., 2017). The existence of these patterns have two implications (Prat et al., 2015). First, the patterns can provide additional justification for choosing one evaluation method for one artifact type. For example, in reviewing one DSR study, it would be reasonable to see that experiment is used to test the instantiation developed, and it would be worth extra checking when seeing that experiment is used to test construct. Second, the patterns can provide some clues for design science researchers to choose appropriate evaluation method for a specific artifact. Therefore, future research could try to find more match patterns. More importantly, future research should examine the widely adopted match patterns to see if there is an intrinsic relationship between the evaluation method and the artifact type.

Broaden the view of evaluation

IS research is posited at the confluence of people, organizations, and technology. The impacts of an IS artifact can be at several levels, i.e., individual, group, organization, industry, and society. However, for now, embracing utilitarianism, research on DSR evaluation only pays attention to the technological impacts of the artifact at the individual or organizational level. The core question concerning the evaluation of an artifact is “does it work?” Future research on DSR evaluation should adopt a multi-level lens and emphasize on both long-term and short-term effects of the artifacts. Shifting from short-term technical impact to evaluating both short-term and long-term impacts at multi-levels requires the development of the whole guide framework. The development of such framework involves many decisions to make, and a general directional guideline or principle might be helpful. Simon (1996) has provided such one general guideline in his work, *The Sciences of the Artificial*. As he describes,

The real result of our actions is to establish initial conditions for the next succeeding stage of action. What we call “final” goals are in fact criteria for choosing the initial conditions that we will leave to our successors. How do we want to leave the world for the next generation? What are good initial conditions for them? One desideratum would be a world offering as many alternatives as possible to future decision makers, avoiding irreversible commitments that they cannot undo…. A second desideratum is to leave the next generation of decision makers with a better body of knowledge and a greater capacity for experience. (Simon, 1996, p. 163)

Therefore, when we think about the long-term evaluation of one artifact, we might need to think if the artifact prohibits the possibilities for future decision makers or leave greater capacity for experience for the next generation.

What is design style? How can design benefit from style?

One interesting concept found in this study is “style”. According to Simon (1971) style is a function of designer’s decisions made during the design process. A few of ISDSR studies has mentioned style without seriously discussing it. The possible role of style in DSR evaluation has been discussed in Section 5. However, the point here is that style’s role is far more than providing evaluation evidence. As we see, from designer’s perspective, style comes from design process as well as directs design process; while, from user’s perspective, style affect user’s perception of the artifact, which, in turn, could possibly influence the effectiveness of the artifact implementation. Apparently, research on design style is very rare now. Future research could pay more attention to design style, examine its origin, features, and impacts, and figure out how can design benefits from the style.

Limitations of This Study

This study is not without limitations. Due to the limitation of time and scope, it is decided at the very beginning that this study would only address ISDSR. Despite a few of papers from organizational theory field, all the sources and discussions in this study are specially aimed at ISDSR. However, this purposefully chose constraint has two limitations, On the one hand, there is no doubt that DSR is applicable to many other fields and, for an exhaustive review of DSR, there is no reason to omit the related progress in other areas. On the other hand, DSR in different areas is both independent and interdependent and that in one area could benefit from incorporate the design thinking revised by and rooted in DSR in other areas. Simon (1996) does not constrain his work, *The Sciences of the Artificial*, which is subsequently viewed as footstone by IS design science researchers, within the management area; instead, he extends the work into several social science fields, such as economics, psychology, and sociology. Besides, even within management area, DSR can be applied to different sub-areas, such as Information Systems, Organizational Behavior, Marketing, and so on. Our point is that if Simon does not set up such constraint on DSR, then maybe neither should we. For a long time, the greatest strength of IS field is its intrinsically interdisciplinary nature. As one emerging research stream in IS, DSR should follow the tradition and posit itself in a broad map of design thinking. Our point here is that great contribution comes from great integration. DSR in different areas possibly has the different explicit knowledge, such as research traditions, concepts, processes, outcomes, evaluations. But all of them make contributions to the tacit knowledge regarding design, or, we can call, design thinking. The design thinking will then guide all DSR in different areas. For IS design science researchers, the first task of conducting DSR is to not omit the design thinking rooted in other areas. Therefore, future research should have a systematic review of design thinking(s) in different areas and see what ISDSR can benefit from it.

Conclusion

Compared to other fields (e.g., engineering, architecture, and art), Information Systems is still new to be exposed to DSR. However, because of its focus on solving practice-relevant problems using rigorous methods by creating effective artifacts, DSR is increasingly accepted by IS researchers and becoming a legitimate research paradigm. Several features of DSR might explain its fast proliferation. First, DSR is expected to balance the relevance and rigor of research. The realm of IS research is at the confluence of people, organizations, and technology (Davis and Olson, 1984; Lee, 1999; Hevner et al., 2004). DSR addresses the unsolved problems by embracing the important business opportunities afforded by the interaction of people, organization, and technology. Besides, DSR evaluates the artifacts built in terms of the applicability and generalizability, under the guide of utility. Second, DSR is also able to achieve a balance between technological creation and theory development. As discussed in previous chapters, kernel theory plays an important role in DSR. While kernel theory provides description and explanation for a problem, it offers designers with a deep understanding of the environment where the expected artifact will operationalize, which, in turn, serves as a basis for designers to develop the prescriptions. However, this does not mean that DSR cannot contribute to the kernel theory. In fact, the result of DSR (mainly concern if the artifact works) can be viewed as not only a justification of the effectiveness of the kernel theory but also an evidence of revising the kernel theory sometimes. Third, in a world of complexity, with explanatory abilities of traditional sciences limited by their nature of reductionism, DSR is becoming the bellwether of problem solving. Design is essentially a search process to discover satisfactory solutions to a specified class of problem. It is an inherently iterative process that utilizes available means to reach desired ends while satisfying laws existing in the environment (Simon, 1996). Different from traditional sciences, in DSR, while it is important to understand why an artifact works, the critical nature of design in IS makes it important to establish that it does work and to characterize the contexts in which it works, even if we cannot completely explain why it works (Hevner et al., 2004). Last, but not least, DSR has the potential of becoming the new paradigmatic tradition of IS field without necessarily costing the freedom of choosing theoretical and methodological foundations. IS has a long tradition of positing itself as an interdisciplinary field, which, has benefited the whole field a lot. For example, researchers in IS field have much broader theoretical and methodological foundations than those in other fields. However, IS also has been struggling with its lack of cumulative paradigmatic research tradition for a long time. DSR, with its ability of balancing, has become a fast proliferating research paradigm and could become a new tradition of IS research in future. Thus, it is very meaningful to figure out how to achieve both relevance and rigor through DSR without costing the established theoretical and methodological diversity. As the first step, the present study aims to investigate the concepts, methods and status quo of ISDSR. A comprehensive literature review has been provided to depict DSR from four interdependent perspectives, namely, concept, process, outcome, and evaluation. The results of this study have many implications, of which, the most important one is that the present study could serve as a roadmap for extant DSR studies as well as a blueprint for future DSR. Also, we hope that this study opens a window to considerably many research opportunities for future DSR, which will be discussed next.

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Appendix 1 - Summary of Design Science Research Process Models

Citation	Process	Content, Specification, and Resource Required
Peffers et al. (2007)	A1: Problem identification and motivation	• *Content*: Define the specific research problem and justify the value of a solution. • *Specification*: Defining may be useful to atomize the problem conceptually so that the solution can capture its complexity. Justifying the value of a solution: 1) motivates researcher and audience of the research to pursue the solution and to accept the results; 2) helps to understand the reasoning associated with the researcher's understanding of the problem. • *Resource required*: knowledge of the state of the problem and the importance of its solution.
	A2: Define the objectives for a solution	• *Content*: Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible. • *Specification*: The objectives can be quantitative or qualitative and should be inferred rationally from the problem specification. • *Resource required*: knowledge of the state of problems and current solutions, if any, and their efficacy.
	A3: Design and development	• *Content*: Determine the artifact's desired functionality and its architecture and then creating the actual artifact. • *Specification*: Conceptually, a design research artifact can be any designed object in which a research contribution is embedded in the design. Artifacts can be constructs, models, methods, or instantiations, or new properties of technical, social, and/or informational resources. • *Resource required*: knowledge of theory that can be brought to bear in a solution.
	A4: Demonstration	• *Content*: Demonstrate the use of the artifact to solve one or more instances of the problem. • *Specification*: This could involve its use in experimentation, simulation, case study, proof, or other appropriate activity. • *Resource required*: effective knowledge of how to use the artifact to solve the problem.
	A5: Evaluation	• *Content*: Observe and measure how well the artifact supports a solution to the problem. • *Specification*: Conceptually, the evaluation could include any appropriate empirical evidence or logical proof. At the end of this activity, the researchers can decide whether to iterate back to activity 3 or to continue on to activity 6. • *Resource required*: knowledge of relevant metrics and analysis techniques.
	A6: Communication	• *Content*: Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate. • *Specification*: In scholarly research publications, researchers might use the structure of this process to structure the paper. • *Resource required*: knowledge of the disciplinary culture.
Takeda et al. (1990)	A1: Awareness of the problem	• *Content*: To pick up a problem by comparing the object under consideration with the specifications
	A2: Suggestion	• *Content*: To suggest key concepts needed to solve the problem
	A3: Development	• *Content*: To construct candidates for the problem from the key concepts using various types of design knowledge • *Content*: When developing a candidate, if something unsolved is found, it becomes a new problem that should be solved in another design cycle
	A4: Evaluation	• *Content*: Evaluate candidates in various ways, such as structural computation, simulation of behavior, and cost evaluation • *Specification*: If a problem is found as a result of the evaluation, it becomes a new problem to be solved in another design cycle
	A5: Conclusion	• *Content*: To decide which candidate to adopt, modifying the descriptions of the object.
Eekels & Roozenburg (1991)	A1: Problem	• *Content*: The starting problem is a discrepancy between the facts and our value-preferences concerning these facts. • *Specification*: Emphasize on the facts have to be changed and value statements.
	A2: Analysis	• *Content*: Investigate through reasoning under which conditions a mentally conceived world could be both realizable and desirable. • *Specification*: The analysis is directed towards desirable possible worlds, and is governed by value statements. • *Resource required*: imagining and argumentation
	A3: Synthesis	• *Content*: Synthesis is directed towards the totality of the entity to be designed.

		A design is a kind of panoramic photography encompassing all aspects. • *Specification*: Synthesis in the design cycle is a priori of a possible material reality that eventually but not necessarily may be realized later. Synthesis results in a first draft of the design of a product/process, or, 'tentative design proposal'.
	A4: Simulation	• *Content*: Construct a simulation model and deduce predictions from the model. • *Specification*: Simulation is based on deduction and is often supported by experiments in the material reality.
	A5: Evaluation	• *Content*: Compare predicted facts with requirements. • *Specification*: Wholly occurs in the realm of the mind. • *Resource required*: Value statements
	A6: Decision	• *Content*: Choose the most attractive alternative from the set of generated design alternatives. • *Specification*: The decision aspect appears throughout the design process.
Nunamaker et al. (1991)	A1: Construct a conceptual framework	• *Content*: State a meaningful research question and justify its significance; Study relevant disciplines for new approaches and ideas.
	A2: Develop a system architecture	• *Content*: Identify the constraints imposed by the environment; State the objectives of the development efforts; Define functionalities of system components and interrelationships among them.
	A3: Analyze & design the system	• *Content*: Understand the studied domain; Apply relevant scientific and technical knowledge; Develop alternative solutions and choose one solution.
	A4: Build the (prototype) system	• *Content*: Build a prototype system to test the system in a real-world setting; Implement the designed system to demonstrate the feasibility and the usability of the system.
	A5: Observe & Evaluate the system	• *Content*: Test the system's performance and usability based on the requirements defined at the earlier stages; Consolidate experiences learned from developing the system.
March & Smith (1995)	A1: Build	• *Content*: Construct an artifact for a specific purpose. • *Specification*: Artifact performance is related to the environment in which it operates. • *Resource required*: Understanding of the environment.
	A2: Evaluate	• *Content*: Determine how well the artifact performs. • *Specification*: Both artifact and the evaluation criteria must be determined for the artifact in a particular environment.
Cole et al. (2005)	A1: Problem identification	• *Content*: Define, conceptualize, and report the problem.
	A2: Intervention	• *Content*: Construct an artifact and intervene to change the organization.
	A3: Evaluation	• *Content*: Incorporate evaluation criteria and evaluate.
	A4: Reflection and learning	• *Content*: Abstract knowledge to make a practical and theoretical contribution to the field.
Offermann et al. (2009)	A1: Problem identification	• *Content*: Identify problem; Literature research; Expert interviews; Pre-evaluate relevance.
	A2: Solution design	• *Content*: Design artifact; Literature research.
	A3: Evaluation	• *Content*: Refine hypothesis; Expert survey; Laboratory experiment; Case study/action research; Summarise results.
Gleasure et al. (2012)	A1: Development of utility requirements	• *Content*: Utility requirements represent the desired change in the problem system and describe the motivation for these changes.
	A2: Development of kernel knowledge	• *Content*: Identify the appropriate existing academic and industrial knowledge that describes related phenomena.
	A3: Development of explanatory/predictive model	• *Content*: Provide a more detailed description of the problem system by breaking it down into a set of related independent and dependent variables, i.e. an underlying theoretical model.
	A4: Development of design theory	• *Content*: Develop actual design prescriptions intended to impact upon the problem system, or "goal-directed plans for manipulating constructs".
	A5: Development of the instantiation	• *Content*: Transit the design prescriptions from the abstract into a real setting by developing an instantiation.
	A6: Development of the utilitarian evaluation	• *Content*: Implement the instantiation and observe the impact on the dependent variable in the system.
	A7: Development of design iterations	• *Content*: Conduct the design science research iteratively.
	A8: Development of additions to knowledge	• *Content*: Conduct a reflection on design prescription with aims to contribute to theory by validating or invalidating the theoretical basis for design.
	A9: Development of design process evaluation	• *Content*: To continuously evaluate the design process.
Alter (2013)	A1: Operation and maintenance	• *Content*: Operation of the work system and monitoring of its performance;

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		Maintenance of the work system (which often includes at least part of the information systems that support it) by identifying small flaws and eliminating or minimizing them through fixes, adaptations, or workarounds; On-going improvement of processes and activities through analysis, experimentation, and adaptation.
	A2: Initiation	• *Content*: Vision for the new or revised work system; Operational goals; Allocation of resources and clarification of time frames; Economic, organizational, and technical feasibility of planned changes.
	A3: Development	• *Content*: Detailed requirements for the new or revised work system (including requirements for information systems that support it); as necessary, creation, acquisition, configuration, and modification of procedures, documentation, training material, software, and hardware; Debugging and testing of hardware, software, and documentation.
	A4: Implementation	• *Content*: Implementation approach and plan (pilot? phased? big bang?); Change management efforts about the rationale and positive or negative impacts of changes; Training on details of the new or revised information system and work system; Conversion to the new or revised work system; Acceptance testing.
Vaishnavi & Kuechler (2015)	A1: Awareness of Problem	• *Content*: Aware of an interesting problem and form a proposal, formal or informal. The proposal should include a tentative design and the evaluation criteria, implicit or explicit.
	A2: Suggestion	• *Content*: Envision the new functionality based on a novel configuration of either existing or new and existing elements.
	A3: Development	• *Content*: Further develop and implement the tentative design.
	A4: Evaluation	• *Content*: Evaluate the artifact according to the criteria made in the earlier phase.
	A5: Conclusion	• *Content*: Make sure the design results are “good enough”; consolidate and write up the design results.
*Note: As to the specification and resource required, if the original author did not address, they will be omitted.		

Appendix 2 - DSR Evaluation Guidelines Coding Results

Citation	Guideline	Statements
Simon (1996)	G1	• Fulfillment of purpose or adaptation to a goal involves a relation among three terms: the purpose or goal, the character of the artifact, and the environment in which the artifact performs. (p. 5) • An artifact can be thought of as a meeting point – an 'interface' in today's terms – between an 'inner' environment, the substance and organization of the artifact itself, and an 'outer' environment, the surroundings in which it operates. If the inner environment is appropriate to the outer environment, or vice versa, the artifact will serve its intended purpose. (p. 6)
	G3	• When we come to the design of systems as complex as cities, or buildings, or economies, …, we must consider whether differences in style of the sort I have just been describing do not represent highly desirable variants in the design process rather than alternatives to be evaluated as 'better' or 'worse.' (p. 130)
March & Smith (1995)	G1	• Significant difficulties in design science result from the fact that artifact performance is related to the environment in which it operates. (p. 254) • Evaluation is complicated by the fact that performance is related to intended use and the intended use of an artifact can cover a range of tasks. (p. 254)
	G2	• Not only must an artifact be evaluated, but the evaluation criteria themselves must be determined for the artifact in a particular environment. (p. 254)
Hevner et al. (2004)	G1	• The business environment establishes the requirements upon which the evaluation of the artifact is based. (p. 85) • As available technology or organizational environments change, assumptions made in prior research may become invalid. (p. 85)
	G2	• The selection of evaluation methods must be matched appropriately with the designed artifact and the selected evaluation metrics. (p. 86)
	G3	• Design, in all of its realizations (e.g., architecture, landscaping, art, music), has style. Given the problem and solution requirements, sufficient degrees of freedom remain to express a variety of forms and functions in the artifact that are aesthetically pleasing to both the designer and the user. Good designers bring an element of style to their work. Thus, we posit that design evaluation should include an assessment of the artifact's style. • The measurement of style lies in the realm of human perception and taste. In other words, we know good style when we see it.
Pries-Heje, Baskerville & Venable (2008)	G1	• Evaluation of artefacts in artificial settings is not limited to simple experimental settings, but includes somewhat imaginary or simulated settings where the technology (or its representation) can be studied under substantially artificial conditions.
	G2	• This paper addresses that gap by developing a framework for choosing among evaluation strategies and methods.
Gregor & Hevner (2013)	G1	• A DSR project has the potential to make different types and levels of research contributions depending on its starting points in terms of problem maturity and solution maturity. (p. 344)
Baskerville, Kaul & Storey (2015)	G2	• Consequently, a corresponding set of criteria for knowledge justification and evaluation is provided for each genre of inquiry. (p. 541)
Prat, Comyn-Wattiau & Akoka (2015)	G2	• When generating a method, the relationships between the "what" and the "how" of evaluation, and between the different dimensions of the "how," should be considered. (p. 260)
	G4	• Beyond immediate usefulness, IS researchers are urged to investigate ways of evaluating the long-term organizational impact and the societal impact of artifacts. (p. 230)
Venable, Pries-Heje & Baskerville (2016)	G1	• In an ordinary design project without scientific aims, evaluation is focused on evaluating the artefact in the context of the utility it contributes to its environment. (p. 2) • One key purpose of evaluation in DSR is to determine how well a designed artefact or ensemble of artefacts achieves its expected environmental utility (an artefact's main purpose). (p. 3) • Rigour in DSR has two senses. … The second is in establishing that the artefact instantiation works in a real situation (effectiveness). (p. 6)
	G2	• The FEDS Framework for Evaluation in Design Science, which has the goal of helping to specifically guide DSR researchers in the design of an appropriate strategy and evaluation activities according to the needs of their DSR project or programme. (p. 4) • The detailed selection of the properties is necessarily unique to the artefact, its purpose(s), and its situation during evaluation. (p. 7)
	G3	• Together with style, the 'utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. (p. 3)
	G4	• Designed artefacts must be analysed as to their use and performance as possible explanations for changes (and hopefully improvements) in the behaviour of systems, people, and organisations. (p. 1) • Especially in the evaluation of safety critical systems and technologies, the evaluation should address potential risks to animals, people, organisations, or the public, including future generations. (p. 7)

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