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Design Science Research in Information Systems: A Systematic Literature Review 2001-2015

Qi Deng
Carleton University, qi.deng3@carleton.ca

Yun Wang
Carleton University, yun.wang3@carleton.ca

Shaobo Ji
Carleton University, shaobo.ji@carleton.ca

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Qi Deng
Carleton University
qi.deng3@carleton.ca

Shaobo Ji
Carleton University
shaobo.ji@carleton.ca

Yun Wang
Carleton University
yun.wang3@carleton.ca

Abstract
In the last few years, design science research has received wide attention within the IS community. It is increasingly recognized as an equal companion to IS behavioral science research and being applied to address IS topics. With the aim of providing an overview of its current state, this paper presents a systematic literature review on design science research in IS field. The results of this paper reveal the focuses of previous theoretical and empirical design science research and provide some directions for future IS design science research.

Keywords
Design science research, Information Systems, Systematic Literature Review

1. Introduction
Design science research (DSR) is a research paradigm that focuses on problem solving (March & Storey, 2008). It aims to create and evaluate artifacts designed to solve identified organizational problems by enabling the transformation of the "present situation" into the "desired situation" (Hevner et al., 2004; March & Smith, 1995; March & Storey, 2008). Among research areas embracing DSR, Information Systems (IS) is the one that exhibits rapid development regarding the adoption of Design Science as an epistemological paradigm for the advancement of knowledge (March & Smith, 1995; Nunamaker et al., 1991; Takeda et al., 1990; Walls et al., 1992). In the last few years, DSR has received wide attention within the IS community. It is increasingly recognized as an equal companion to IS behavioral science research and the novel paradigm that can tie all the other IS paradigms together (Hevner, 2007; Iivari, 2007). With the idea that "*the IS field needs more design science research*" (Goes, 2014, p. vi), researchers are addressing DSR from both theoretical (e.g., Beck et al., 2013; Hevner et al., 2004; Gregor & Hevner, 2013; Peffers et al., 2007; Lee et al., 2015) and empirical (e.g., Abbasi et al., 2012; Arnott, 2006; Bapna et al., 2004) perspectives, and a lot of high quality papers are being published in the top IS journals and conference proceedings. However, confusion and misunderstandings still exist and are hindering DSR from having a further profound influence on the IS field (Gregor & Hevner, 2013). With such consideration, this paper presents a systematic literature review on design science research in IS field (ISDSR). The purpose of this paper is to provide an overview of the current state of ISDSR and to answer questions such as "How to identify DSR in top IS publications and how is DSR distributed in them?", "What research questions have been addressed/overlooked in the theoretical ISDSR?", and "What is the most common artifact type/evaluation method in ISDSR? Are there any patterns between artifact types and evaluation methods?"

The rest of the paper is organized as follows. Section 2 presents the method of identifying ISDSR. Section 3 describes the coding framework and process of the systematic review. Section

4 presents the review results. Section 5 concludes the paper with discussions of the results, the contributions and the limitations of the study, and suggestions for future research.

2. Design Science Research in Top IS Publications: Identification

The identification of ISDSR was an iterative process that went through five steps, with each step determined based on the search result of the previous step (see Figure 1). Two criteria (i.e., accuracy and completeness) were applied to determine the goodness of the search result. High accuracy means that the search result should mainly consist of design science research. One major disturbance of search accuracy is the existence of design-related research (DRR). A paper will be treated as DRR if it addresses the topic of design without adopting design science paradigm or method. An example of DRR is Cyr, Head, Larios & Pan's paper (2009), *Exploring human images in website design: a multi-method approach*, which is published in MIS Quarterly. In that paper, Cyr et al. (2009) examined how Internet users perceive human images as one element of website design and the impact of such perception on users' perception of the website. This paper is viewed as DRR because it does not follow DSR paradigm or adopt DSR method, even though it addresses the topic of website design. To ensure the accuracy of our search result, our primary task is to differentiate DSR from DRR through using proper search terms. High completeness means that, under the existing conditions (e.g., the time and scope limitation of this paper, the accessibility to the related database), the search result should include major DSR in top IS publications. As to the completeness, the search sources and the sample size are the main considerations.

At the very beginning, it was decided to use the IS senior scholars' basket of journals, i.e., *MIS Quarterly (MISQ)*, *Information Systems Research (ISR)*, *Information Systems Journal (ISJ)*, *Journal of the Association for Information Systems (JAIS)*, *Journal of Management Information Systems (JMIS)*, *Journal of Strategic Information Systems (JSIS)*, *Journal of Information Technology (JIT)*, *European Journal of Information Systems (EJIS)*, as original data source. It has been proposed to treat this "basket" of eight journals as top journals in IS field (Association for Information Systems, 2017). To get a final sample, the search went through five steps. First three steps were conducted in the Web of Science. Step 1 was conducted as a pilot search. In step 1, we searched topic, using term "design" and "design science research" respectively, with publication date limited to "from 1991 to 2015". The two searches resulted, respectively, in 1,161 and 129 papers. The pilot search showed that searching topic using "design" would return a too-broad result while using "design science research" would return a too-narrow result. Therefore, in step 2, we replaced the search terms with "design science" and "design research." This decision was not made without appropriate theoretical foundations. Many researchers have proposed that the design science research consists of two compositions, design science and design research (Winter, 2008). The search in step 2 resulted in 715 papers. One quick review of this sample indicated that it includes too much DRR. So to exclude the DRR, in step 3, the sample derived from step 2 was refined with the criterion of "title or abstract or keywords including 'design science' or 'design research.'" This search resulted in 103 papers, of which, interestingly, only one paper was published before 2001. This is possibly because that the DSR, especially the use of the terms "design science" and "design research," is mainly proliferating after the publication of Hevner et al. (2004). Therefore, to improve the representativeness of the sample, we decided to limit the publication date as "from 2001 to 2015". Step 3 resulted in 102 papers. A quick review indicated that most of the papers are within the topic of design science research. However, the sample size seemed too small to meet the requirement of completeness. To improve the completeness of the sample, it was decided to include conference proceedings as another data source.

	Step 1	Step 2	Step 3	Step 4	Step 5
Source	Senior Scholars' Basket of Journals: Eight Top IS Journals	Senior Scholars' Basket of Journals: Eight Top IS Journals	Result of Step 2: 715 papers	Proceedings of four top IS conferences: ICIS, AMCIS, ECIS, HICSS	Result of Step 3 & 4: 416 papers
Search	1) Topic with “D” 2) Topic with “DSR” Date: 1991-2015	Topic with “DS”, “DR” or “DSR” Date: 1991-2015	Title/Abstract/ Keyword with “DS”, “DR” or “DSR” Date: 2001-2015	Title/Abstract with “DS”, “DR” or “DSR” Date: 2001-2015	Data Cleaning: De-duplication & Only retain full research papers
Sample	1) Size: 1161 2) Size: 129	Size: 715	Size: 102	Size: 314	Size: 332 (84 Journal & 248 Conference)
Evaluation	1) Topic: too broad 2) Topic: too narrow	Topic: include too many design related studies	Topic: good	Topic: good	Topic: good

***Abbr.**: D-Design; S-Science; R-Research; DS-Design Science; DR-Design Research; DSR-Design Science Research;*

Figure 1. An Iterative Process for Identifying Design Science Research in IS Area

Four top IS conferences, i.e., International Conference on Information Systems (ICIS), Americas Conference on Information Systems (AMCIS), and European Conference on Information Systems (ECIS), and Hawaii International Conference on System Sciences (HICSS) were selected. Due to the functional limitations of the Associate for Information Systems (AIS) database, the search of conference papers started with the criterion of "title or abstract with 'design science' or 'design research.'" Here, the criterion of keyword was removed because that the AIS database provides neither a keyword search function nor the keyword information in the bibliographical records. Step 4 resulted in 314 conference papers, which, indicated by a quick review, mainly consist of DSR. Combining the results of step 3 and step 5 resulted in 416 papers. Before going directly to the coding process, it is necessary to clean the sample. The data cleaning has two objectives. The first is to remove duplicated papers. The second is to remove papers, which are not full research, such as editor's commentary, research-in-process, and introduction to a special issue or conference mini-tracks. Data cleaning resulted in 332 papers, of which, 84 are journal papers and 248 are conference papers. The 332 papers were used as the initial sample and were entered the next step, systematic literature analysis.

3. Design Science Research in Top IS Publications: Analysis

An analysis framework (Table 1) and a review process (Figure 2) were developed and applied to guide the systematic literature review. For each paper in the sample, the review followed the process shown in Figure 2. The review is mainly based on the examination of one paper's title, abstract and method parts. If the analysis decision could not be made by solely reading these three parts, other parts of the paper would be examined until the coding is completed.

Variable	Node	Description
Subject	DSR	• If the paper follows the DSR paradigm, adopts the DSR method, or addresses on at least one of the DSR theoretical topics.
	Other	• If the paper is not DSR.
Type	Empirical	• If there is at least one artifact being proposed or built in the research.
	Theoretical	• If there is not artifact being proposed or built in the research.
Artifact Type	Construct	• Vocabulary or symbols used to define and understand problems and solutions.
	Model	• Designed representations of the problem possible solutions, such as mathematical models, diagrammatical models, and logic models.
	Method	• Instructions for performing goal-driven activities, such as algorithms, frameworks, mechanisms, architectures, approaches, processes, etc.
	Instantiation	• Physical realizations that act on the natural world, such as software, websites, prototypes, etc.
	Theory	• An abstract, coherent body of prescriptive knowledge that describes the principles of form and function, methods, and justificatory theory that are used to develop an artifact or accomplish some end (e.g., design principles, technical rules, and design theories).
Evaluation Method	Observational	• Case Study: Study artifact in depth in a business environment. • Field Study: Monitor use of artifact in multiple projects.
	Analytical	• Static Analysis: Examine the structure of artifact for static qualities (e.g., expert evaluation). • Architecture Analysis: Study fit of the artifact into technical IS architecture. • Optimization: Demonstrate inherent optimal properties of an artifact or provide optimality bounds on artifact behavior. • Dynamic Analysis: Study artifact in use for dynamic qualities (e.g., performance).
	Experimental	• Controlled Experiment: Study artifact in a controlled environment for qualities (e.g., usability).

		• Simulation: Execute artifact with artificial data.
	Testing	• Functional (Black Box) Testing: Execute artifact interfaces to discover failures and identify defects. • Structural (White Box) Testing: Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation.
	Descriptive	• Informed Argument: Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility. • Scenarios: Construct detailed scenarios around the artifact to demonstrate its utility.
Topic	Concept	• General Discussion: If the paper mainly addresses basic concepts of DSR or general discussion of DSR (e.g. what is DSR? Is DSR a paradigm or a method? How to achieve relevance and rigor by DSR?). • Philosophical Discussion: If the paper mainly addresses philosophy-related questions of DSR (e.g., what is the epistemology of DSR? Pragmatism in DSR?).
	Methodology	• Process: If the paper mainly addresses the process of conducting DSR (e.g., DSR process model.). • Method: If the paper mainly addresses the method of conducting DSR (e.g., how to conduct action design research? Ethnography in DSR; Grounded theory in DSR.).
	Outcome	• Design knowledge: If the paper addresses DSR mainly from the knowledge perspective (e.g., what is the knowledge contribution of DSR? What types of knowledge does DSR produce?). • Artifact: If the paper mainly addresses the artifacts built in DSR (e.g., how to categorize the artifacts?).
	Evaluation	• If the paper mainly addresses the evaluation method of DSR (e.g., how to evaluate the DSR? How to evaluate the artifacts?).
	Theory	• The principle of Design: If the paper mainly addresses the general principles of design. • Theory or Theorizing: If the paper mainly addresses the design theory or theorizing (e.g., what is design theory? How to develop design theory?).

Table 1. The Systematic Literature Analysis Framework*

* Developed based on *March & Smith (1995), Hevner et al. (2004), Gregor & Hevner (2013), Gregor & Jones (2007), Vaishnavi & Kuechler (2015).*

As Figure 2 shows, the first step of coding is to decide whether one paper is design science research. If yes, the paper would enter the subsequent analysis, if not, the paper would be coded as "Other" in Paper Type and finally removed from the sample. The aim of this step is to ensure that our final sample only includes design science research and to improve the accuracy of the analysis results. In the end, 54 papers were identified not being design science research and removed. In total, 278 papers were identified as design science research and they were included in the data analysis. The detailed analysis of the 278 papers is presented in next section.

4. Design Science Research in Top IS Publications: Findings

4.1. ISDSR: Distribution across publications and over time

Of the 278 papers identified, 70 were published in journals and 208 in conference proceedings. The distribution of these papers across publications is shown in Table 2. MISQ is the journal where most ISDSR being published, followed by JAIS and JMIS; while, AMCIS is the conference where most ISDSR being published, followed by HICSS and ECIS. Considering the empirical-conceptual ratio, we can find that empirical research is more welcomed than conceptual research; the average empirical-conceptual ratio is about 3.5. Furthermore, MISQ and JMIS are the journals where empirical research is most popular; while the HICSS is the conference where conceptual research is less popular with empirical-conceptual ratio at 6.375. The distribution of ISDSR over time is shown in Figure 3. Although fluctuations exist, overall, ISDSR publication shows an increasing trend. Several important nodes need to be paid attention to in this figure. The first one is the year 2004, after which, DSR publications usher in rapid growth. This significant change comes possibly because of the publication of Hevner et al.'s (2004) work in MISQ, which marks the starting of the formalization process of DSR as a paradigm in IS.

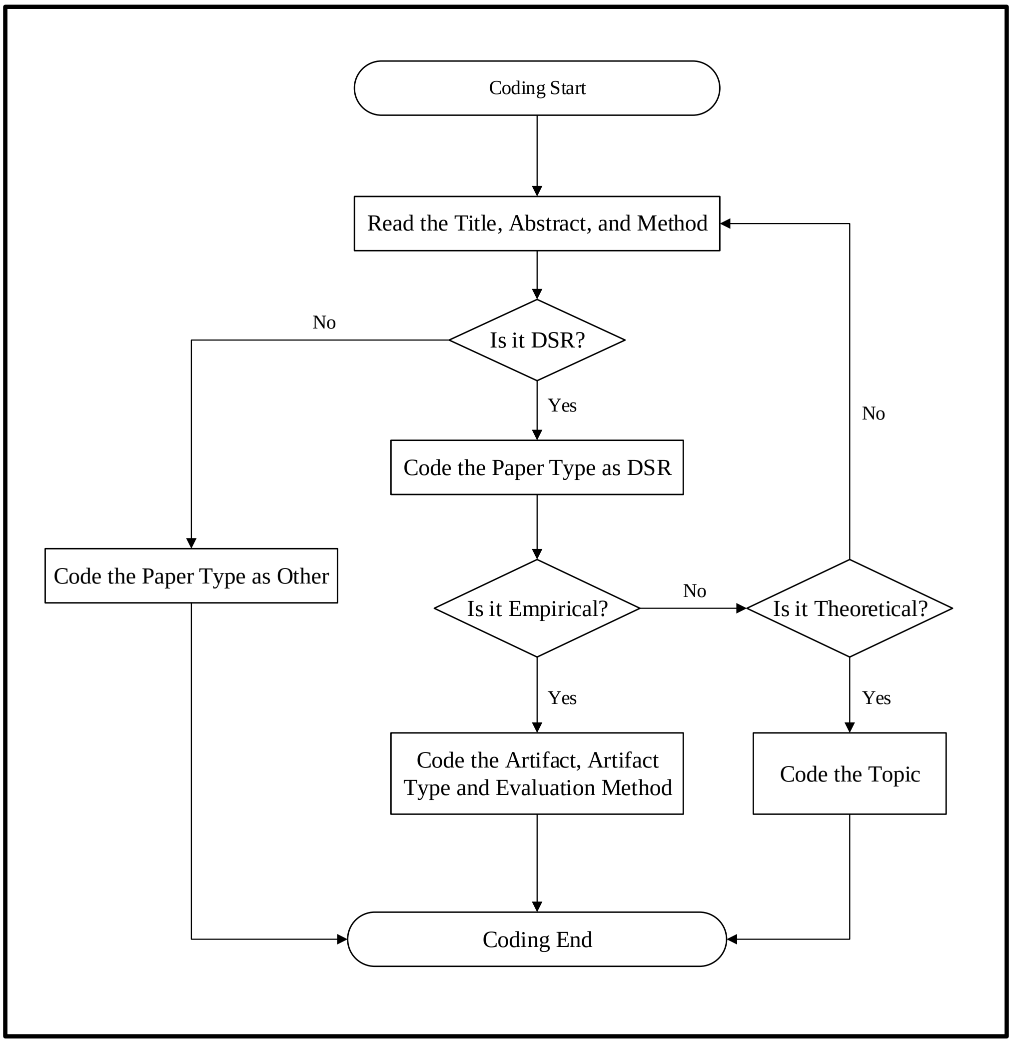

Figure 2. The Flowchart of Coding Process

Type	Publication Name	Amount	
		Conceptual	Empirical
Journal	MIS Quarterly (MISQ)	6	18
	Journal of Management Information Systems (JMIS)	3	9
	Journal of the Association for Information Systems (JAIS)	7	9
	European Journal of Information Systems (EJIS)	2	5
	Information Systems Journal (ISJ)	2	2
	Information System Research (ISR)	1	2
	Journal of Strategic Information Systems (JSIS)	1	2
	Journal of Information Technology (JIT)	1	0
Conference	International Conference on Information Systems (ICIS)	10	24
	Americas Conference on Information Systems (AMCIS)	19	46
	European Conference on Information Systems (ECIS)	17	33
	Hawaii International Conference on System Sciences (HICSS)	8	51

Table 2. The Sample Distribution in Different Publications

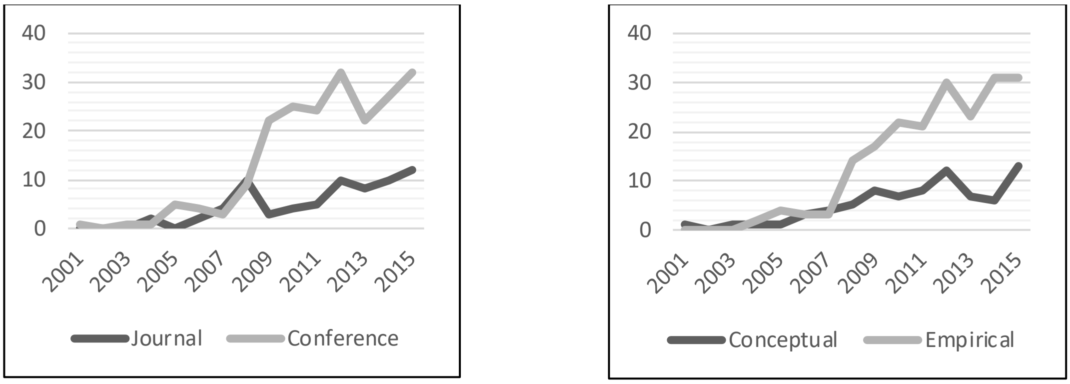

Figure 3. The Distribution of ISDSR: 2001-2015

The second node is the year 2013. The amount of the publications (both journal and conference, and both conceptual and empirical) reduced evidently from 2012 to 2013. A close examination of data indicates that this is mainly caused by ECIS, of which the publication reduced from 10 in 2012 to 2 in 2013. The third node is the year 2014. After the evident decrease from 2012, the DSR publication grows again from 2014. This is possibly because of the publication of Goes's (2014) editor's comments in MISQ. From an editor's perspective and as the editor-in-chief of MISQ himself, Goes (2014) analyzed the DSR's publication opportunities in top IS journals based on the knowledge contribution framework proposed by Gregor & Hevner in 2013 and suggested that IS field needs more DSR publications. There is no doubt that a proposal from the editor-in-chief of the top journal in a field would have some direct impacts on the research popularity of the field.

4.2. ISDSR: What we have addressed and created, and how we have evaluated

In this section, we present and discuss the evolution of ISDSR from three perspectives: 1) the topics of conceptual papers; 2) artifact developed in empirical papers; and 3) evaluation method used by empirical papers. The analysis results are shown in Figure 4. To facilitate the discussion, we divided the 15 years into five periods, with each period including three years.

4.2.1. Topics addressed by prior conceptual ISDSR

In total, there are 77 conceptual papers in the sample, of which, 23 come from journals and 54 come from conference proceedings. As Figure 4 shows, *Methodology* is the fastest growing topic. Research on *Concept* shows a steady trend, and research on *Evaluation* shows a slow and steady growth, with an increasing rate.

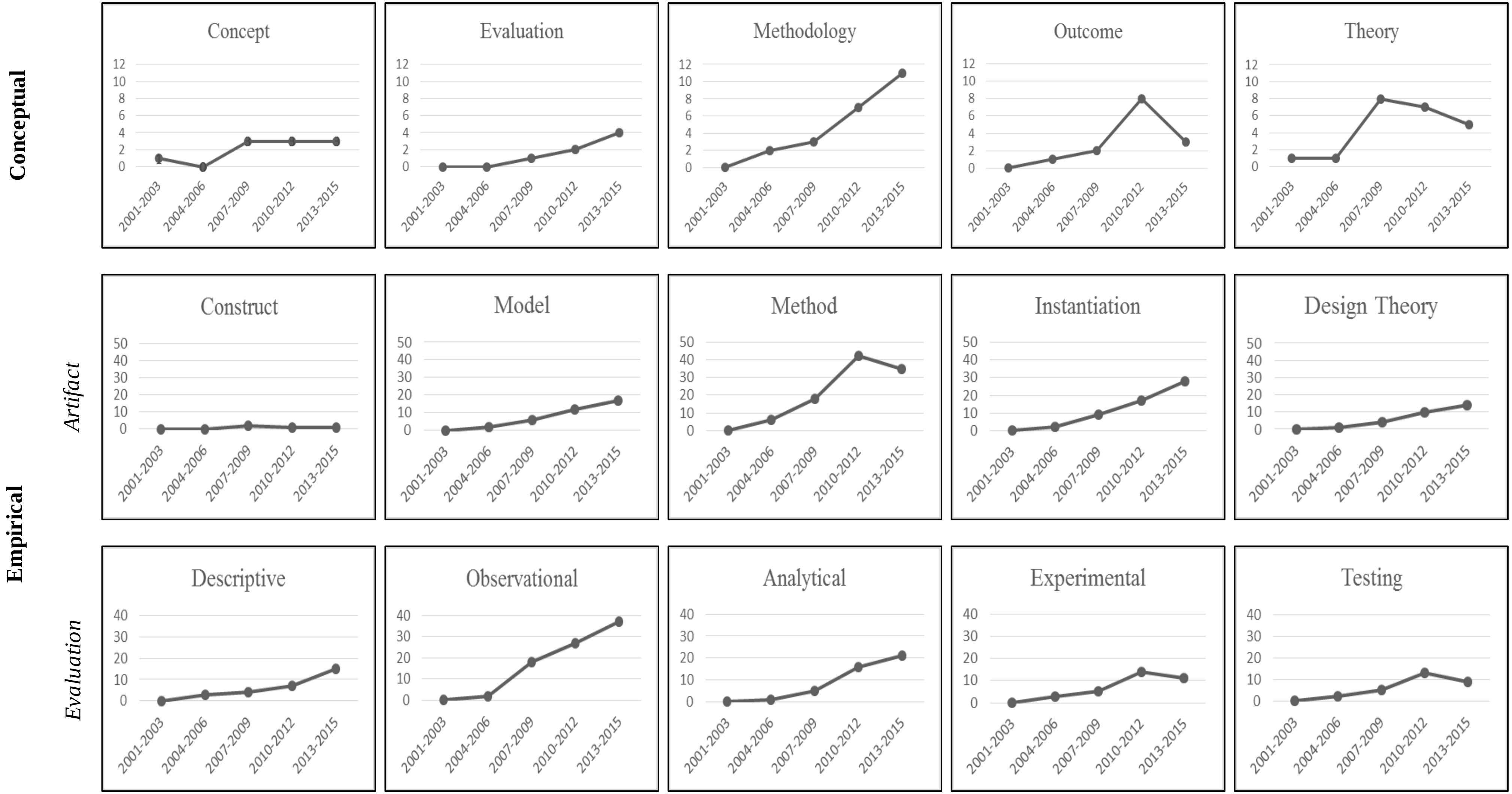

Figure 4. Evolution of ISDSR: Conceptual and Empirical Research

Research on *Outcome* and *Theory* reached their peaks in the past and began decreasing recently. The results indicate that, currently, IS design science researchers care most about how to conduct DSR and start to pay attention to how to evaluate the artifact developed. Considering the current stage of design science research (early-paradigm/pre-paradigm), the result seems not surprisingly. Research on method usually aims to provide guidelines for researchers on how to conduct research. More importantly, such research is often cited by researchers to justify the legitimacy of their ways of doing research. As to the sub-topics (see Table 1), the DSR *Theory/Theorizing* is another popular topic in both journals and conference proceedings. It has been proposed that the major feature that differentiates DSR from professional design is that DSR addresses a class of problems, instead of one specific problem. As the most abstract type of knowledge, design theory is expected to be able to guide the whole DSR field. There are two topics, *philosophical discussion*, and *principles of design*, that have not been covered by the journal publications. However, the current overlook does not indicate that the two topics are less important than others. Philosophical assumptions are the foundation of the whole research area. It provides the most basic guideline for researchers every decision made during the research process. Clarifying the philosophical assumption should be one of the major tasks of a paradigm in its early stage. At first glance, the principles of design should be embedded in the specific context where the design is conducted. However, general principles of design are necessary, because they provide a bridge between design theory and design method. Both *philosophical discussion* and *principles of design* can provide a solid ground for addressing questions such as how to conduct and how to evaluate. Therefore, in future, IS journals could consider accepting more research on philosophical discussion and principles of design.

4.2.2. Artifacts created in prior empirical ISDSR

There is no consensus on the categorization of artifact types of DSR. In this part, following Gregor & Hevner (2013), the artifacts were categorized into five types, construct, model, method, instantiation, and theory (see Table 1). Since some papers (28 papers) developed more than one artifact, the total number of artifacts is larger than the number of papers. A list of artifacts built in the 201 empirical papers can be found in Table 3.

Author	Source	Artifacts for Problem Solving
Abbasi et al. (2012)	MISQ	MetaFraud, a novel meta-learning framework for enhanced financial fraud detection
Astor et al. (2013)	JMIS	A game-based NeuroIS tool that continuously displays the player's individual emotional state, via biofeedback.
…………	……	……………………

Table 3. Artifacts Developed in Prior Empirical Research (Sample)*

* The complete list can be accessed by contacting the author.

As Figure 4 shows, in ISDSR, the numbers of *model*, *instantiation*, and *theory* developed grew steadily. *Method* shows the fastest growth, but shows an evident decrease recently; *Construct* seems to have been overlooked persistently. Specifically, *Method* is the most popular artifact type, and, under *Method*, the four most common artifact types are “method,” “approach,” “framework,” and “mechanism.” Under *Design Theory*, the most common artifact type is “design principles.” Taking a step forward, we examined the combinations of different artifact types in same papers. We found that the most “popular” artifact combination is “method & instantiation” (8 times), which is followed by “instantiation & theory” (7 times). According to what we learned during coding, one possible explanation is that instantiation is usually developed as a prototype to demonstrate that the method or the theory (in this case, design principles) works well. Notably, four artifact combinations did not show in the sample, which are “construct & method,” “construct & instantiation,” “construct & theory,” and “model &

theory." This is interesting because it seems to imply that construct itself is not able to support the development of method, instantiation, or theory, and model itself is not able to support the theory development. Indeed, the dependency relationships between artifact types has been discussed in previous research (March & Smith, 1995):

> *"Constructs constitute a conceptualization used to describe problems within the domain and to specify their solutions… A model is a set of propositions or statements expressing relationships among constructs… Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space… Instantiations operationalize constructs, models, and methods."* (March & Smith, 1995, pp. 256-258)

Although March & Smith (1995) did not address theory in their work, it is reasonable to infer that directly drawing theory from conceptualization of problems (constructs) does happen rarely. Our analysis result partly justified the description above.

4.2.3. Evaluation method used in prior empirical ISDSR

There are five types of evaluation methods, namely, descriptive, analytical, observational, experimental, and testing. As Figure 4 shows, the fastest growing evaluation method is the observational method, followed by the analytical method and the descriptive method. Specifically, the most common observational method is case study, while the most common analytical method is expert evaluation. Of 84 papers using observational method, 54 used case study; of 43 papers adopting the analytical method, 36 used expert evaluation. Experimental and testing methods grew steadily in the past but show some slight decreases recently. Although the decreases are caused by the decrease of total ISDSR publications very likely, it is obvious that experimental and testing methods are not the dominated ones in ISDSR. Interestingly, although the IS design science research is rooted in Engineering and Computer Science, the dominated evaluation methods (i.e. experimental and testing methods) in those two areas were not inherited by IS researchers in the same way as design thinking. One possible explanation of this situation could be drawn from the logic statement that "the selection of evaluation method must be matched appropriately with the designed artifact" (Hevner et al., 2004). Although the statement emphasizes the importance of match in selecting appropriate evaluation method, it does not explain how to decide the appropriateness. Therefore, we examine the combination patterns between artifact and evaluation method, aiming to shed light on the *appropriateness*. Since some papers in the sample have multi-artifacts, multi-evaluation methods, or both, it is necessary to add a new coding rule to help connect evaluation method to the artifact. Briefly, the rule is that "*one evaluation method should be coded to be related to the artifact it directly evaluates the artifact*." This rule could be clarified using an imaginary example. For example, paper A has two artifact (*method* and *instantiation)*, and two evaluation methods (*case study* and *expert evaluation*). The *method* is developed to support the construction of the *instantiation*, and the evaluations are directly applied to the *instantiation*. In this case, the two evaluation methods will be coded as evaluation methods of the *instantiation*, not the *method*, and we would get two combinations (*instantiation and case study* and *instantiation and expert evaluation*). Following this rule, the coding result is shown in Table 4.

	Descriptive	Analytical	Observational	Experimental	Testing
Construct			3		
Model	9	9	12	4	1
Method	11	18	39	14	15
Instantiation	5	10	18	15	12
Theory	4	6	12		1

Table 4. Patterns between Artifact Type and Evaluation Method

As Table 4 shows, the observational method is most popular in evaluating construct, model, method, and theory. The only exception is with instantiation. Experiment turns out to be the dominant method of instantiation evaluation. It has been proposed that "build" and "evaluate" are the core activities in DSR. If we adopt the lens of anatomy, take one combination of artifact (product of build) and evaluation method (the method of evaluating) as a basic unit of design science research, and view design science research as the combination of the basic units, then we can find several popular basic units of ISDSR. Using "[artifact type * evaluation method]" as the communication style and taking "occurrence number ≥ 15" as the criterion, five popular basic units of DSR would be identified:

- [Method * Analytical];
- [Method * Observational];
- [Method * Testing];
- [Instantiation * Observational];
- [Instantiation * Experimental];

The analysis result and discussion above indicate that there are dominant artifact type and evaluation method of ISDSR, which are, respectively, method and observational method. Researchers who are interested in conducting DSR could take that into consideration. As ISDSR is still at the beginning of its second growth, it is acceptable and possibly necessary for researchers to follow the dominant way of doing DSR. However, for the long-term thinking, more artifact types and evaluation methods should be developed and validated. Only by that, can DSR become a mature paradigm and regurgitate to its reference fields.

5. Discussion and Conclusion

In this paper, we systematically reviewed the design science research published in the top IS publications from 2001 to 2015. The results of this paper have many implications. From the academic perspective, this study can help to identify the possible research gaps and provide directions for future researches. From the practical perspective, this study can provide an overview of solved problems and artifacts built to solve those problems, which could be used to direct practitioners to the areas most related to their problems. This paper is not without limitations. First, the way we searched our sample might limit the sample we got. Future research could extend the search into pre-2000 by using keywords such as, "*sciences of the artificial*" (Simon, 1969), "*systemeering*" (Iivari, 1983), "*constructive approach*" (Iivari, 2007), and "*systems development*" (Nunamaker et al., 1991). Second, we mainly review the ISDSR from a methodological perspective because in our analysis we found that design science is mostly used by IS researchers as a research methodology. The topics of ISDSR are diversified, which implies that design science could be used in a broad context. This could be reflected from our complete list of artifacts developed in previous ISDSR. Future research could review ISDSR from a topic perspective.

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