From Artefact to Theory: Ten Years of Using Design Science in Information Systems Research

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Abstract: After almost one decade from the introduction of design science research (DSR) by Hevner et al (2004) to the information systems (IS) discipline, several studies have benefited from this approach and produced significant results which range from new IT artefacts to IS theories. The focus of the approach on solving real problems through developing an IT artefact and its potential to study further consequences, have made the approach popular for IS scholars and practitioners. However, the approach is “neither extensively cited nor considered salient to their own research by authors or referees” according to the well-known author in the field, Eric K. Clemons. The current research aims to investigate the theoretical background, topics, context, output and research techniques in papers which used a DSR approach. This paper employs a systematic literature review approach to study 14 top ranking journals in the field of IS. After an in-depth study of 569 papers, our search resulted in a final set of 72 papers which used this approach. Based on comprehensive analysis of these papers, their main theoretical foundations are identified and compared according to different components in DSR (problem, artefact, evaluation, result). This study indicates that although a DSR approach has been used for a variety of topics, there is still opportunity for using it in many others. The results may be beneficial to show new researchers the benefits, current status and future opportunities to use the DSR approach. Moreover this paper can show practitioners how to benefit from the DSR approach in solving their problems.

Keywords: design science, research, systematic literature review, problem solving, IT artefact

1. Introduction

The term Design Science was first coined in the 1960s in the architecture and engineering literature; subsequently Simon (1969) introduced the term to computing science. However this concept did not enter information system (IS) research until 1990 when Nunamaker and Chen (1990) introduced their methodology of IS research based on system development. Their multi-methodological approach to IS research is based on system development as a core which results in experimentation, observation and theory building.

The work of March and Smith (1995) is another influential paper which called for an IT/IS research framework which best contributes to design tasks faced by practitioners. Based on activities in natural science research and design research outputs, they developed a 2D framework for IT research. However, the most cited reference (more than 4600 times) on the topic was published by Hevner et al (2004) which definitely shaped the literature with the seven guidelines it provided. After that many theoretical works have been published as an attempt to shift design science from a paradigm to a research method (Peffers et al, 2007, Beck et al, 2012) and these principles have been used in various topics for generating artefacts, models, and theories.

The current paper seeks to study areas in which design science has recently been used and related trends in IS research by using a systematic literature review method. To do so, we searched 14 top ranking journals in the field of IS with related phrases and, by this review, made an attempt to answer the following research questions:

RQ1. Which theoretical contributions have been made to the design science research (DSR) in IS research?
RQ2. In which areas of IS research have the DSR approach been used?
RQ3. How research papers in IS have used the DSR approach?

The result of this study can help future research to extend use of DSR to new areas or select the best theoretical basis for use of the approach in future research. While use of DSR in solving practical problems in industry have been highlighted in recent years (Land et al, 2009), this paper will also help practitioners by providing a short introduction and directing them to the best area that may solve their business problems.
The remainder of this paper is organized as follows: section 2 is a brief introduction to the DSR concept and an overview of similar terms, section 3 introduces our method for conducting the review, section 4 indicates the result of our review in terms of both theoretical and empirical work, and finally the findings are discussed in section 5.

2. Design science research

After initial studies in fields like engineering, architecture, and computer science, Hevner et al (2004) introduced design science as ‘the other side of IS research cycle’ which attempts to solve organizational problems with creating and evaluating IT artefacts. According to March and Smith (1995) four different categories of artefacts are: construct (constitute a conceptualization used to describe problems within the domain and to specify their solutions), model (a set of propositions or statements expressing relationships among constructs), method (a set of steps used to perform a task) and instantiation (the realization of an artefact in its environment which operationalize constructs, models, and methods). Later Gregor and Jones (2007) also introduced theorizing as an important output in DSR research.

Similar terms have been cited in IS literature which are to some extent related to the design science area. Baskerville (2008) in his editorial note differentiated design (in terms of creating knowledge), design theory (in terms of its tendency to create theory instead of using theory), action research (in terms of its focus on creating artefact instead of social or organizational change) and IT artefact (by pointing out the fact that the DSR may result in a conceptual artefact). Winter (2008) also differentiated ‘design science’ and ‘design research’ by pointing out an implication of word ‘research’ which is usually associated with “solutions which are generic and applicable to a set of problem solutions” (p. 471).

Purao et al (2008) used the term ‘the sciences of design’ as a bridge-building area between IS discipline and allied social and technical disciplines. He differentiated the term with design as research (which is meant to be the activity in which researcher arrives to an understanding of the phenomenon at the time of designing it) and research design (which focuses on methods of designing). The current study however uses the term Design Science Research (DSR) as a general term which refers to the concept of designing and evaluating IT artefact as proposed by Hevner et al (2004).

3. Research method

We use a systematic literature review method in the current paper to study the main theoretical and empirical papers in the DSR literature. A systematic literature review is a methodical way to identify, evaluate, and interpret the available empirical studies conducted on a topic, research question, or a phenomenon of interest (Kitchenham, 2004).

In order to conduct this review, we used guidelines provided by Kitchenham and Charters (2007) which suggest five different steps for review: (1) identify resources; (2) study selection; (3) data extraction; (4) data synthesis; and (5) write-up study as a report. To follow these steps we first selected 14 journals which were ranked as A+ and A in the Australian Research Council ERA Journal list and searched them with our keywords. Our first search resulted in 569 papers which contained the defined keywords. By in-depth study of the papers we arrived at a final list of 72 papers and performed our analysis and classification based on these.

3.1 Sources and keywords

Table 1: List of journals and distribution of research papers

<table>
<thead>
<tr>
<th>Journal</th>
<th>Rank</th>
<th>Number of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Journal of Information Systems</td>
<td>A*</td>
<td>6</td>
</tr>
<tr>
<td>Communications of the Association for Information Systems (CAIS)</td>
<td>A</td>
<td>18</td>
</tr>
<tr>
<td>Information and Organization</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>International Journal of Medical Informatics (IJMI)</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Journal of Information Systems (JIS)</td>
<td>A*</td>
<td>1</td>
</tr>
<tr>
<td>Information Systems Research (ISR)</td>
<td>A*</td>
<td>4</td>
</tr>
<tr>
<td>Information Systems Journal (ISJ)</td>
<td>A*</td>
<td>1</td>
</tr>
<tr>
<td>Information Technology and People (ITP)</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>Journal of the Association for Information Systems (JAIIS)</td>
<td>A</td>
<td>13</td>
</tr>
<tr>
<td>Journal of Management Information Systems (JMIS)</td>
<td>A*</td>
<td>4</td>
</tr>
<tr>
<td>Journal of Computer Information Systems (JCIS)</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>Journal of Strategic Information Systems (JSIS)</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>MIS Quarterly (MISQ)</td>
<td>A*</td>
<td>8</td>
</tr>
<tr>
<td>Scandinavian Journal of Information Systems</td>
<td>A</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>72</td>
</tr>
</tbody>
</table>

3.2 Inclusion / exclusion criteria

Our first search for the keywords resulted in 569 papers. We then read the title, abstract and keywords of the papers and removed papers which did not really use DSR as their research approach or ones which have not theoretically contributed to this research area. Finally we made another round of filtering by referring to the full texts with the same criteria and formulated the final list of 72 papers. Table 2 illustrates the process of inclusion / exclusion for our research.

Table 2: Different stages of inclusion / exclusion and number of papers in each round

<table>
<thead>
<tr>
<th>Round</th>
<th>Number of Papers Excluded</th>
<th>Number of Papers Remained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial list of papers</td>
<td>-</td>
<td>569</td>
</tr>
<tr>
<td>Exclusion based on title</td>
<td>329</td>
<td>240</td>
</tr>
<tr>
<td>Exclusion based on abstract</td>
<td>75</td>
<td>165</td>
</tr>
<tr>
<td>Exclusion based on full-text</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>Final List</td>
<td>-</td>
<td>72</td>
</tr>
</tbody>
</table>

3.3 Data analysis

After identification, we then started to select appropriate labels for relevant papers. To do this, we focused on peer review of publications: one of the authors reviewed each paper thoroughly and assigned a code to the paper for each criterion (Context, Problem, IT artefact, Evaluation Method, Output). After finishing the first round of labelling, we continued to second and third rounds in order to gain a better classification. We revised some codes with better vocabulary or merged some of the categories in the second and third rounds to achieve our final classification.

Afterward, the complete set of papers and sets of final codes were presented to the other two authors and they were asked to assign an appropriate code to each paper or create their own code. This time the proposed set of codes remained the same, but five papers were assigned different codes from those given by the first author. These five papers, as well as the complete sets of codes were discussed in a meeting with six people (including the three authors) and a consensus on the coding was reached. Details can be seen in Figure 1.

4. Results

Among the final pool of 72 papers, we found a variety of topics, methods and research problems. During the 10 year period of the current study –as depicted in Figure 2– different falls and rises can be observed. After a few papers in the first half of the 2000s, a peak of research can be found in years 2007 and 2008 which is mainly because of a special issue of MISQ in 2008 and influential work by livari (2007) and many commentary
papers which were published in the same issue of Scandinavian Journal of IS. After these two years, the DSR approach remained a focus of interest until recently. The following sections provide a description for the different classifications of the literature.

![Diagram](image)

**Figure 1:** Data analysis process

**Figure 2:** Demographic information about our final pool of research papers

Our study of research papers indicates that 43% of papers in our final set of research papers are not empirical studies. These include editorials, reviews, commentaries, and more than all of these, theoretical works. Figure 3 depicts the number of empirical and theoretical papers with regard to each journal. The following sections describe our findings on theoretical and empirical research papers.

### 4.1 Theoretical work

The very first theoretical works which we found in our final pool of papers is the work of livari (2003) who suggested that developing engineering-like ‘meta-artefacts’ can improve IS research discipline. Hevner et al (2004) developed a conceptual framework for conducting DSR in IS. His framework considers an intermediate role for IS research which is informed by the environment of business needs and applicable knowledge from knowledge base. This research by develop and evaluate activities, provides application and additional knowledge for environment and knowledge base relatively.
Figure 3: Theoretical vs. empirical research in final pool of research papers

Hevner et al (2004) also provided seven guidelines which are the subject of wide attention in subsequent studies. Attention to the development of an IT artefact, finding relevant business problems, evaluation of design (as well as five evaluation methods), clear and verifiable contributions, using rigorous methods, using an effective search process and effective communication of research are the guidelines highlighted by the authors.

Gregor and Jones (2007) contributed to the body of literature by extending it to design theory in IS. They claimed that all outputs of DSR other than [IT] artefact (constructs, models and methods) are components of theory. For this reason, the study identifies eight components of design theories: purpose and scope, constructs, principles of form and function, artefact mutability, testable propositions, justificatory knowledge (kernel theories), principles of implementation, and an expository instantiation.

After that livari (2007) studied DSR in terms of ontology, epistemology, methodology and ethics. In this paper he expressed the need for constructive research methods in DSR. Several famous researchers commented on livari’s work. For example, Bratteteig (2007) challenged his view on IS design; Carlsson (2007) also debated the types of knowledge IS design science research should produce, and Niehaves (2007) pointed out that alternative epistemologies other than positivist (or constructive methods as suggested by livari) may enhance the understanding of this domain.

Hevner (2007) also introduced a complementary to his previous work as a commentary to livari’s essay. This new framework includes Relevance Cycle (as connector of environment and DSR), Rigor cycle (as connector of knowledge base and DSR) and Design cycle (as connector of build and evaluate components of DSR).

In the same year, Peffers et al (2007) published the first methodology for DSR. The identified process consists of six steps: problem identification and motivation (results in problem centred initiation), definition of the objectives for a solution (results in objective centred solution), design and development (results in design and development centred solution), demonstration (results in client/context initiated), evaluation, and communication.

Kuechler and Vaishnavi (2008) also paid attention to theory development with DSR through testing and refinement of a kernel theory. Their study indicated that kernel theories can both inform DSR efforts in IS and can in turn be refined and developed. Their general design cycle of DSR is an extension to previous work which starts with awareness of problem and continues with suggestion, development, evaluation and conclusion in which later steps provide feedback to the first components of the cycle.
Pries-Heje and Baskerville (2008) has proposed a set of constructs and methods named design theory nexus for addressing ill-structured or wicked problems. They defined goals, environment, alternative design theories, theory nexus, and design solutions as constructs of their method. Tremblay et al (2010) is another theoretical work which paid attention to adaptation of focus groups in DSR.

The work of Kuechler and Vaishnavi (2012) is another attempt to develop a framework for theory development through DSR. This framework is named “Design-Relevant Explanatory/Predictive Theory” (DREPT) and introduces the concept of mid-range theories (information system design theories and design-relevant explanatory/ predictive theories) as a way by which researchers can arrive at artefacts from kernel theories and informal, experience based insights into a technological issue.

Table 3 reflects main theoretical references in our final pool of research papers as well as their main contributions. This table also shows whether the reference focused on IS research, developing IT artefact or developing theories. Finally this table reflects if the reference posits DSR as a paradigm / research stream, or a well-defined methodology for IS research.

4.2 Empirical work

Among the 41 empirical research papers in our final set of papers, we found a variety of topics, contexts, and methods. In this section we briefly study these papers according to their context and nature of problem, evaluation method and research output.

Table 3: Main theoretical works

<table>
<thead>
<tr>
<th>Reference</th>
<th>Main contribution</th>
<th>Output focus</th>
<th>DSR position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilivari (2003)</td>
<td>Introduces “meta-artefacts” concept as a way to enhance IS research</td>
<td>Research</td>
<td>Paradigm</td>
</tr>
<tr>
<td>Gregor and Jones (2007)</td>
<td>Eight components of design theories</td>
<td>Theory</td>
<td>Paradigm</td>
</tr>
<tr>
<td>Ilivari (2007)</td>
<td>Study of DSR in terms of ontology, epistemology, methodology and ethics</td>
<td>Research</td>
<td>Paradigm</td>
</tr>
<tr>
<td>Hevner (2007)</td>
<td>Complementary to DSR framework</td>
<td>Artefact</td>
<td>Paradigm</td>
</tr>
<tr>
<td>Kuechler &amp; Vaishnavi (2008)</td>
<td>General design cycle of DSR</td>
<td>Theory</td>
<td>Method</td>
</tr>
<tr>
<td>Pries-Heje and Baskerville (2008)</td>
<td>Set of constructs and methods named design theory nexus for addressing ill-structured or wicked problems</td>
<td>Artefact</td>
<td>Method</td>
</tr>
</tbody>
</table>

4.2.1 Context of the problem

According to the nature of problems which are the subject of attention in each research paper and the artefact which is developed in each, we categorized empirical papers in our final set to three different categories:

a. Business problems

We found several studies which were centred around soft problems which are related to business processes in organisations. These papers usually result in a soft artefact like method or theory and are less involved in technical aspects of the IT artefact (if there is any). Our survey indicates that 49% of papers can be categorized in this group.

A variety of topics have been studied in research papers in this category. Adomavicius et al (2008) for example addressed making information technology investment decisions and developed an IT ecosystem model which is developed through a combination of visual mapping and quantification strategies. The study of Shanks et al (2009) also dealt with benefits of Customer Relationship Management (CRM) systems. The framework which is provided in this study is developed as a DSR artefact and aimed to inform both researchers and practitioners about CRM.
Other topics which are studied in this category are: Security (as a functional requirement in the analysis and modelling of business processes) (D’Aubeterre et al, 2008), Application Portfolio Management (APM) (Simon et al, 2010), free/open source software and licenses (Alspaugh et al, 2010) and Enterprise architecture (Choi et al, 2010, Närman et al, 2012).

b. Technology problems

This category of studies is mainly focused on the technological development of IT artefact and related algorithms, and frameworks. 34% of studies in the final set of reviewed papers in the current study can be categorised in this section. The main output of these studies is usually an IT artefact in the form of an information system, or technical method.

The work of Schweiger et al (2007) is an example of research in this category which developed a software agent-based approach for realizing the vision of seamless healthcare. The study explained a methodology as well as a case study. Xu et al (2007) also proposed a machine learning technique for the identity matching problem by focusing on the social relationships between criminals. Some other topics which were subject of attention are: use of RFID technology (Kamoun, 2008), e-mail interaction mining method (Stuit and Wortmann, 2012), data summarization engine (Wang and Wang, 2012) and Information retrieval from web (Storey et al, 2008).

c. System development problems:

Following the early adoption of DSR in IS (Nunamaker and Chen, 1990), many studies have used DSR as an approach for system development. These studies which form 17% of the empirical studies in our final set, dealt with step by step guidelines of developing various types of systems including knowledge management systems (KMS) (Le Rouge and Niederman, 2006, Wu and Gordon, 2009), Electronic Medical Record (EMR) systems (Knaup et al, 2007) and Decision Support Systems (DSS) (Arnott, 2006).

4.2.2 Evaluation methods

As part of their guideline for design evaluation, Hevner et al (2004) introduced five different types of evaluation methods which are: observational (case study and field study), analytical (static analysis, architecture analysis, optimization, dynamic analysis), experimental (controlled experiment, simulation), testing (functional and structural) and descriptive (informed arguments and scenarios).

![Figure 4: Different evaluation methods in final pool of research papers](image)

However the current study seeks for different classification of evaluation methods in which we first differentiated those studies which were based on technical evaluation of artefacts (like: accuracy and speed) with those which evaluated the artefact based on survey of people (users, administrators, managers) and then
paid attention to survey approach (qualitative and quantitative). We named these methods relatively: effectiveness, qualitative survey and quantitative survey. We also noticed some references have used more than one method for evaluation and many others didn’t introduce their approach of evaluation or omitted evaluation phase from their study. Figure 4 indicates the frequency of each evaluation method.

4.2.3 Research output

The current study based on previous classifications of DSR artefacts (Winter, 2008, Hevner et al, 2004), suggest a new classification which differentiates IT artefacts and other types of soft artefacts (models and methods) and includes theory as an important output of DSR in recent studies (Kuechler and Vaishnavi, 2008, Kuechler and Vaishnavi, 2012). Figure 5, indicates frequency of papers in terms of different outputs.

![Figure 5: Different research outputs in final pool of research papers](image)

5. Discussion

This paper presents an overview of DSR research in IS discipline. To do this, 72 related papers were selected from 14 top ranked IS journals and, after analysis of their content, provided a classification of their theoretical findings, problem context, evaluation method and research output are provided. The results indicate that most of the researchers in the field focused on developing methods and DSR studies have largely used survey-based evaluations.

Our study indicates that 43% of the papers in our final set are theoretical studies which constitute a relatively big portion. Moreover figure 3 indicates that many IS journals tend to publish theoretical works in the field (more than 50% of papers in CAIS and European J of IS and all papers in Scandinavian J of IS). On the other hand journals with tendency to publish more software and IT papers (such as: IJMI, JMIS and JSIS) have published few DSR papers. Moreover our study on three randomly selected empirical studies in CAIS, MISQ and ISR indicates that the number of citation to those papers are respectively 29%, 17% and 48% of the average number of citations to other papers in the same issue.

The above facts may indicate that the reviewers of the top ranked journals and IS researchers cannot still trust DSR as a research approach. Further investigation on this pessimistic attitude may lead us to a critique about DSR contribution and its ability to generate knowledge which goes beyond the boundaries of specified artefact (Gregor and Jones, 2007). New efforts for selecting appropriate position for DSR in terms of epistemology and methodology may help to tackle this shortcoming. Although Ivarri (2007) and other authors who responded to his essay, made a great effort in this regard, but subsequent studies especially those which focused on the concept of DSR methodology have raised questions which make it really hard for new researcher to adopt a good position for DSR in their research.
Although theory development is highlighted as an important output of DSR in the literature (Gregor and Jones, 2007, Peffers et al, 2007), very few studies (only 12%) have extended their work to theory development. Considering the recent efforts in developing methodologies for theory building DSR, the current study calls for more theory based research which we believe can help DSR in dealing with the above mentioned contribution dilemma.

Finally as depicted in figure 2, 93% of research papers which are included in the final study, are conducted in western countries and Australia. While there are numerous opportunities for developing IT artefacts in developing countries and conducting studies based on them, researchers in those contexts should consider DSR as an appropriate approach for research in IS discipline.

References


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