Design Science in Information Systems Research: foundational and evolutionary aspects

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Abstract. Academic research on design science in IS field has proliferated significantly over the last two decades. From Simon research to nowadays, the importance of design science is well recognized in the IS literature. However, despite the IS literature is paying more attention on this topic, there is no extensive analysis of a comprehensive set of sources has been performed in order to explore this emerging body of knowledge. The aim of this study is to understand the state of design science in ISR by performing a survey of the existing body of knowledge. Using several online database literature searches, we obtained 245 publications for data analysis. A comprehensive list of references is presented together with a roadmap for performing a bibliographic analysis. Our analysis provides useful insights for IS practitioners and researchers on the major historical trends that can guide future research in this fertile area of inquiry.

Keywords: Design science, IS research, bibliographic analysis.

1 Introduction

In his seminal book, "The Sciences of the Artificial", Simon [1, p. 111] posits: "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones". According to Simon, the science of design is aimed to define the "problem space" (the present situation, the desired situations, or the differences between desired and the present state) by utility and statistical decision theory and the optimization and "satisficing" techniques to search it [2]. In this regard design science is fundamentally a problem-solving paradigm, in which the design problems and the generation and evaluation of design solutions are the major tasks.

Based on Simon's seminal work, March and Smith [3] underlined the differences between two species of science such as natural science and design science. Natural science is concerned with explaining how and why things are, while design science refers to devising artifacts to attain goals [1; 3]. In this regard, "natural science ties to understand reality, design science attempts to create things that serve human purposes" [3, p. 253]. The advent of special issues on design science by Information Systems (IS) journals, tracks by the most major IS conferences (e.g., ICIS, AMCIS, and

PACIS), and conferences on design science in IS (e.g., DESRIST) is a sign of the increasing interest in design science within the IS Research (ISR) community.

IS literature now considers design science research as an equal companion to behavioral science research in the information systems field. However, while the behavioral science paradigm seeks to develop and verify theories that explain or predict human or organizational behavior, the design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts [4]. Combining novelty and utility of constructed artifacts, design science research mainly contributes to IS literature demonstrating whether IT artifacts are or are not adequate for a specified problem.

This paper aims to analyze the progress of design science in ISR identifying its knowledge base by using bibliometric analysis. To date, no extensive analysis of a comprehensive set of sources has been performed in order to explore this emerging body of knowledge. Specifically, this study addresses the following research question: What is the knowledge development of the design science in ISR? This study attempts to address this question by analyzing publication trends and has a few objectives: to identify the trends of the published articles related to design science; to identify the most productive authors; to identify the universities associated with the most research publications; to develop a classification framework that is based on theory and informed by existing design science research for summarizing what is known about design science in ISR.

Therefore, the main purpose of this paper is to perform a comprehensive bibliographic analysis on design science in ISR that was published from January 1995 to February 2012. We provide a representative overview of design research within the IS discipline that can guide future research in this fertile area of inquiry.

The paper is organized as follows. First, we describe relevant related work. Second, the research methodology used in the study. Third, the articles are analyzed and the classification findings are reported. In the following section, we discuss the findings and their implications for research. Finally, limitations and conclusions of the study are presented.

2 Related Work

In the last 17 years, a significant amount of design research has been conducted in IS field, but no systematic and comprehensive review of this body of knowledge has been published to date.

Many conceptual papers provide literature reviews, but without offering a rigorous analysis of bibliographical data. Recent systematic reviews on design science in ISR exist, however consider only top IS journals or IS conference proceedings [5; 6; 7; 8; 9]. In particular, Fischer [5] identify contributions on design science in ISR in recent issues (2007-2010) of six top IS journals as defined by the Association for Information Systems (EJIS, ISJ, ISR, JAIS, JMIS, and MISQ). Park et al. [6] conduct a review of ISR papers from 1970 to 2007 that are related to design research published in two premier IS journal, MIS Quarterly and Information Systems Research. Offermann

et al. [7] consider DESRIST publications (2006-2009) and contributions in MIS Quarterly special issue on design science (2008, vol. 32 n. 4). Samuel-Ojo et al. [8] conduct meta-analysis of the research published by DESRIST. Finally, Olbrich [9] examines the proceedings of the three major IS conferences, ICIS, ECIS and AMCIS.

Our study attempts to synthesize existing studies on design science in IS field and to provide an overview of this paradigm in order to advance scholarly understanding of the current state. Our position in this study is a descriptive rather than a normative approach. With regard to the link between design science and IS, we report the articles published by the journals and by the conference proceedings in order to understand the evolution of the design science studies overtime and to address the ongoing debate in the discipline of IS. Understanding the current status of design science research and to examine contemporary trends in the research domain is important to continue the advancement of knowledge in this area.

3 Research methodology

The aim of this study is to understand the state of design science in ISR by performing a comprehensive survey of the published literature to provide insights for IS practitioners and researchers on the major historical trends.

A bibliometric analysis was conducted in this research for "the collection, the handling, and the analysis of quantitative bibliographic data, derived from scientific publications" [10, p. 181]. Bibliometric methods serve three main functions such as description, evaluation, and scientific monitoring. Bibliometric indicators used over prolonged periods of time provide a means of identifying trends. In recent years, this method has been applied across a variety of research fields for investigating, for example, the trends and contributions in RFID, virtual communities, and dynamic capabilities research.

Online database literature searches were performed in to obtain relevant research publications to review. Literature on design science in ISR was collected from January 1995 to February 2012. In this study, we only discuss the papers published in the period beginning 1995 because there were less data regarding design science in IS research prior to that year. In fact, the articles of March and Smith [3], that together with Simon's book is a milestone in design science, was published in the 1995. Articles and conference proceedings on theme were included to literature review, while books and essays were excluded.

As a first step, we conducted a literature search using the following electronic databases: Web of Science (Thomson Scientific); Business Source Premier (EBSCO Publishing); Science Direct (Elsevier); ACM Digital Library. Moreover, we analyzed the proceedings of the five AIS-sponsored IS conferences (ACIS, AMCIS, ECIS, ICIS and PACIS), the Hawaii International Conference on System Sciences (HICSS), and the International Conference on Design Science in Information Systems and Technology (DESRIST).

Searching the terms “design science” AND “Information Systems” OR “IS research” in title, abstract or among key words, we identified the articles that have investigated the design science in IS field from the beginning of 1995.

Finally, we looked through the bibliographies of key articles and conference proceedings to ensure that we had not overlooked other articles.

The search returned 1.048 articles and we have proceeded with a screening process. Duplicates papers were deleted. Moreover, the abstract of each article was read to eliminate articles that were not really related to our requirements. The aim of this study was to understand the state-of-art of the design science in ISR by examining the published literature to provide insights on the major historical trends and future directions for design science in ISR. However, many publications returned by search resulted from false hits because they were related to other research areas other than ISR. For instance, using the terms “Information Systems” or “IS research” we have not collected the articles on design science in Human-Computer Interaction (HCI) stream. HCI is a discipline primarily focusing on design, evaluation, and implementation of interactive systems. In this regard, design science research might be appropriate for HCI as well as IS. Furthermore, our review included publications selected by subjective criteria. After the screening process, the final dataset for the subsequent analysis consisted of 245 publications (see the attached PDF file). Table 1 shows the summary of dataset.

Table 1. Summary of the dataset

Scientific database	**Results**	**Screening**
Online search	*746*	*116*
Web of Science	649	79
Business Source Premier	89	36
Science Direct	8	1
Conference proceedings	*286*	*113*
ACIS	13	13
AMCIS	7	7
ECIS	7	7
ICIS	13	13
MCIS	2	2
PACIS	2	2
HICSS	19	19
DESRIST	44	44
ACM Digital Library	179	6
Most important article references	*16*	*16*
Articles	13	13
Conference proceedings	3	3
Total	**1.048**	**245**

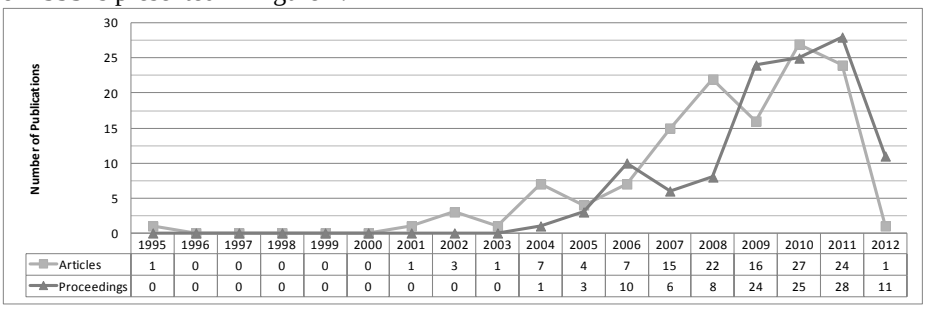
Of 1.048, only 245 publications have investigated the design science in IS field, of which 129 are articles and 116 are conference proceedings.

4 Results and analysis of the articles

The analysis of the data was divided into three parts. The first and second identified the distribution of articles by year from 1995 to February 2012 and the distribution of articles by journals. The third capture the distribution of articles by the most productive authors and universities associated with the most research publications.

4.1 Distribution of articles by year of publication

The distribution of articles and proceedings by year of publication from the beginning of 1995 is presented in Figure 1.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Articles	1	0	0	0	0	0	1	3	1	7	4	7	15	22	16	27	24	1
Proceedings	0	0	0	0	0	0	0	0	0	1	3	10	6	8	24	25	28	11

Fig. 1. Distribution of articles by year

As shown in Fig. 1, we distinguish the articles (129) from proceedings (116). Overall, research on design science in IS field is initially linear and grew exponentially during the period after. Data analysis results have shown the lack of publications on design science in IS research from 1995 to 2000 except for March and Smith [3], while few articles were published from 2001 to 2003. On the contrary, the data analysis results have shown that IS literature has paid more attention on topic from 2004 to 2010. Please note that articles grew exponentially during the period from 2005 to 2011, while conference proceedings papers grew exponentially during the period from 2004 to 2011.

4.2 Distribution of articles by journals

Table 2 lists the journals that published articles on design science in ISR during the study period. In particular, table 2 shows the distribution of those by both IS journals that published four or more articles on the topic and AIS journals[1].

Table 2. Journals publishing articles on design science in IS field

List of top IS journals	Number of articles	Number of articles (%)	List of AIS journals	Number of articles	Number of articles (%)

[1] http://home.aisnet.org/displaycommon.cfm?an=1&subarticlenbr=346

IT&P	4	3.13%	ISR	1	0.78%
ISJ	5	3.91%	JIT	2	1.56%
DSS	5	3.91%	JSIS	2	1.56%
ISeB	5	3.91%	ISJ	5	3.91%
JMIS	5	3.91%	JMIS	5	3.91%
BISE	7	5.47%	EJIS	10	7.81%
EJIS	10	7.81%	JAIS	11	8.59%
CAIS	11	8.59%	MIS	18	14.06%
JAIS	11	8.59%			
MIS	18	14.06%			

Our results include a list of top 10 IS journals as well as a list of 8 AIS journals that published design science articles during the period from 1995 to 2012[2]. Please note that MIS Quarterly has published the greatest number of design science articles (18 articles; 14.06%), followed by Journal of Association for Information Systems and Communications of the Association for Information Systems (11 articles; 8.59%) and by European Journal of Information Systems (10 articles; 7.81%).

4.3 Distribution of articles by productive authors

For assessing the research productivity, the normal count approach was used. In particular, based on Palvia and colleagues [11] and Dwivedi and Kuljis [12] approach, all publications naming the researcher are counted equally for assessing research productivity. Therefore, an article with more co-authors will provide one count for each and the combined count of all authors will be greater than the total number of articles [11]. For reporting purposes, we limited the number of articles to only those authors who had four or more publications on design science in IS research during the period studied.

Further analysis was conducted to determine the current affiliation and the geographic location according to AIS Regions of most productive authors. As suggested by Palvia and colleagues [11], adjustments were made so that a university having two or more authors on a single publication was counted only once.

Table 3 lists the most productive authors as well as their current affiliation and geographic location according to AIS Regions.

[2] Information Technology & People (IT&P); Information Systems Journal (ISJ); Decision Support Systems (DSS); Information Systems and e-Business Management (ISeB); Journal of Management Information Systems (JMIS); Business & Information Systems Engineering (BISE); European Journal of Information Systems (EJIS); Communications of the Association for Information Systems (CAIS); Journal of Association for Information Systems (JAIS); MIS Quarterly (MIS); Information Systems Research (ISR); Journal of Information Technology (JIT); Journal of Strategic Information Systems (JSIS).

Table 3. List of 'Top 21' most productive authors, current affiliation and geographic location

Author	Number of publications	Affiliation	Region 1	Region 2	Region 3
			The Ameri-cas	Europe Middle East Africa	Asia Pacific
Arnott D.	4	Monash University			Australia
Baskerville R.	17	Georgia State University	Georgia		
Becker J.	5	University of Muenster		Germany	
Chatterjee S.	4	Millikin University	Illinois		
Chen H.	4	University of Arizona	Arizona		
Fischer C.	4	University of St. Gallen		Switzerland	
Gregor S.	8	The Australian National University			Australia
Gregory R.W.	4	University of Göttingen		Germany	
Hevner A.	9	University of South Florida	Florida		
Hovorka D.S.	4	Bond University			Australia
Livari J.	4	University of Oulu		Finland	
Lyytinen K.	7	Case Western Reserve University	Ohio		
March S.T.	4	Vanderbilt University	Tennessee		
Niehaves B.	6	University of Muenster		Germany	
Pries-Heje J.	11	Roskilde University		Denmark	
Purao S.	4	Penn State University	Pennsylvania		
Storey V.	4	Georgia State University	Georgia		
Venable J.	7	Curtin University of Technology			Australia
von Brocke J.	4	University of Liechtenstein		Liechtenstein	
Weber S.	4	Goethe University Frankfurt		Germany	
Winter R.	9	University of St. Gallen		Switzerland	

The findings suggest that the highest number of publications were contributed by Richard Baskerville with 17 manuscripts, followed by Jan Pries-Heje with 11, Alan Hevner and Robert Winter with 9, and Shirley Gregor with 8.

Findings also show that authors of AIS Region 1 (The Americas) and AIS Region 2 (Europe, Middle East, and Africa) pay more attention to theme of design science in IS research. Among their, please note that two AIS Region 1's Professors are affiliated at Georgia State University, while for AIS Region 2 two Professors are affiliated at University of Muenster and other two are affiliated at University of St. Gallen. Finally, only four authors are from AIS Region 3 (Asia and Pacific).

5 Discussion

With the objective of achieving a better understanding on the knowledge development of design science in IS research, we have analyzed publication trends in the last two decades. Our bibliometric analysis covers a large body of literature published in IS journal and conferences.

As a first result of our analysis we found that the number of articles in this stream of research is exponentially increasing in both conference and journals. This trend starts on 2004 more than a decade after the publication of the first article that introduced the "design theory" concept in ISR [13]. In 2004 the work of Hevner, March, Park, and Ram [4] has been published by MISQ. This paper is still having a strong impact on current research (about 3.000 citations). Nowadays each journal in the IS basket has published many papers that explicitly refer to this research paradigm. Some of the papers are contributing to the ontological and epistemological positioning of design research by focusing on a meta-level [i.e., 14; 15. Some other contributions are related to the debate on methodologies for conducting design research [i.e., 16; 17]. Finally a third set of papers is actual pieces of design research and provides generalized contributions adopting a design research approach. Some recent examples are the Wong et al. [18] paper on ISJ, addressing the design problem of credit card fraud detection, Hanseth and Lyytinen [19] on JIT, addressing the design of Information Infrastructures and Aanestad and Jensen [20] on JSIS, addressing the design of healthcare information infrastructures.

The discourse on design research has been nurtured also through special issues of important European and American journals (e.g., SJIS 2007 Issue 2, EJIS 2008 Issue 5, and MISQ 2008 Issue 4) and conferences (e.g., DESRIST and AMCIS minitracks). Surprisingly the trend of conference papers is almost overlapping with the trend of journal publications both in terms of number of papers, and time distribution. We explain this phenomenon with the initial burst provided by the meta-level articles published in top level journals which have prepared the ground for an increasing number of design contributions with a design research orientation. Therefore we expect that the number of papers in IS conference will increase in the next years.

As a second result, the variety of design research contributions requires an empirical validation to be performed by classifying papers in three categories (i.e., meta-level, methodology, actual design). Each category can be further divided into subcategories in order to classify papers and to identify those areas of research that need further development. For instance previous classifications of artifact types can be adopted for identifying trends within the "actual design" category [7]. A network analysis of co-citations can serve as a valuable means for gaining insights on the mutual relationships between meta-level positioning, methodologies adopted, and artifact trends.

As a third result, the analysis of the most productive journals shows that additional journals with the respect to the basket of seven are publishing design research papers. Some of them have a strong design research orientation being grounded in the engineering culture. An example is BISE whose scope is stated as follows: "…Specific solutions for application systems are published only if they serve as a model for other fields of application". BISE is an interesting case since its impact factor shows a similar trend of the overall design research publications (IF 0.296 in 2007, IF 0.880 in 2010). In a recent paper published by this journal the authors identify three schools of thought named "kernel theory fundamentalist", "design theory opponents", and "kernel theory pragmatist" depending on the role of theories within design research contributions [21]. This distinction can be adopted for classifying current journal publica-

tions in order to provide insights on the design research orientations of these outlets. Achieving a better understanding on the design research orientation of IS journals can provide guidance to the authors in this research field [22, 23].

Finally the fourth result refers to the geographical distribution of the authors who have contributed the most in the last decade to the advancement of design research in IS. By analyzing the affiliations, a full coverage of the three Regions of AIS appears evident. However a more careful analysis of the evolution of this map, performed through a co-authorship analysis, can provide insights on the institutional processes behind the diffusion of design science research. Such investigation can be enriched by mixing the results with the above mentioned analysis of the conference and journals publication trends and with the analysis of the design science orientation of IS journals. In this way an evolutionary temporospatial map of design research in IS can be traced to guide further developments in this field of study.

6 Conclusions

This study is aimed at understanding the state-of-art of the design science in ISR by examining the published literature. Despite academic research into design science has proliferated significantly over the last years, no systematic and comprehensive review of this body of knowledge has been published to date. We collected and analyzed 245 publications distinguishing them by year, by journal, by most productive authors, and the universities associated with the most research publications.

This literature review has some limitations. Firstly, our literature review is comprehensive, but is not exhaustive. Despite we used several online research databases to collect the publications on theme, we found only the articles and conference proceedings from those databases. Furthermore, we analyzed the proceedings of the five AIS-sponsored IS conferences (ACIS, AMCIS, ECIS, ICIS and PACIS), of the HICSS, and of DESRIST. Other publications could not have been found. The second limitation concerns the search terms. Although we performed the online search using the terms “design science”, “Information Systems”, and “IS research”, other search terms (e.g., “design theory” or “Hevner”) can also be used and could potentially yield different results. Finally, the data analysis was not completed because has not been realized citation and co-citation analyses. Indeed, one of the most common bibliometric techniques is co-citation analysis, a method used to examine relationships among articles or authors contributing to the development of a research field. In this phase, we carried out several objectives of our research. In the next phase, we will complete the data analysis, we will investigate the type of design research, by analyzing topics and research methodologies, and we will develop a classification framework for summarizing what is known about design science in IS research.

Despite these limitations, this paper provides a general picture of past and current research, and create a database of the academic literature on design science in IS research from 1995 to nowadays. The design science in IS research is an approach still relatively young and continues to show considerable growth. It is an emerging research area, in which most researchers have focused their attention on conceptual or

descriptive analyses. Overall, this paper provides useful insights for IS practitioners and researchers and suggests a roadmap for future research in this fertile area of inquiry.

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