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A design science research methodology and its application to accounting information systems research

Guido L. Geerts

University of Delaware, United States

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ABSTRACT

Natural science research follows a stereotypical pattern and such uniformity makes it easier to recognize and evaluate the results of such research. A similar format has been lacking for design science research. This issue was addressed by Peffers et al. (2008) who defined such a template for design science research for information systems: the design science research methodology (DSRM). In this paper, we first discuss design science research and the DSRM. Then, we illustrate the application of the DSRM to AIS research through retroactive analysis. Finally, we integrate the DSRM into the operational specification of artifact networks and use the REA literature for illustration purposes.

1. Introduction

Most of the research currently conducted in the accounting information systems (AIS) and information systems (IS) areas focuses on understanding phenomena and finding new truths: why things work the way they do. Such research is generally known as "natural science" research. Natural science research papers typically adhere to a structure that consists of the following steps: problem definition, literature review, hypothesis development, data collection, analysis, results, and discussion. Such uniformity helps with both production—how to conduct a research project—and presentation—how to make it easier for readers and reviewers to recognize and evaluate the paper's research contribution.

On the other hand, design science research, which is popular in disciplines such as engineering and architecture, focuses on creation: "how things ought to be in order to attain goals, and to function" (Simon, 1996).[1] The purpose of design is "to change existing situations into preferred ones" (Simon, 1996). Design science research creates artifacts: "something created by humans usually for a practical purpose" (Artifact, 2010). March and Smith (1995) differentiate among four different types of artifacts: concepts, models, methods,

E-mail address: geerts@udel.edu.

[1] Simon's book, *The Sciences of the Artificial*, was first published in 1969. We refer here to the most recent (3rd) edition published in 1996.

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and instantiations. Two important characteristics of design science artifacts are relevance and novelty. First, an artifact must solve an important problem: i.e., being relevant. Second, to differentiate design science research from routine design, Hevner et al. (2004) suggest that design science research should address either an unsolved problem in a unique and innovative way or a solved problem in a more effective or efficient way.

In recent years, there has been a growing interest in design science research in the IS literature. First, a series of papers–including Nunamaker et al. (1991), Walls et al. (1992), March and Smith (1995), and Hevner et al. (2004)–have discussed the importance of design science research in IS. Second, this research has paved the path for the publication of a series of design science papers in top-tier IS journals such as *MIS Quarterly* and the *Journal of Management Information Systems*. The following are three examples of recently published design science papers in those journals: Lee et al. (2008), Kolfschoten and de Vreede (2009), and Choi et al. (2010). Third, as pointed out by Indulska and Recker (2008), a number of IS journals launched special issues on design science research in recent years, including the *Journal of Information Technology Theory and Application* (JITTA) in 2004, the *Journal of the Association of Information Systems* (JAIS) in 2007, and *MIS Quarterly* (MISQ) in 2008. Fourth, since 2006, an annual conference, the International Conference on Design Science Research in Information Systems and Technology (DESRIST) has focused on design science research.

The application of the design science research paradigm in the AIS area was extensively discussed in a monograph on "researching accounting as an information systems discipline" published by the American Accounting Association in 2002 (Arnold and Sutton, 2002). More specifically, three of the papers in the monograph deal with design science research: Weber (2002), David et al. (2002), and Leech and Sangster (2002). Weber (2002) considers design science research as an appropriate method for ontological research in accounting and argues for research that is rigorous, well-grounded in prior research, and satisfies the novelty requirement. David et al. (2002) also emphasize the importance of properties such as novelty, complexity, and feasibility. Heavily relying on the work by March and Smith (1995), they give an overview of the different types of artifacts–concept, model, method, and instantiation–created by REA research papers. Their classification helps to better understand the contribution of this research stream to the AIS literature. Leech and Sangster (2002) use the frameworks presented in March and Smith (1995) and David et al. (1999) to discuss accounting expert systems from a design science perspective. A key issue addressed in their paper is how much developing expert systems can advance knowledge and, therefore, can be considered as research.

While design science research papers are rare in top-tier accounting journals such as the *Accounting Review*, the major AIS journals such as the *International Journal of Accounting Information Systems* (IJAIS), the *Journal of Emerging Technologies in Accounting* (JETA), and the *Journal of Information Systems* (JIS) have been more receptive to such research. Examples of design science papers published in AIS journals include Grabski and Marsh (1994), O'Leary (1999), Geerts and McCarthy (2000, 2006), Geerts (2004), Murthy and Groomer (2004), Bovee et al. (2005), Dull et al. (2006), Fisher (2007), Geerts and Wang (2007), and Sedbrook and Newmark (2008).

Until recently, the lack of a stereotypical template similar to the one used for natural science research was an important concern in design science research (McCay and Marshall, 2005). Peffers et al. (2008) address this issue by presenting a design science research methodology (DSRM) consisting of a nominal sequence of six activities: (1) problem identification and motivation, (2) definition of the objectives of a solution, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. The primary goal of this paper is to introduce the DSRM into the AIS literature. The remainder of the paper is organized as follows. First, we discuss the DSRM as presented in Peffers et al. (2008). Next, we retroactively apply the DSRM to six AIS design science papers. The main goal of this retroactive analysis is to illustrate the different DSRM activities using examples from the AIS literature. Finally, we integrate the DSRM as part of operational specifications of artifact networks using the REA literature for illustration purposes.

2. The design science research methodology

Peffers et al. (2008) created the design science research methodology or DSRM with three objectives in mind: "(1) provide a nominal process for the conduct of DS research, (2) build upon prior literature about DS in IS and reference disciplines, and (3) provide researchers with a mental model or template for a structure for research outputs." Stated differently, the DSRM aims at improving the production, presentation, and evaluation of design science research while being consistent with the principles and guidelines of design science research established in previous research studies such as Nunamaker et al. (1991), Walls et al. (1992), and Hevner et al. (2004).

Table 1 shows the DSRM presented in Peffers et al. (2008) although the format we use is somewhat different from theirs. The first column in Table 1 lists the six activities that make up the DSRM as a nominal sequence. Column two further describes each of the activities in detail: what to do? The third column links the knowledge base with the different activities: how the activities are executed. The knowledge base provides the raw materials from and through which design science research is accomplished. It is composed of knowledge tools such as foundational theories, frameworks, instruments, constructs, models, methods, and instantiations (Hevner et al., 2004). The explicit integration of the knowledge base further improves the DSRM since researchers must look for the most effective knowledge tools, explain their selection, and explain how they are applied. Such accountability will increase rigor.

The nature of the knowledge base has become an area of research by itself. Hevner et al. (2004) discuss criteria for knowledge tools–they should rigorously demonstrate the utility, quality, and efficacy of the design artifacts–and examples of knowledge tools—they list the following as examples of evaluation methods: observational, analytical, experimental, testing, and descriptive. Vaishnavi and Kuechler (2008) and Offermann et al. (2009) further provide an extensive list of knowledge tools and best practices that can be applied during each of the six DSRM activities.

The arrows on the left side of Table 1 emphasize the importance of iteration as part of the DSRM. They show that activities such as Evaluation and Communication often result in revising the artifact's objectives and design. Iteration is ingrained in design science research and Hevner et al. (2004) illustrate that with their build-and-evaluate loop: evaluation provides feedback information on the designed artifact and a better understanding of the problem which leads to a re-iteration of the design process.

To illustrate the DSRM, in Table 2 we apply it to one of the most influential papers in AIS: "The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment" (McCarthy, 1982). It shows that McCarthy (1982) executed four of the six DSRM activities. First, he discusses the weaknesses with current accounting systems based on a literature review (problem identification and motivation). Second, he infers a main objective for improving current systems: the need for a shared data environment (define the objectives of a solution).Third, he presents an alternative model rooted in economic, accounting, and database theories–the Resource-Event-Agent (REA) accounting model–that helps structuring data in a shared environment (design and development). Finally, he published the results of his research, a semantic accounting system, in the *Accounting Review*

Table 1
Design science research methodology (DSRM).

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	*What is the problem?* Define the research problem and justify the value of a solution.	Understand the problem's relevance and its current solutions and their weaknesses.
Define the objectives of a solution	*How should the problem be solved?* In addition to general objectives such as feasibility and performance, what are the specific criteria that a solution for the problen defined in step one should meet?	Kowledge of what is possible and what is feasible. Knowledge of methods, technologies, and theories that can help with defining the objectives.
Design and development	*Create an artifact that solves the problem.* Create constructs, models, methods, or instantiations in which a research contribution is embedded.	Application of methods, technologies, and theories to create an artifact that solves the problem.
Demonstration	*Demonstrate the use of the artifact.* Prove that the artifact works by solving one or more instances of the problem.	Knowledge of how to use the artifact to solve the problem.
Evaluation	*How well does the artifact work?* Observe and measure how well the artifact supports a solution to the problem by comparing the objectives with observed results.	Knowledge of relevant metrics and evaluation techniques.
Communication	Communicate the problem, its solution, and the utility, novelty,and effectiveness of the solution to researchers and other relevant audiences.	Knowledge of the disciplinary culture.

Table 2
DSRM applied to "The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment" (McCarthy, 1982).

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	The conventional accounting model needs to be extended to accommodate a broader spectrum of management information.	Literature review of studies that discuss weaknesses of the conventional accounting model: reports published by the AAA and a series of papers that explore the integration of the events accounting theory with different approaches to database management
Define the objectives of a solution	Design of accounting information systems that are able to support multiple "views" of a centrally defined database and therefore allow the diverse and flexible use of economic transaction data	Knowledge of semantic modeling and shared databases which had been successfully implemented in computer science.
Design and development	Design of the REA accounting model: a framework to be used in a shared data environment where both accountants and non-accountants are interested in maintaining information about the same set of economic phenomena.	Accounting and economic theory, database theory, semantic modeling.
Demonstration		
Evaluation		
Communication	Published in the *Accounting Review;* the premier accounting journal.	Last one in a series of papers published in the *Accounting Review* that discusses alternative structures for the conventional accounting model.

(communication). Retroactive analysis in terms of the DSRM helps to better understand the nature, objectives, contributions, and rigor of a design science paper.

3. Applying the DSRM to AIS research

Following others such as Klein and Myers (1999), Hevner et al. (2004), and Peffers et al. (2008), we are illustrating the application of the DSRM to AIS research through retroactive analysis in this paper. We examine the following six design science papers that were recently published in the three main AIS journals from a DSRM perspective: Murthy and Groomer (2004), Bovee et al. (2005), Dull et al. (2006), Fisher (2007), Geerts and Wang (2007), and Sedbrook and Newmark (2008).[2] All six papers design an artifact to solve a specific problem in the AIS domain. It is important to emphasize that our goal is not to perform a critical evaluation of the quality of the research contributions presented in these papers.[3] Each of them makes a valuable contribution to the AIS literature. Also, given that all six papers were published before or at the same time as Peffers et al. (2008), it would be unfair to expect them to precisely mirror the six activities outlined in the DSRM.

The retroactive analysis of the six papers is presented in Table 3[4] and is especially helpful since it illustrates the different DSRM activities with examples from the AIS literature. There is at least one paper for each DSRM activity, and the integrated specification of knowledge tools is illustrated through numerous examples. Our examination of the six papers further resulted in several observations.

[2] We selected two recent design science papers from each of the three major AIS journals: IJAIS, JETA, and JIS.
[3] We invited the authors of all six papers to comment on our description of their paper in terms of the DSRM. For all six papers, the authors felt that our description was fair.
[4] We ignore the DSRM Communication activity in our analysis since all six papers were published in one of the main AIS journals.

First, in a literature study of design science research in IS, Indulska and Recker (2008) find that most design science research papers lack a structured discussion of how it is done. The retroactive analysis in this paper shows that the same is true for design science research papers published in the AIS literature. The additional row at the bottom of Table 3–Design science research–evaluates to what extent the authors present their research as being "design science." Only two of the six papers claim that they use design science as research paradigm: Fisher (2007) and Sedbrook and Newmark (2008). Fisher (2007) further organizes the discussion of her research contribution in terms of the four different artifact types distinguished in March and Smith (1995): construct, model, method, and instantiation. Sedbrook and Newmark (2008) recognize the importance of a proof-of-concept prototype as part of a design science project.

Second, as pointed out by Vaishnavi and Kuechler (2008), the awareness of an interesting problem can come from multiple sources such as new developments in industry or in a reference discipline. Our retroactive analysis indicates that AIS design science research is strongly driven by the needs of accounting practice. Fisher (2007) answers the AICPA's call to deal with the rapid change in and expansion of performance and reporting standards. Dull et al. (2006) provide a solution to a need identified in an article published in *The CPA Journal*: "Automating the confirmation process should enhance a confirmation's effectiveness by improving respondent authentication, which itself reduces the opportunity for confirmation fraud" (Aldhizer and Cashell, 2006).

Third, the knowledge base entries in Table 3 show that in all six papers the new AIS artifacts are created by applying emerging technologies. For example, Fisher (2007) employs XML to improve the processing of semi-structured data while Sedbrook and Newmark (2008) employ semantic web technologies to enable network-based and semantic interoperability among independent and geographically distributed partners. Five of the six papers examined–Geerts and Wang (2007) being the exception–employ web technologies such as OWL, SWRL, XML, and XBRL to create their artifact.

Fourth, AIS design science research seems to focus on a few specific areas including continuous auditing, REA, and XBRL.

Finally, the retroactive analysis of the six AIS papers in terms of the DSRM was challenging. The lack of uniformity and structured discussions of how knowledge tools are selected and applied puts an extra burden on the reader when evaluating a paper's research contribution. Best practices need to be developed that provide guidelines for issues such as determining the following: when a problem is considered relevant, how to articulate the research contribution embedded in the artifact, how to select the most effective knowledge tools, what is considered a sufficient demonstration, etc.

4. Definition and applications of artifact networks

An additional observation with regards to Tables 2 and 3 is that most papers do not cover all DSRM activities. For example, the Demonstration and Evaluation activities in Table 2 (McCarthy, 1982) are empty. However, both activities are addressed in other papers. Gal and McCarthy (1986) and Denna and McCarthy (1987) demonstrate the implementation of the REA model and its use for the generation of multi-dimensional information. Evaluation of the REA model was done in O'Leary (2004) who studied the REA-ness of SAP, the leading ERP system. Such fragmentation is common practice for design science research projects, and two main causes are (1) a substantial time lag often occurs between DSRM activities, and (2) some of the activities require very different skill sets. What is really being created is an artifact network: "a coherent stream of efforts by different individuals or groups in different places at different times" (Vaishnavi and Kuechler, 2008). McCarthy (1982) can be considered as either (1) a node in the more generic "alternative accounting systems" artifact network, or (2) the initial node or root of the "semantic accounting systems" artifact network.

Vaishnavi and Kuechler (2008) introduce the concept of an artifact (information) network but do not further operationalize it. Fig. 1 graphically defines a small segment of the REA artifact network. An important feature of the representation in Fig. 1 is the integration of the DSRM activities which allows a better understanding of each paper's contribution and of how the research area evolves. The main objective of the network representation is to illustrate the different types of research interactions based on the DSRM. Each node presents a research paper and defines the different DSRM activities that are conducted in that paper. McCarthy (1982) is the network's root node. The nodes are further connected through links

Table 3
Retroactive analysis of AIS research in terms of the DSRM.

	Murthy and Groomer (2004) DSRM activities	Murthy and Groomer (2004) knowledge base	Bovee et al. (2005) DSRM activities	Bovee et al. (2005) knowledge base	Dull et al. (2006) DSRM activities	Dull et al. (2006) knowledge base
Problem identification and motivation	Need to address issues with conventional continuous auditing techniques including high costs and detractions resulting from being installed in the client's application system.	Literature review. Understanding of weaknesses of current systems.	Difficulties with the timely access to and the automatic processing of financial information including SEC filings (semi-structured natural-text documents).	Literature review. Understanding of weaknesses of existing tools such as EdgarScan.	Need to address inefficiencies inherent in a manual confirmation process.	Literature review.
Define the objectives of a solution	Pull model for continuous auditing.	Literature review. Understanding of emerging technologies.	Intelligent parsing and integration of financial information available from various sources on the Internet.	Literature review. Knowledge of emerging technologies.	Real-time confirmation process.	Literature review. Knowledge of emerging technologies.
Design and development	Definition of a continuous auditing web service (CAWS) architecture.	Knowledge of continuous auditing methods and web service technologies.	Implementation of FRAANK: Financial Reporting and Auditing Agent with Net Knowledge.	AI techniques (intelligent parsing), XBRL, Internet agents.	Conceptual design of an inter-organizational system by which data from an AIS can be electronically confirmed with a third-party's system.	Knowledge of audit standards, inter-organizational systems, and web service technologies.
Demonstration			Prototype was used to generate financial information for 50 randomly selected companies.			
Evaluation			Evaluation of FRAANK's parsing and tagging performance.	Definition of performance measures.		
Design science research						

(continued on next page)

Table 3 (*continued*)

	Fisher (2007) DSRM activities	Fisher (2007) knowledge base	Geerts and Wang (2007) DSRM activities	Geerts and Wang (2007) knowledge base	Sedbrook and Newmark (2008) DSRM activities	Sedbrook and Newmark (2008) knowledge base
Problem identification and motivation	Rapid and continued expansion of the Financial Accounting Standards (FAS) literature has imposed excessive difficulty in navigating and applying FASs.	Literature review.	A continuously changing business environment requires more adaptable enterprise systems.	Literature review. Understanding of current solutions and their weaknesses.	Failure of implementation of a multi-enterprise collaboration system due to lack of flexibility.	Real world problem. Understanding of current solution and its weaknesses.
Define the objectives of a solution	Temporal digital reconstruction of financial accounting standards.	Literature review. Knowledge of emerging technologies.	Active use of enterprise ontologies in the design and operation of reflective (enterprise) systems to increase adaptability and reusability.	Literature review. Knowledge of emerging technologies.	Implementation of a more flexible system that enables the automated capturing and managing of policies for multi-enterprise collaborations.	Understanding of current solutions and their weaknesses. Knowledge of emerging technologies.
Design and development	Design of a system that is able to reconstruct financial standards.	Knowledge of financial accounting standards and their structure and emerging technologies (XML).	Design of a reflective enterprise architecture that integrates an explicit definition of the REA Enterprise Ontology.	Reflective architectures, REA Enterprise Ontology, timeless algorithms.	Design and implementation of an architecture that enables network-based and semantic interoperability among independent and geographically distributed partners.	Semantic Web Technologies (OWL, SWRL). REA Enterprise Ontology.
Demonstration	Illustration of an example using a prototype.	Knowledge of the standard and the amendments used in the example.	Illustration of an example using a prototype.	Applying timeless modeling principles and REA to the problem.	Case study demonstration using a prototype.	Applying Semantic Web Technologies and REA to a real-world problem.
Evaluation					Comparative analysis.	Understanding of current solution and its weaknesses.
Design science research	Discussion structured based on the four different types of artifacts: concepts, models, methods, and instantiations.	Understanding of design science research guidelines and artifacts.			Recognition of the importance of a proof-of-concept prototype.	Understanding of the basic principles of design science research.

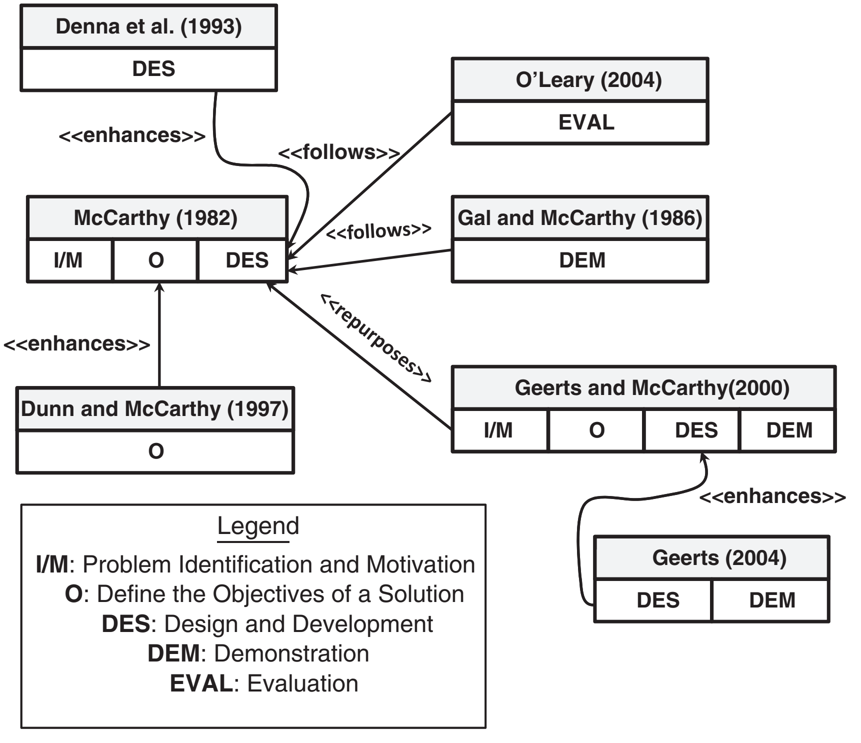

Fig. 1. Segment of the REA artifact network.

which describe how the studies relate to each other. We differentiate between three types of links in Fig. 1: follows, repurposes, and enhances. Arrows are used to indicate how to read the link; e.g., the Geerts and McCarthy (2000) paper repurposes the artifact (DES) created in the McCarthy (1982) paper. Next, we discuss each of the three link types in more detail.

The "follows" link is used to connect the different activities in a DSRM sequence. For example, McCarthy (1982) neither demonstrates nor evaluates an REA system. The Gal and McCarthy (1986) paper demonstrates how to implement an REA system–and thus an accounting system that is able to support different views–using relational database technology. O'Leary (2004), on the other hand, evaluates the REA-ness of an ERP system (SAP). The reader should notice that the Gal and McCarthy (1986) and O'Leary (2004) nodes are not directly connected. It is not the prototype system (demonstration) but actual systems that are evaluated.

Geerts and McCarthy (2000) illustrate that the explicit definition of REA semantics can be used to increase interoperability between applications. They therefore provide a new purpose to the REA model as is illustrated by the "repurposes" link between Geerts and McCarthy (2000) and McCarthy (1982). As shown in Fig. 1, Geerts and McCarthy (2000) identify a new problem—the need for increased interoperability and reuse of code; define a new objective—the need for a formal specification; design a new artifact—the formal definition of the REA semantics using a knowledge representation language (Prolog); and demonstrate the use of the new artifact in a simple application—a shared procedure to determine different types of claims.

Fig. 1 further has three "enhances" links. The first "enhances" link is between Dunn and McCarthy (1997) and McCarthy (1982) and indicates that the former redefines the objectives of REA enterprise systems. They argue that such systems are expected to have the following three criteria: (1) a database orientation, meaning that data need to be stored at their most primitive level; (2) a semantic orientation; and (3) a structuring orientation. Dunn and McCarthy (1997) do not make any changes to the research motivation presented in McCarthy (1982) or the REA model (the artifact). The second "enhances" link is between Denna et al. (1993)

and McCarthy (1982). The former extends the REA model by adding a location primitive and thus redefines its scope. As shown in Fig. 1, Denna et al. (1993) do not change the motivation and objectives presented in McCarthy (1982). The third “enhances” link is between Geerts (2004) and Geerts and McCarthy (2000). As pointed out above, one of the goals of design science research is to address a solved problem in a more effective or efficient way (Hevner et al., 2004). Geerts(2004) more formally defines the concepts underlying the REA model and uses XML technologies for implementation purposes. XML technologies are more effective for sharing knowledge across applications. We therefore use an “enhances” link to characterize the research interaction between Geerts (2004) and Geerts and McCarthy (2000).

We created the artifact network representation in Fig. 1 for illustration purposes only. Actual specifications will require much more effort, including a more elaborate classification of possible research interactions. Next, we explore three potential uses of artifact networks. First, they represent in essence elaborate literature studies. They portray the research studies that contribute to the network (nodes), how the different research studies interact based on DSRM activities (links), how papers are grouped into DSRM sequences (patterns), incomplete DSRM sequences (patterns), how the artifact is repurposed, etc. Second, artifact network specifications make it easy for authors to position new research contributions. They can explain their contribution by drawing links with existing nodes and explain the nature of these links. Third, each domain has its own culture, publication outlets, and expectations. This is also true for the AIS and IS areas. DSRM-based artifact network specifications might help journals both indicate the type of research they are interested in and list their requirements in terms of rigor. An example would be for a journal to only accept papers that cover at least the first four DSRM activities; i.e., the artifact must be demonstrated. Another journal might encourage “evaluation” research.

Most artifact network specifications will be very complex; therefore, it would be useful to have software tools available to support them. Given the need for widely available specifications and the number of people involved in their development, the use of community-oriented software such as a wiki is recommended.

5. Conclusion

The main objective of this paper was to introduce the design science research methodology (DSRM) into the AIS literature. We discussed the DSRM's six activities and how integrated explanations of the selection and use of knowledge tools can increase rigor. The application of the DSRM to AIS research was illustrated through the retroactive analysis of six AIS papers. Our analysis resulted in the following observations: there is a lack of detailed methodological discussions, making the evaluation of a paper's research contribution more challenging; research is primarily driven by the needs of accounting practice; focus is on the creation of new AIS artifacts by applying emerging technologies, in most cases web technologies; and research focuses on a few areas. We finished the paper by exploring the role of the DSRM in defining artifact networks. We illustrated the operational definition of such networks and discussed a number of potential uses.

Many of the topics discussed in this paper need further exploration, including: (1) more in-depth research with regard to the integrated use of knowledge tools in the DSRM and more specifically the development of best practices; (2) a more elaborate classification of possible DSRM-based research interactions; (3) the specification of full-blown networks for AIS artifacts such as REA semantic models and XBRL.

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