1-2013

Design science research: The road traveled and the road that lies ahead

M. ROSSI

O. HENFRIDSSON

K. LYYTINEN

Keng SIAU
Singapore Management University, klsiau@smu.edu.sg

Design Science Research:
The Road Traveled and the Road That Lies Ahead

Matti Rossi, Aalto University School of Economics, Aalto, Finland

Ola Henfridsson, University of Warwick, Coventry, UK

Kalle Lyytinen, Case Western Reserve University, Cleveland, OH, USA

Keng Siau, Missouri University of Science and Technology, Rolla, MO, USA

ABSTRACT

In this introductory piece to the special issue on design science research (DSR) in information systems, the authors probe the past research in DSR, introduce the papers in the special issue, discuss their contributions to the field, and conclude the paper by highlighting some potential directions for future research. To provide a good overview of the research domain, the authors review the key research approaches (or processes) that have been proposed and identify the concrete products of DSR that come in the form of artifacts. As the production of artifact is only part of the DSR process, the authors discuss the role of theorizing about these results and propose avenues for future design-oriented research. It is the authors' strong belief that DSR should be at the heart of information systems discipline because it invites people to research the issues surrounding the development and organizational implementation of new systems.

Keywords: *Artifact, Design Science Research (DSR), Design Theorizing, Information Systems Discipline, Theory Building*

INTRODUCTION

Design science research (DSR) or design research is a central pillar to information systems research since its inception as testified by works of scholars such as Langefors, Teichroew or Mumford. It has matured since its inauguration about 20 years ago (Nunamaker et al., 1991; Walls et al., 1992). After two decades, we have a more encompassing set of methods and approaches for conducting design-oriented information systems research (e.g. Hevner et al., 2004; Peffers et al., 2007). The maturation of DSR has also rendered it to a more viable and publishable approach, which can be seen in the growth of design-oriented tracks in conferences such as ICIS, ECIS, HICSS and the longevity of the DESRIST conference series. Design science is becoming, indeed, a part of the normal science. This should come naturally because the idea of design is central to the IS field. Building new artifacts that expand the

DOI: 10.4018/jdm.2013070101

limits of possibility (Sein et al., 2011) is one of the dominant modes of valid knowledge generation in the IS discipline.

In the early days of the IS discipline, there were abundant information systems research papers on building new kinds of systems and observing them in organizational settings. At the same time, the growing field and institutional pressure called for intensified use of more 'rigorous scientific approaches' seeking to explain, and accordingly the construction-oriented inquiries in IS research had to yield to behavioral approaches. This does not suggest, however, that construction-oriented inquiries in IS research at that time were not rigorous or non-scientific. They just did not draw upon social science based methodology.

The key canon of dominant behavioral research was identifying and explaining effects or antecedents of using a 'given' IS. In this regard, behavioral research is different from construction-oriented inquiries in IS research that it does not take the use as 'given' - theorizing starts often before the artifact is built and not after to explain what are its effects. Accordingly, as these decisions are made there is an increased emphasis on whether the followed methodical approach is valid and sound, and whether the phenomena under study are indeed measurable and controllable. Due to the fact that the foundations of design science research were not widely recognized in the mainstream research and design science scholars had often a difficult time publishing in mainstream IS journals, many design-oriented scholars felt that they had diminished publication opportunities. A significant portion of research on IS had little to do with what the actual information system functioned, and how it was developed.

Concerned about the lack of deeper understanding of the nature of artifacts in IS research, (Orlikowski & Iacono 2001) a growing number of scholars have started to engage in research on how to build information systems in naturalistic settings. Earlier, Nunamaker called for solutions to the "last mile" problem, and proposed systems development as a research method (Nunamaker et al., 1991). Hevner et al., (2004) article in MISQ opened design science as a legitimate approach to IS mainstream. Since the publication of this article, a vast number of different DSR approaches have been proposed: some are calling for injecting more rigor and theory to DSR (Walls et al., 1992; Venable 2006; Gregor & Jones 2007) while others stress the need to engage with practice through action research (Sein et al., 2011). Recently, some have raised concerns about the continued expansion of papers that theorize design science: the focus of DSR should be on *doing* design science, *not* on *theorizing* about design science research. If the focus of DSR becomes just theorizing about DSR, we face a danger that design science will soon denote different things to different people. Therefore, there is a need for DSR scholars to balance the doing and thinking about DSR, and also to sharpen what DSR is and what it is not. When building up this issue, we fathom that we found a healthy balance: two articles are about doing DSR and one is about theorizing.

As Hevner and Chatterjee (2010) point out in their introduction to the book on design science research, the definition of design should dominate the discussion, especially whether it's a process or a product. The second issue is whether DSR is research or science. We will discuss each of these issues shortly.

SPECIAL ISSUE CONTRIBUTIONS

We received 13 papers for this special issue. After two rounds of reviews, we accepted three papers that reflect well the quality and the nature of current DSR discourse. These papers contribute to a wide array of outcomes of design science research: the first one develops a method, the second one a prototype and a preliminary design theory, and the third one challenges and outlines ontological basis of design science research.

In the first paper, Rosenkranz and Holten develop a method for changing organizational structures using design science research approach. They call it the Variety Engineering

method. The method is based on cybernetic theory and formalized through the proprietary VSM language.

The second paper by Juan Manuel Gomez Reynoso, Lorne Olfman, Terry Ryan and Tom Horan develops an Information System Development Technique (ISDT) for training expert system. The paper validates the expert system through a quasi-experiment. The research develops a fully working prototype and distills the learning through design science approach into the proposed ISDT.

The third paper by Sandeep Purao investigates the ontology in design science research by reviewing world-views and canonical assumptions behind design science research. Purao stresses that due to the nature of DSR, where reality is being reconstructed through the creation of novel artifacts (Simon, 1969; Iivari, 2003), we need an ontology that takes into account this evolution of reality as a consequence of the research process.

PROCESS FOR DESIGN SCIENCE RESEARCH

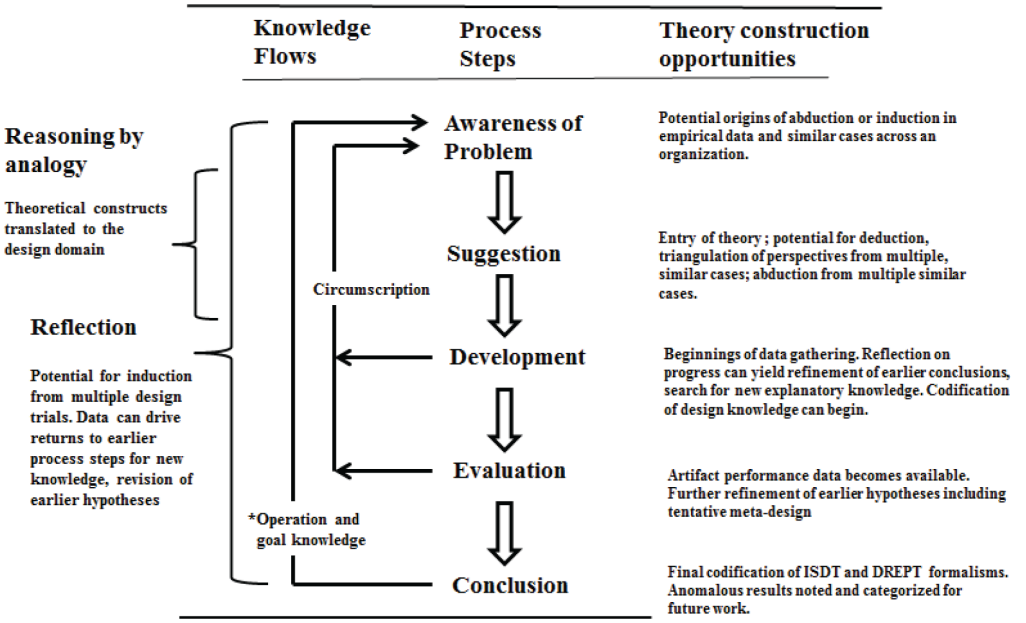
As a viable way of doing information systems research, design was proposed initially by Nunamaker and Chen (1991). A few years later, March and Smith (1995) define the properties of theory building constructive research. The first theorizing article on building a concrete information system (Markus et al., 2002) gave the community a better idea on how to theorize about the building of systems. Hevner et al. (2004) canonized a set of principles for doing design science research. This article has a pivotal role in the development of DSR, for providing a set of guidelines for performing and evaluating DSR. This is demonstrated by the current count of more than 4000 citations for the paper in Google Scholar. A number of more detailed methodical articles and their extensions followed (e.g. Peffers et al., 2007). Peffers et al. (2007) call their approach a design science research methodology and they provide a framework for performing DSR and communicating the results. Kuechler and Vaishnavi (2012) have extended the general design cycle by reflecting on DSR purposes. Several recent approaches have emphasized the central role of practitioners in the design science research process, which has led to proposals to add action research cycles into the DSR process (Figueiredo & Cunha 2007; Järvinen, 2007; Sein et al., 2011). Recently, Gregor and Hevner have codified the process outcome into a canonical publication genre (Gregor & Hevner 2013). All of the frameworks follow the high level pattern that is shown in Figure 1 with various degrees of explicit cycles and various levels of defined research outputs.

Evaluating the design results forms an important part of the DSR process. March and Smith (1995) highlight the difficulties in evaluating new constructs, because these difficulties may apply to a large variety of problems and change the operating environment. This may have been the ground for earlier evaluative measures. Therefore, they point out the importance of developing and validating evaluation criteria for the constructed artifacts (March & Smith, 1995). Hevner et al. (2004) laid out a set of quality attributes for design products. They stressed the technical quality of the artifact and the artifact should be fit for the intended organizational purposes. Baskerville, Pries-Heje and Venable have developed a set of evaluation criteria for DSR (Baskerville et al., 2008; Pries-Heje et al., 2008). The evaluation should be formative in the early stages of the project. This allows for changes to the problem and to the nature of the artifact, and, if warranted, redirecting the design (Sein et al., 2011). There should be summative evaluations to assess the value and utility of the outcomes towards the end of the project.

PRODUCTS OF DESIGN SCIENCE RESEARCH

One of the essential, perhaps the most important, results of DSR is the artifact itself. The artifact, however, is not surprisingly a widely

Figure 1. High level design science research process (Kuechler & Vaishnavi 2012)



discussed aspect in the literature. The conceptualization of the artifact certainly influences our ability to build knowledge that is valid. Whereas DSR seeks to generate general solution concepts (Aken 2004) or meta-artifacts (Iivari, 2003; Iivari, 2007), the process by which such knowledge is generated is intertwined with our understanding of the artifact. Hevner et al. (2004) understand the notion of artifact in terms of "a construct, a model, a method, and/or an instantiation" (cf. March and Smith 1995). They also underline that the artifact should be viable.

What is a viable artifact? Our reading of Hevner et al.'s (2004) work suggests that a viable artifact is relevant to a context (e.g., a business context) and can successfully address a problem. Also, the viable artifact should be formulated in a way that captures the influences of people, organization, and technology. Further, viable artifacts exhibit a level of novelty by addressing a problem in a new and original way. Such artifacts are both relevant to a context and new to the literature, and they can adopt many forms including those of constructs, models, methods, or instantiations (Hevner et al., 2004; Iivari 2007).

One point to emphasize is the temporal dimension of viability. Viability assumes that the artifact will have a capacity to survive and prosper. As problem spaces evolve, so must the artifact, or the research products of the design science research. In an era that is characterized by complexity and unprecedented change, the outcomes of DSR must sustain their values over time -- rather than being a one-time shot that cannot survive changes with evolving technology and organization. Consequently, there is a growing interest in conceptualizing the artifact in socio-technical terms, where the artifact is regarded not only as a stand-alone piece of technology, but also as something that is significantly interwoven with organizational and social elements and related logics. In this vein, Sein et al. (2011) and more recently Purao et al. (2013) propose the ensemble artifact (Orlikowski and Iacono 2001) as a framing with which to accommodate the various influences that determine the fate of

a design artifact over time. Viewing artifacts as "the material and organizational features that are socially recognized as bundles of hardware and/or software" (cf. Orlikowski and Iacono 2001), Sein et al. (2011, p. 38) make designers attentive to qualities that support multiple design paths to the future.

THEORIZING ABOUT DESIGN SCIENCE RESEARCH

On the theory development level, the key output of design science research should be new insights into design processes and products. Gregor and Jones (2007) propose that a DSR project should produce a design theory. In order to achieve this, natural research outputs are distilled exemplars from the above, such as design principles (Romme and Endenburg 2006) or design propositions or rules (Aken 2004). The "ultimate" goal should be an organized set of principles, typically for a certain domain, which would form a new or modified design theory (Gregor and Jones 2007). Kuechler and Vaishnavi (Kuechler and Vaishnavi 2008; Kuechler and Vaishnavi 2012) further argue that mid-range theories form a plausible DSR result. Such mid-range theories can act as a "bridge" between kernel theories and local design theories. The bridge should allow the systematic movement from explanations to prescriptions. Likewise, Purao (2013) and Sein et al., (2011) argue that one of the goals of design science research is not only to try to address the specific problem at hand, but also to view it as an instance of a more generic class of problems. Analogously, when the DSR process results in design rules, the researchers should formulate them at a higher level of abstraction with appropriate boundary conditions.

The design principles capture generic knowledge gained from the process of building solutions for a given domain (e.g., design rules (Aken, 2004) or they capture design propositions (Romme 2003) and encompass valid knowledge about creating other instances that belong to the same class of artifacts. They follow an inductive step that is similar to the move from empirical to theoretical statements (Lee & Baskerville, 2003), and they are validated (or in some cases falsified) via the DSR project. A key moment in this conceptual move is the shift on the level of abstraction, which can precipitate the move from design principles to the formulation of Gregor's Type V design theories. There is, however, a considerable disagreement on the ease of derivation and the usefulness of mid-level design theories (Lukyanenk & Parsons, 2013; Venable, 2013) when there are very few fully specified design theories.

THE ROAD AHEAD

In this paper, we have discussed what design science research was like in the past, what we have learned, what are the current research issues, how the papers in this special issue contribute to existing knowledge, and what we should study in the future.

As noted above, there are many research activities focusing on theorizing design science research processes recently. At the same time, we still use Markus et al. (2002) paper as an exemplar of theorizing about design. It can be observed that we now have the building blocks in place for performing sound design science research according to accepted principles (Hevner et al., 2004; Sein et al., 2011) and several alternative processes (Peffers et al., 2007; Sein et al., 2011). Further, we have more cogent guidelines for evaluating and theorizing designs (Gregor & Jones 2007).

With this special issue, we would like to make a call for actually doing sound and vigorous design science research and reflecting on the designs in a way that advances both practice and science of information system design. Design science remains a central pillar in IS research and it has now been accepted as a viable paradigm of doing research in IS. In other words, it is time to do more design science research!

REFERENCES

Aken, J. E. v. (2004). Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. *Journal of Management Studies*, *41*(2), 219–246. doi:10.1111/j.1467-6486.2004.00430.x

Baskerville, R., Pries-Heje, J., & Venable, J. (2008). Evaluation risks in design science research: A framework. In V. Vaishnavi & R. Baskerville (Eds.), *Proceedings of the DESRIST 2008*, Atlanta, GA (pp. 329-334).

Figueiredo, A. D., & Cunha, P. D. (2007). Action research and design in information systems: Two faces of a single coin. In N. Kock (Ed.), *Information systems action research: An applied view of emerging concepts and methods* (pp. 61–96). Springer. doi:10.1007/978-0-387-36060-7_4

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *Management Information Systems Quarterly*, *37*(2), 337–355.

Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5), 312–335.

Hevner, A. R., & Chatterjee, S. (2010). *Design research in information systems: Theory and practice*. Springer. doi:10.1007/978-1-4419-5653-8

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *Management Information Systems Quarterly*, *28*(1), 75–105.

Iivari, J. (2003). The IS core – VII: Towards information systems as a science of meta-artifacts. *Communications of the AIS*, *12*, 568–581.

Iivari, J. (2007). A paradigmatic analysis of information systems as a design science. *Scandinavian Journal of Information Systems*, *19*(2), 39.

Järvinen, P. (2007). Action research is similar to design science. *Quality & Quantity*, *41*, 37–54. doi:10.1007/s11135-005-5427-1

Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489–504. doi:10.1057/ejis.2008.40

Kuechler, W., & Vaishnavi, V. (2012). A framework for theory development in design science research: Multiple perspectives. *Journal of the Association for Information Systems*, *13*(6), 3.

Lee, A., & Baskerville, R. L. (2003). Generalizing generalizability in information systems research. *Information Systems Research*, *14*(3), 221–243. doi:10.1287/isre.14.3.221.16560

Lukyanenk, R., & Parsons, J. (2013). Reconciling theories with design choices in design science research. In J. Brocke, R. Hekkala, S. Ram, & M. Rossi (Eds.), *Design science at the intersection of physical and virtual design* (Vol. 7939, pp. 165–180). Springer Berlin Heidelberg. doi:10.1007/978-3-642-38827-9_12

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251–266. doi:10.1016/0167-9236(94)00041-2

Markus, M. L., Majchrzak, A., & Gasser, L. (2002). A design theory for systems that support emergent knowledge processes. *Management Information Systems Quarterly*, *26*(3), 179–212.

Nunamaker, J. F., & Chen, M., M., & Purdin, T. D. M. (1991). Systems development in information systems research. *Journal of Management Information Systems*, *7*(3), 89–106.

Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the "IT" in IT research - A call to theorizing the IT artifact. *Information Systems Research*, *12*(2), 13. doi:10.1287/isre.12.2.121.9700

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77. doi:10.2753/MIS0742-1222240302

Pries-Heje, J., Baskerville, R., & Venable, J. (2008). Strategies for design science research evaluation. In W. Golden, T. Acton, K. Conboy, H. V. D. Heijden & V. K. Tuunainen (Eds.), *Proceedings of the 16th European Conference on Information Systems*, Galway, Ireland, National University of Ireland.

Purao, S., & Henfridsson, O. et al. (2013). (To appear). Ensemble artifacts: From viewing to designing in action design research. *Systems*. *Signs & Actions*.

Romme, A. G. L. (2003). Making a difference: Organization as design. *Organization Science*, *14*(5), 558–573. doi:10.1287/orsc.14.5.558.16769

Romme, A. G. L., & Endenburg, G. (2006). Construction principles and design rules in the case of circular design. *Organization Science*, *17*(2), 287–297. doi:10.1287/orsc.1050.0169

Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. *Management Information Systems Quarterly*, *35*(1), 37–56.

Simon, H. A. (1969). *The sciences of the artificial*. Cambridge, MA: MIT Press.

Venable, J. (2006). The role of theory and theorising in design science research. In *Proceedings of the 1st International Conference on Design Science in Information Systems and Technology (DESRIST 2006)*. Citeseer.

Venable, J. (2013). Rethinking design theory in information systems. In J. Brocke, R. Hekkala, S. Ram, & M. Rossi (Eds.), *Design science at the intersection of physical and virtual design* (Vol. 7939, pp. 136–149). Springer Berlin Heidelberg. doi:10.1007/978-3-642-38827-9_10

Walls, J. G., Widmeyer, G. R., & Sawy, O. A. E. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research*, *3*(1), 36–59. doi:10.1287/isre.3.1.36

Matti Rossi is a professor of information systems at Aalto University School of Business. He holds a Ph.D. degree in Business Administration from the University of Jyväskylä. He has worked as research fellow at Erasmus University Rotterdam, as a visiting assistant professor at Georgia State University, Atlanta and visiting researcher at Claremont Graduate University. His research papers have appeared in journals such as MIS Quarterly, IEEE Software, Journal of AIS, Information and Organization, Information and Management*, and* Information Systems*, and over forty of them have appeared in conferences such as ICIS, HICSS and CAiSE. He is the editor in chief of* Communications of the Association for Information Systems*. He has been a senior editor at* JAIS and Database for Advances in Information Systems *and serves as an associate editor for* MIS Quarterly. *He was a co-chair of DESRIST 2007 and 2008 and program co-chair of DESRIST 2013, program co-chair for ECIS 2011, organizing chair for IRIS 2004, organizing committee member and technology chair for ICIS'98 and minitrack chair for Hawaii International Conference on Systems Sciences 98 - 14. He has been the principal investigator in several major research projects funded by the technological development center of Finland and Academy of Finland. He has been involved in the development of two research prototypes and further commercial products, which are sold by MetaCASE Consulting Plc., Jyväskylä, Finland. MetaEdit Personal is a single user CASE tool, used in 30 countries and in more than 20 Universities. MetaEdit+ is a multi-user integrated CASE tool, selected among the three most innovative new software tools at CeBIT'95 by Byte and used for the development of user interfaces for Nokia's feature phones. Matti Rossi is a member of IEEE, ACM and AIS.*

Ola Henfridsson is a Professor of Information Systems and Management at Warwick Business School, the University of Warwick, United Kingdom. He is also an adjunct professor at the Department of Applied Information Technology at Chalmers University of Technology, Sweden. His research interests include digital innovation, digital infrastructure, platforms, and technology management. Professor Henfridsson's research has been published in top journals such as Information Systems Research, MIS Quarterly*, and* Organization Science*.*

Kalle Lyytinen (PhD, Computer Science, University of Jyvaskyla; Dr. h.c. from Umeå University) is Iris S. Wolstein professor at Case Western Reserve University, adjunct professor at University of Jyvaskyla, Finland, and a visiting professor at University of Umeå, Sweden and at London School of Economics. He is the former Editor-in-Chief of the Journal of AIS *and Senior Editor of MISQ serves on the editorial boards of several leading organization theory and IS journals. Between 1992 and 2012 he was the 3rd most productive scholar in the IS field when measured by AIS basket of journals; he is currently among the 5 most cited scholars in the IS field based on his adjusted h-index (61); He is AIS fellow (2004), and the former chairperson of IFIP WG 8.2, and a founding member of SIGSAND. He has published around 300 refereed articles and edited or written nearly 20 books or special issues on the nature of IS discipline, system design, method engineering, computer supported cooperative work, standardization, ubiquitous computing, social networks.*

Keng Siau is the Chair of the Department of Business and Information Technology at the Missouri University of Science and Technology. Professor Siau is the Editor-in-Chief for the Journal of Database Management*, North America Regional Editor for the* Requirements Engineering *journal, and Co-Editor-in-Chief for the* Advances in Database Research *series. He is the Vice President of Education for the Association for Information Systems and serves on the Board of Partnership for Advancing Computing Education (PACE). He received his Ph.D. from the University of British Columbia, Canada. His M.S. and B.S. (honors) degrees are in Computer and Information Sciences from the National University of Singapore. Professor Siau has published more than 250 refereed journal and conference papers. According to the ISI Web of Science and Google Scholar, he has more than 1700 and 5200 citation counts respectively. His h-index, according to Harzing's Publish or Perish, is 37. In 2011, he was ranked as one of the top researchers in his field based on h-index and productivity rate. In 2006, he was ranked as one of the top ten e-commerce researchers in the world (Arithmetic Rank of 7, Geometric Rank of 3). In the same year, the citation count for his paper "Building Customer Trust in Mobile Commerce" is ranked in the top 1% within the field as reported by Essential Science Indicators. Professor Siau has received numerous teaching, research, and service awards. He is a recipient of the prestigious International Federation for Information Processing (IFIP) Outstanding Service Award in 2006, the IBM Faculty Awards in 2006 and 2008, and the IBM Faculty Innovation Award in 2010.*