Chapter 2
Design Science Research in Information Systems

Good design is a renaissance attitude that combines technology, cognitive science, human need, and beauty to produce something that the world didn't know it was missing.
– Paola Antonelli

Design is where science and art break even.
– Robin Mathew

2.1 Information Systems Research

Design activities are central to most applied disciplines. Research in design has a long history in many fields including architecture, engineering, education, psychology, and the fine arts (Cross 2001). The computing and information technology (CIT) field since its advent in the late 1940s has appropriated many of the ideas, concepts, and methods of design science that have originated in these other disciplines. However, information systems (IS) as composed of inherently mutable and adaptable hardware, software, and human interfaces provide many unique and challenging design problems that call for new and creative ideas.

The design science research paradigm is highly relevant to information systems (IS) research because it directly addresses two of the key issues of the discipline: the central, albeit controversial, role of the IT artifact in IS research (Weber 1987; Orlikowski and Iacono 2001; Benbasat and Zmud 2003) and the perceived lack of professional relevance of IS research (Benbasat and Zmud 1999; Hirschheim and Klein 2003). Design science, as conceptualized by Simon (1996), supports a pragmatic research paradigm that calls for the creation of innovative artifacts to solve real-world problems. Thus, design science research combines a focus on the IT artifact with a high priority on relevance in the application domain.

A tradition of design science research in the IS field has been slow to coalesce. Research in IS has been dominated by studies of the impacts of IT artifacts on organizations, teams, and individuals. Design research was considered the province of more technical disciplines such as computer science and electrical engineering. However, in the early 1990s the IS community recognized the importance of design science research to improve the effectiveness and utility of the

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IT artifact in the context of solving real-world business problems. Evidence of this awakening came in the 1991 formation of the Workshop on Information Technology and Systems (WITS), ground-breaking research by Nunamaker and his Electronic Group Decision Support Systems (GDSS) team at the University of Arizona (Nunamaker et al. 1991) and new thinking on how design science is defined, theorized, and actualized in the IS field (e.g., Iivari 1991; Walls et al. 1992; March and Smith 1995).

With encouragement from many leaders of the IS community, the author team of Alan Hevner, Salvatore March, Jinsoo Park, and Sudha Ram thought deeply about what constitutes good design science research in IS. They adapted the design research traditions of other fields to the unique contexts of IS design research. In particular, the seminal thinking of Herbert Simon in *Sciences of the Artificial* (Simon 1996) supported their ideas. After a number of review cycles and benefiting from many insightful reviewer comments, their research essay appeared in *Management Information Systems Quarterly* (*MISQ*) in March 2004 (Hevner et al. 2004). This paper is included in an appendix to this book. The following section provides a concise overview of the paper. The remainder of this chapter discusses the impacts of the 2004 *MISQ* paper and expands on its content.

2.2 Summary of Hevner, March, Park, and Ram 2004 *MISQ* Paper

Information systems are implemented within an organization for the purpose of improving the effectiveness and efficiency of that organization. The utility of the information system and characteristics of the organization, its work systems, its people, and its development and implementation methodologies together determine the extent to which that purpose is achieved. It is incumbent upon researchers in the Information Systems (IS) discipline to further knowledge that aids in the productive application of information technology to human organizations and their management and to develop and communicate "knowledge concerning both the management of information technology and the use of information technology for managerial and organizational purposes" (Zmud 1997).

Acquiring such knowledge involves two complementary but distinct paradigms, natural (or behavioral) science and design science (March and Smith 1995). The behavioral science paradigm has its roots in natural science research methods. It seeks to develop and justify theories (i.e., principles and laws) that explain or predict organizational and human phenomena surrounding the analysis, design, implementation, and use of information systems. Such theories ultimately inform researchers and practitioners of the interactions among people, technology, and organizations that must be managed if an information system is to achieve its stated purpose, namely improving the effectiveness and efficiency of an organization. These theories impact and are impacted by design decisions made with respect to the system development methodology used and the functional capabilities, information contents, and human interfaces implemented within the information system.

The design science paradigm has its roots in engineering and the sciences of the artificial (Simon 1996). It is fundamentally a problem-solving paradigm. It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, and use of information systems can be effectively and efficiently accomplished. Design science research in IS addresses what are considered to be *wicked problems* (Rittel and Webber 1984; Brooks 1987). That is, those problems characterized by

- unstable requirements and constraints based on ill-defined environmental contexts,
- complex interactions among subcomponents of the problem,
- inherent flexibility to change design processes as well as design artifacts (i.e., malleable processes and artifacts),
- a critical dependence upon human cognitive abilities (e.g., creativity) to produce effective solutions, and
- a critical dependence upon human social abilities (e.g., teamwork) to produce effective solutions.

Technological advances are the result of innovative, creative design science processes. If not "capricious," they are at least "arbitrary" (Brooks 1987) with respect to business needs and existing knowledge. Innovations, such as database management systems, high-level languages, personal computers, software components, intelligent agents, object technology, the Internet, and the World Wide Web, have had dramatic and at times unintended impacts on the way in which information systems are conceived, designed, implemented, and managed.

A key insight here is that there is a complementary research cycle between design science and behavioral science to address fundamental problems faced in the productive application of information technology (see Fig. 2.1). Technology and

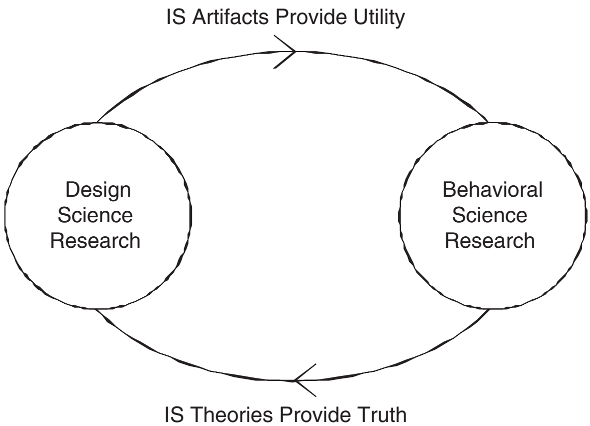

Fig. 2.1 Complementary nature of design science and behavioral science research

behavior are not dichotomous in an information system. They are inseparable. They are similarly inseparable in IS research. Philosophically these arguments draw from a pragmatist philosophy that argues that truth (justified theory) and utility (artifacts that are effective) are two sides of the same coin and that scientific research should be evaluated in light of its practical implications. In other words, the practical relevance of the research result should be valued equally with the rigor of the research performed to achieve the result.

The primary goal of the *MISQ* paper is to provide an understanding of how to conduct, evaluate, and present design science research to IS researchers and practicing business managers. The research activities of design science within the IS discipline are described via a conceptual framework for understanding information systems research and a clear set of guidelines or principles are proscribed for conducting and evaluating good design science research (see Table 2.1). A detailed discussion of each of the seven guidelines is presented in the 2004 *MISQ* paper. The proposed guidelines are applied to assess recent exemplar papers published in the IS literature in order to illustrate how authors, reviewers, and editors can apply the guidelines consistently. The paper concludes with an analysis of the challenges of performing high-quality design science research and a call for greater synergistic efforts between behavioral science and design science researchers.

Table 2.1 Design Science Research Guidelines

Guideline	Description
Guideline 1: Design as an Artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation
Guideline 2: Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems
Guideline 3: Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods
Guideline 4: Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies
Guideline 5: Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact
Guideline 6: Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment
Guideline 7: Communication of research	Design science research must be presented effectively to both technology-oriented and management-oriented audiences

2.3 Impacts of 2004 *MISQ* Paper on Design Science Research

The 2004 *MISQ* paper has had a strong impact on the field as Information Systems researchers recognize the values the design science paradigm brings to a research project. It is the natural desire of researchers to improve things. For some it is not enough to study and understand why nature is as it is, but they want to know how they can improve the way it is. Design science research attempts to focus human creativity into the design and construction of artifacts that have utility in application environments.

Design science offers an effective means of addressing the relevancy gap that has plagued academic research, particularly in the management and information systems disciplines. Natural science research methods are appropriate for the study of existing and emergent phenomena; however, they are insufficient for the study of "wicked organizational problems," the type of problems that require creative, novel, and innovative solutions. Such problems are more effectively addressed using type of paradigm shift offered by design science.

Design science research in the IS field is now better positioned as an equal, complementary partner to the more prevalent behavioral science research paradigm. The key contribution is a new way of thinking about what makes IS research relevant to its various audiences of managers, practitioners, and peer researchers in related fields. Design must still be informed by appropriate theories that explain or predict human behavior; however, these may be insufficient to enable the development and adaptation of new and more effective organizational artifacts. Scientific theories may explain existing or emergent organizational phenomena related to extant organizational forms and artifacts but they cannot account for the qualitative novelty achieved by human intention, creativity, and innovation in the design and appropriation of such artifacts. That is, science, the process of understanding "what is," may be insufficient for design, the process of understanding "what can be."

Researchers in application domains as disparate as health care, E-commerce, biology, transportation, and the fine arts identify the key role of designed artifacts in improving domain-specific systems and processes. The models and guidelines of the 2004 *MISQ* paper support researchers to bring a rigorous design science research process into projects that heretofore had not clearly described how new ideas become embedded in purposeful artifacts and then how those artifacts are field tested in real-world environments.

Since the 2004 publication of the Hevner, March, Park, and Ram paper, the broadening recognition of design science research in the IS field has led to a number of important new activities and research directions:

- A new, multi-disciplinary research conference, Design Science Research in Information Systems & Technology (DESRIST), has been established and four offerings of the conference have been held from 2006 to 2009. An important characteristic of DESRIST has been its multi-disciplinary attendance and agenda. This environment has allowed the IS community to interact more closely with other design-focused disciplines, such as engineering and architecture.

– A special issue of MISQ on Design Science Research appeared in 2008 (MISQ 2008).
– The design science guidelines described in this paper have provided a structured path for doctoral students interested in using this methodology in their research, structuring and legitimizing their research. Most IS doctoral programs in major universities now provide a research seminar dedicated to design science research methods and projects.
– Leading international scholars in IS are actively extending the research ideas found in the 2004 MISQ paper. Examples include research by Gregor and Jones (2007), Iivari (2007), and Peffers, Tuunanen, Rothenberger, and Chatterjee (2008).
– Leading journals in the IS field have expanded their boards to include more senior editors and associate editors who have used and who now understand the design science approach. This will ultimately pave the way for more design science research papers to get published and thus benefit the whole field by enhancing the relevance of IS research.

It is exciting to see the ongoing discussions and increased interest in design science research projects in the IS field. Information systems and organizational routines are among the key components of organizational design as they are extensions of human cognitive capabilities. They are the tools of knowledge work enabling new organizational forms and providing management and decision-making support. For example, incentive structures related to job performance such as achieving sales, product quality, or customer satisfaction goals require information gathering and analysis capabilities. Management of outsourcing and inter-organizational partnerships requires secure information sharing. Identification of problems and opportunities requires the gathering and analysis of business intelligence. More and more frequently business decisions are made relying on information from the computer-based analysis and recommendations. Similarly, organizational routines are intended to provide guidance to human action within prescribed organizational contexts. Yet even such artifacts are appropriated and adapted by humans in ways and for purposes that the designers may not have envisioned. With the renewed interest in design science research in the information systems and organizational science disciplines, future research will focus on the co-design of information processing capabilities and organizational structures.

2.4 Extending the Reach of Design Science Research in IS

The critical reactions (both positive and negative) from the IS community toward the 2004 *MISQ* paper and the design science guidelines have led to several important extensions for the application of design science ideas to IS research. To conclude this chapter, a number of key issues are addressed.

2.4.1 Design Science Research vs. Professional Design

One issue that must be clearly addressed in design science research is differentiating high-quality professional design or system building from design science research. The difference is in the nature of the problems and solutions. Professional design is the application of existing knowledge to organizational problems, such as constructing a financial or marketing information system using "best practice" artifacts (constructs, models, methods, and instantiations) existing in the knowledge base. On the other hand, design science research addresses important unsolved problems in unique or innovative ways or solved problems in more effective or efficient ways. The key differentiator between professional design and design research is the clear identification of a contribution to the archival knowledge base of foundations and methodologies and the communication of the contribution to the stakeholder communities.

In the early stages of a discipline or with significant changes in the environment, each new artifact created for that discipline or changed environment is "an experiment" that "poses a question to nature" (Newell and Simon 1976). Existing knowledge is used where appropriate; however, often the requisite knowledge is nonexistent. In other words the knowledge base is inadequate. Reliance on creativity and trial and error search are characteristic of such research efforts. As design science research results are codified in the knowledge base, they become "best practices." Professional design and system building then become the routine application of the knowledge base to known problems.

2.4.2 Design as Research vs. Researching Design

Design science research has been interpreted as including two distinctly different classes of research – ‘design as research’ and ‘researching design.’ While the 2004 *MISQ* paper focuses on the former class of research, it is important to recognize the existence and importance of both types of research.

Design as Research encompasses the idea that doing innovative design that results in clear contributions to the knowledge base constitutes research. Knowledge generated via design can take several forms including constructs, models, methods, and instantiations (March and Smith 1995). Design research projects are often performed in a specific application context and the resulting designs and design research contributions may be clearly influenced by the opportunities and constraints of the application domain. Additional research may be needed to generalize the research results to broader domains. Design as research, thus, provides an important strand of research that values research outcomes that focus on improvement of an artifact in a specific domain as the primary research concern and, then, seeks a broader, more general understanding of theories and phenomena surrounding the artifact as an extended outcome.

Researching Design shifts the focus to a study of designs, designers, and design processes. The community of researchers engaged in this mode of research was organized under the umbrella of the design research society starting as early as the mid-1960s. Because of their focus on methods of designing, they have been able to articulate and follow the goal of generating domain-independent understanding of design processes, although their investigations have been focused largely in the fields of architecture, engineering, and product design. Although it is difficult to provide unambiguous and universally accepted definitions of design processes, working definitions suggest designing is an iterative process of planning, generating alternatives, and selecting a satisfactory design. Examples of work from this stream, therefore, include use of representations and languages (Oxman 1997), use of cognitive schemas (Goldschmidt 1994), and theoretical explorations (Love 2002).

Although similarities are many, the two fields of design study have been different in their focus and trajectory. Of the differences, three are most visible. First, design as research emphasizes the domain in which the design activity will take place, placing a premium on innovativeness within a specific context. In contrast, researching design emphasizes increased understanding of design methods often independent of the domain. Second, the domains of study for the first subfield have typically been the information and computing technologies as opposed to architecture and engineering for the second. Finally, the closest alliances from the design as research have been formed with disciplines such as computer science, software engineering, and organization science. Researching design is more closely allied with cognitive science and professional fields such as architecture and engineering.

2.4.3 Design Science Research Cycles

The 2004 *MISQ* paper presents design science as a research paradigm to be employed in IS research projects. As such, the discussion does not propose a detailed process for performing design science research. However, a key insight can be gained by identifying and understanding the existence of three design science research cycles in any design research project as shown in Fig. 2.2 (Hevner 2007).

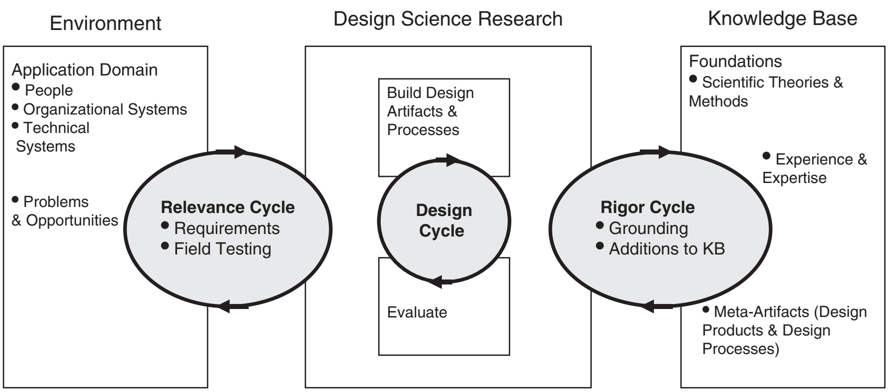

Fig. 2.2 Design science research cycles

Figure 2.2 borrows the IS research framework found in (Hevner et al. 2004) and overlays a focus on three inherent research cycles. The *Relevance Cycle* bridges the contextual environment of the research project with the design science activities. The *Rigor Cycle* connects the design science activities with the knowledge base of scientific foundations, experience, and expertise that informs the research project. The central *Design Cycle* iterates between the core activities of building and evaluating the design artifacts and processes of the research. These three cycles must be present and clearly identifiable in a design science research project. The following sections briefly expand on the definitions and meanings of each cycle.

2.4.3.1 The Relevance Cycle

Design science research is motivated by the desire to improve the environment by the introduction of new and innovative artifacts and the processes for building these artifacts (Simon 1996). An application domain consists of the people, organizational systems, and technical systems that interact to work toward a goal. Good design science research often begins by identifying and representing opportunities and problems in an actual application environment.

Thus, the relevance cycle initiates design science research with an application context that not only provides the requirements for the research (e.g., the opportunity/problem to be addressed) as inputs but also defines acceptance criteria for the ultimate evaluation of the research results. Does the design artifact improve the environment and how can this improvement be measured? The output from the design science research must be returned into the environment for study and evaluation in the application domain. The field study of the artifact can be executed by means of appropriate technology transfer methods such as action research (Cole et al. 2005; Jarvinen 2007).

The results of the field testing will determine whether additional iterations of the relevance cycle are needed in this design science research project. The new artifact may have deficiencies in functionality or in its inherent qualities (e.g., performance, usability) that may limit its utility in practice. Another result of field testing may be that the requirements input to the design science research were incorrect or incomplete with the resulting artifact satisfying the requirements but still inadequate to the opportunity or problem presented. Another iteration of the relevance cycle will commence with feedback from the environment from field testing and a restatement of the research requirements as discovered from actual experience.

2.4.3.2 The Rigor Cycle

Design science draws from a vast knowledge base of scientific theories and engineering methods that provides the foundations for rigorous design science research. As importantly, the knowledge base also contains two types of additional knowledge:

- The experiences and expertise that define the state of the art in the application domain of the research.
- The existing artifacts and processes (or meta-artifacts (Iivari 2007)) found in the application domain.

The rigor cycle provides past knowledge to the research project to ensure its innovation. It is contingent on the researchers to thoroughly research and reference the knowledge base in order to guarantee that the designs produced are research contributions and not routine designs based on the application of known design processes and the appropriation of known design artifacts.

While rigorous advances in design are what separate a research project from the practice of routine design, we need to be careful to identify the sources and types of rigor appropriate for design research. The risk comes when experts in other research paradigms attempt to apply their standards of rigor to design research projects in which creative inspiration or gut instinct may lead to design decisions. To insist that all design decisions and design processes be based on grounded behavioral or mathematical theories may not be appropriate or even feasible for a truly cutting-edge design artifact. Such theories may as yet be undiscovered or incomplete and the research activities of design and evaluation of the artifact may advance the development and study of such theories.

Consideration of rigor in design research is based on the researcher's skilled selection and application of the appropriate theories and methods for constructing and evaluating the artifact. Design science research is grounded on existing ideas drawn from the domain knowledge base. Inspiration for creative design activity can be drawn from many different sources to include rich opportunities/problems from the application environment, existing artifacts, analogies/metaphors, and theories (Iivari 2007). This list of design inspiration can be expanded to include additional sources of creative insights (Csikszentmihalyi 1996).

Additions to the knowledge base as results of design research will include any additions or extensions to the original theories and methods made during the research, the new artifacts (design products and processes), and all experiences gained from performing the iterative design cycles and field testing the artifact in the application environment. It is imperative that a design research project makes a compelling case for its rigorous bases and contributions lest the research be dismissed as a case of routine design. Definitive research contributions to the knowledge base are essential to selling the research to an academic audience just as useful contributions to the environment are the key selling points to a practitioner audience.

2.4.3.3 The Design Cycle

The internal design cycle is the heart of any design science research project. This cycle of research activities iterates more rapidly between the construction of an artifact, its evaluation, and subsequent feedback to refine the design further. Simon (1996) describes the nature of this cycle as generating design alternatives and evaluating the alternatives against requirements until a satisfactory design is achieved. As discussed above, the requirements are input from the relevance cycle and the design and evaluation theories and methods are drawn from the rigor cycle. However, the design cycle is where the hard work of design science research is done. It is important to understand the dependencies of the design cycle on the other two cycles while appreciating its relative independence during the actual execution of the research.

During the performance of the design cycle a balance must be maintained between the efforts spent in constructing and evaluating the evolving design artifact. Both activities must be convincingly based on relevance and rigor. Having a strong grounded argument for the construction of the artifact, as discussed above, is insufficient if the subsequent evaluation is weak. Juhani (2007) states, “The essence of Information Systems as design science lies in the scientific evaluation of artifacts.” Artifacts must be rigorously and thoroughly tested in laboratory and experimental situations before releasing them into field testing along the relevance cycle. This calls for multiple iterations of the design cycle in design science research before contributions are output into the relevance cycle and the rigor cycle.

2.4.4 A Checklist for Design Science Research

While the seven guidelines in the 2004 *MISQ* paper have been largely accepted as integral to top quality design science research, requests have been made for a more specific checklist of questions to evaluate a design research project. The questions in Table 2.2 provide such a checklist that has been used to assess progress on design research projects. In practice, design researchers have found these questions to form a useful checklist to ensure that their projects address the key aspects of design science research. To demonstrate the relationship of these questions with the three research cycles discussed in the previous section, Fig. 2.3 maps the eight questions to the appropriate research cycle.

2.4.5 Publication of Design Science Research

Guideline 7 (see Table 2.1) addresses the dissemination of design science research results in appropriate journal outlets. Much feedback to the 2004 *MISQ* paper has centered on the willingness of top-ranked journals in the IS and computer science (CS) fields to publish design science results. Any discussion of top-quality publication outlets must draw a distinction between journals with technology-focused audiences and management-focused audiences. Good design science research produces results of interest for both audiences. Technology audiences need sufficient detail to enable the described artifact to be constructed (implemented) and used within an appropriate context. It is important for such audiences to understand the processes by which the artifact was constructed and evaluated. This establishes repeatability of the research project and builds the knowledge base for further research extensions by future design science researchers.

Table 2.2 Design science research checklist

Questions	Answers
1. What is the research question (design requirements)?	
2. What is the artifact? How is the artifact represented?	
3. What design processes (search heuristics) will be used to build the artifact?	
4. How are the artifact and the design processes grounded by the knowledge base? What, if any, theories support the artifact design and the design process?	
5. What evaluations are performed during the internal design cycles? What design improvements are identified during each design cycle?	
6. How is the artifact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artifact utility and improvement over previous artifacts?	
7. What new knowledge is added to the knowledge base and in what form (e.g., peer-reviewed literature, meta-artifacts, new theory, new method)?	
8. Has the research question been satisfactorily addressed?	

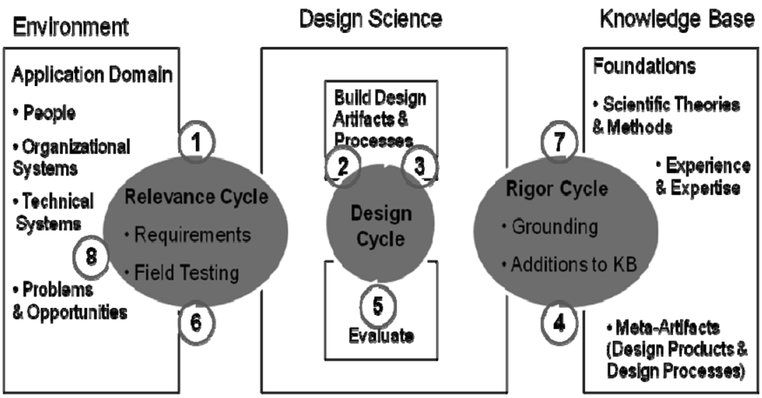

Fig. 2.3 Questions mapped to three design research cycles

On the other hand, management audiences need sufficient detail to determine if organizational resources should be committed to constructing (or purchasing) and using the artifact within their specific organizational context. The rigor of the artifact design process must be complemented by a thorough presentation of the experimental design of the artifact's field test in a realistic organizational environment. The emphasis must be on the importance of the problem and the novelty and utility of the solution approach realized in the artifact.

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