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A Four-Cycle Model of IS Design Science Research: Capturing the Dynamic Nature of IS Artifact Design

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Abstract. *We propose to extend the well-known three-cycle view for design science research (DSR) with a fourth cycle (change and impact cycle) that captures the dynamic nature of IS artifact design for volatile environments. The appropriation of innovative designs results in organizational changes that happen outside the new artifacts' immediate application contexts. The intention behind introducing the fourth cycle is to integrate recent advances in the DSR discourse conceptually within the DSR cycle model. We critically review such recent advances and integrate them into an extended model. We show how this change and impact (CI) cycle adds an important facet to DSR to cope with dynamic application contexts as well as artifact-induced organizational change and the resulting need for follow-up design efforts. Iterations of the CI cycle represent the continuous design evolution required to keep up with changing organizational environments.*

Keywords: design science research; DSR cycle model; rigor cycle; relevance cycle; design cycle; change and impact cycle

1 Introduction

In recent years, design science research (DSR) has become an established research paradigm in the IS field [4]. A widely cited model visualizing the paradigm's foundations is Hevner's three cycle view of DSR [6], comprising a rigor, a design, and a relevance cycle. While this three-cycle view comprehensively conceptualizes the critical aspects of a DSR project, it lacks a key dynamic perspective on how the DSR project relates to the organizational context with which it is embedded. Due to the strong link to a real-world problem or situation, the design researcher is, unlike in other research paradigms, not necessarily controlling the DSR project's progress speed. For instance, rapidly changing environmental conditions may require quick and short design cycles to maintain artifact utility. In turn, quick design cycles may leave only limited opportunities to draw on and grow extant theoretical knowledge bases in the rigor cycle [4]. Recent advances in the DSR discourse – such as emergent design science [10] or agile design science [1] – have proposed additional measures for the DSR process to cope with dynamics and time-related aspects in DSR. The root sources for these dynamics often lie in the wider environment outside the artifacts' immediate application context or environment and therefore outside the three cycles of the original model [6].

Against this backdrop, we propose to extend the three-cycle view on DSR with a fourth cycle that covers exactly this wider application context and integrates this source of contextual change and dynamics into the conceptual cycle model of DSR. The extended four-cycle view thus treats dealing with these dynamic aspects not as an exception that a DSR process needs to mitigate or manage outside the research scope. Instead, the four-cycle view elevates these dynamic issues to the same level as refining the artifact in the design cycle or ensuring a research contribution in the rigor cycle. In turn, the four-cycle view allows the DSR paradigm to integrate the proposed individual measures from the literature on how to deal with dynamics in DSR into a comprehensive knowledge base. Further, the four-cycle view allows us to extend our perspective on artifact design beyond its immediate uses to the artifacts' longer-term impacts on their wider organizational or societal environments. Lastly, we propose to extend the underlying cycle metaphor to consider dynamic and different cycle turning speeds. This extension represents design science researchers' needs to consider and synchronize the cycle speeds during a research project to achieve and to take – depending on the extent of friction they experience between different cycles – explicit measures to increase the traction between the cycles so that they keep turning synchronously.

We organize our research-in-progress paper as follows. In the second section, we briefly summarize the three-cycle view and review selected recent advances to the DSR discourse that cover more dynamic DSR aspects. In Section 3, we introduce our proposal for a four-cycle view and show how it integrates dynamic DSR process aspects discussed in the previously reviewed literature. In the fourth section, we draw conclusions and outline further research avenues to build upon our proposed model.

2 The DSR Three Cycle Model and Proposed Extensions

This section briefly introduces the extant three-cycle view of design science research and outlines recent proposed extensions.

2.1 The Established Three-Cycle View

Figure 1 shows a graphical representation of the three cycles: the rigor cycle, the relevance cycle, and, in between, the design cycle. The relevance cycle provides the research problem or opportunity, the requirements, and the acceptance criteria for the artifact's utility in the field [6]. This cycle links the environment to the artifact that we view – in-line with Simon [11] – as a coherent human-made entity that constitutes an interface between its inner workings and the elements of its environment as they are represented in Figure 1: people, organizational systems, and technical systems within a particular application domain (e.g., business, healthcare IT, smart cities). The rigor cycle covers how the artifact design is grounded in extant knowledge bases that include, but are not limited to, scientific theories, but also experience and expertise. Simultaneously, artifact evaluation should rigorously contribute to these knowledge bases in capturing what works, what does not work, and how the evaluation findings fit with and extend the extant theories and experiences. The central design cycle supports the actual artifact design/redesign and the corresponding artifact evaluation. Artifact evaluation can take place within the design cycle in artificial settings (e.g., thought or laboratory experiments) or in real-world contexts [12]. The latter evaluation type comprises field tests that become part of the relevance cycle.

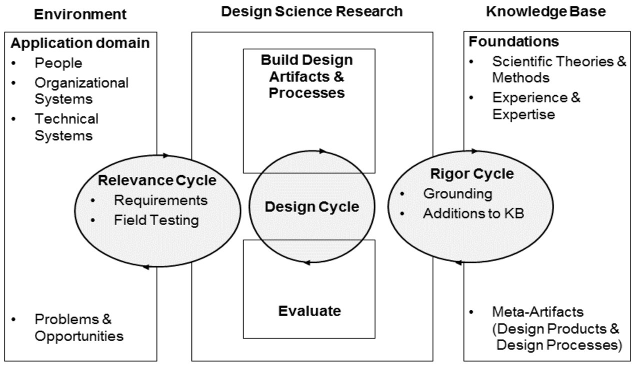

Fig. 1. The Three Cycle View of Design Science Research (From Hevner [6])

Overall, the three-cycle view captures the DSR idea to refine the artifact design iteratively through several interconnected design, relevance, and rigor cycles. This refinement is to increase both the artifact's effectiveness to address the real-world problem as well as its knowledge contributions over several iterations.

2.2 Beyond the Three Cycle Model - Extensions

We briefly review several recent contributions to the DSR literature that cover issues that lie beyond the three cycles. We acknowledge that the limited scope and size of this paper does not allow us to conduct a systematic and comprehensive literature review. Despite this, we think that even a few selected sources make a sufficient case for the viability of the four-cycle model that we present in the following section.

Pirkkalainen [10] highlights the emergent nature of many design research projects. Often, DSR projects take place in complex settings with many stakeholders from research and practice communities driving the project. Such projects also often have large-scale overarching objectives beyond just the development of a single artifact. A key initial part of these projects is locating and agreeing on issues that warrant the design of a novel DSR artifact in the first place. Likewise, Mullarkey and Hevner [7] highlight the challenge of defining and agreeing on a design problem to start DSR or Action Design Research (ADR) processes, especially in "wicked" environments. Here, it is pointed out that the three-cycle view does not explicitly contain the starting point or problem trigger that initially sets the cycles in motion.

Conboy, Gleasure, and Cullina [1] speak of complex and changing contexts of DSR projects and propose to adopt an agile metaphor to DSR. The overall objective is broken down into sub-objectives, which are to be reached in shorter iteration cycles in the form of "sprints". Each sprint comprises (re)designs and subsequent evaluations, and may lead to a problem redefinition and corresponding new solution requirements. In contrast, the three-cycle view lacks the notion of a dynamic environment beyond the artifact's immediate application context. There is also no conceptualization of the factor time and iteration speed in the original three-cycle view.

Further, Gill and Hevner [3] propose to consider artifact fitness in addition to artifact utility. In essence, they distinguish two artifact fitness types: 1) Fitness as maximizing an economic utility function focusing on goodness of fit in a design context and 2) Fitness as biological reproduction focusing on sustained design utility over changing 'generational' contexts. In the three-cycle view, the former type of fitness can be placed at the bridge between the design and the relevance cycle. However, since the three-cycle view does not cover changing contexts, there is no place to integrate the latter fitness type into the model.

Lastly, Pandza and Thorpe [8] highlight that one should not treat an artifact's introduction into a context as an engineering-like installation. Instead, introducing an artifact into an organizational context triggers subsequent organizational (or social) change that (hopefully) contributes toward reaching the overarching goal or addressing the problem that served as DSR project trigger. The eventual outcome of such an organizational/societal change process cannot be predicted with certainty, however. We concur and have proposed to conceptualize such a change process not as causation-oriented, but as effectuation-oriented [2], borrowing a model from entrepreneurship research. In contrast, the term "field testing" in the three-cycle view implies that one should just examine whether the artifact manages to cause the intended effects or solution and evaluate its utility accordingly. Again, the idea of having an artifact leading to deliberate larger-scale organizational or societal transformations as well as emergent changes in its contexts, is explicitly absent from the three-cycle view.

3 Proposing a Four Cycle View of Design Science Research

Here, we propose an extension to the three-cycle view of Figure 1 that allows us to place the advances reviewed in Section 2.2 within the same cycle metaphor and, thus, make sense of them in the greater DSR context.

To better capture the dynamic nature of artifact design for dynamic real-world contexts, we include a fourth cycle in the DSR model as shown in Figure 2. This new cycle is termed the *Change and Impact* (CI) cycle. The newly introduced cycle covers the design artifacts' second-order impacts to their wider organizational and societal contexts. We therefore propose to distinguish an artifact's immediate application context – that covers the direct artifact user(s) within their environment – from the encompassing socio-technical system within which the immediate application context is a subsystem.

For instance, for an information system that is to be used within a particular business process, this business process would be the immediate application context. In contrast, the entire business process chain, the respective business function(s), the encompassing enterprise or even an entire supply chain would form the wider context. Likewise, for a mobile healthcare IT app, the app itself, the mobile device(s), and the doctors and/or patients that use the app would be the immediate application context, while the more encompassing healthcare system and, in an even grander scale, the corresponding country's society in need of improved health care would constitute the wider context.

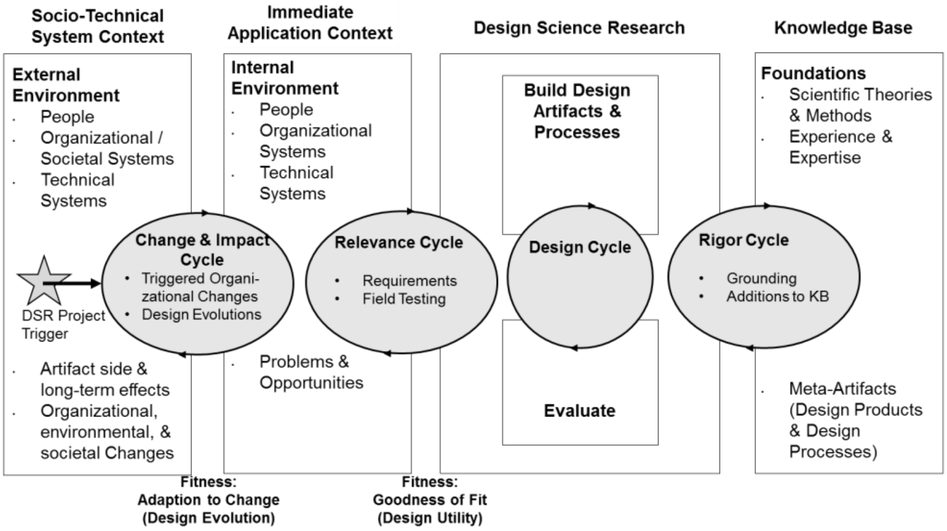

Fig. 2. A Four Cycle View of Design Science Research

We recognize that the delineation between these two contexts can change depending on the design researchers' interests and initial DSR project goals. Thus, in the second example above, is the mobile app itself the "unit of design" that is of key interest and is its intended utility defined as its immediate effects on the patients, or is the mobile app just a part of a more comprehensive healthcare system research project to increase patient care quality for an entire city or region? This delineation may even shift during the project when additional artifact effects within the wider contexts are to be found relevant as part of the immediate artifact's evaluation.

To aid the initial delineation between the immediate and the wider application contexts, we propose to consider the direct trigger for the DSR project as being "just" outside the immediate application context. By this we mean that the objectives of many DSR projects are typically driven by factors in the external environment within which the designed artifacts are to be embedded. Viewed from a stakeholders' perspective within this external environment, the goals of a DSR project are not simply the building and evaluation of artifacts as such but to provide broader impacts to stakeholder communities in organizations and/or society. Simultaneously, there may be DSR projects, such the ones with a design/artifact-centric starting point [9], without an external environment where a CI cycle could take place. Therefore, we do not consider iterations through the CI cycle as necessarily mandatory for DSR.

4 Benefits and Implications of the CI Cycle

In a static perspective, the additional CI cycle allows researchers to explicitly distinguish the immediate artifact effects or impacts from those it may have indirectly on the wider context, i.e. parts of the research setting that are initially outside the DSR project's scope. Such indirect effects may include long-term effects, but also unintended side-effects a traditional artifact utility evaluation may not be designed to capture. We posit that artifacts especially in complex research settings (such as today's enterprises or societies) will almost invariably trigger such indirect effects. The added notion of societal systems in the extended model also formally reflects the extended role of IS research nowadays that impacts society in domains such as healthcare IT or smart cities compared to traditionally being limited to business organization settings.

In a dynamic perspective, the CI cycle provides a lens for researchers to become more aware of dynamics in the wider organizational or societal context and to make sense of and cope with these dynamics within a research project's scope. Today's organizations and societies are consistently changing (through deliberate efforts as well as due to emergence from within) and, thus, serve as major source for dynamics outside a DSR project's scope. Such external dynamics highlight that goals, rationales, and requirements for DSR projects may change as well over the duration of a research project. Even for purely technical IS artifacts changes in the wider context (such as mergers between enterprises or new legislation) may impact an artifact's viability and utility. A particular change in the wider context may also create a problem that has not existed (or perceived) before and thus constitute the trigger for the entire DSR project. In turn, the artifact's introduction to its immediate application context may likewise serve as trigger for additional changes in the wider environment that will lead to new or changed requirements for the artifact, therefore to new subsequent iterations through the cycles, or, in the worst case, even may make the artifact not viable anymore.

An extended dynamic perspective also enables us to consider the factor of time in DSR in a more differentiated way. First, in DSR projects it is often not the researcher that controls the project's execution speed. Especially when being closely embedded in volatile environments, the pace of environmental change and key stakeholders' urgent needs may demand quick results in form of artifacts that address these needs. Thus, we can regard the CI cycle as often being the "driving axle" for the entire DSR project right from the start when researchers address a particular real-world problem. The CI cycle may also start turning more quickly after the artifact's first incarnation has been placed in the real-world setting and it becomes evident during the evaluation that it requires comprehensive redesigns for immediate utility. In any case, a high rotation speed CI cycle consequently calls for equivalent speeds for the other cycles.

However, depending on the CI cycle turning speed, it may not be possible or feasible to arrive at sufficiently quick artifact redesigns or contributions to the knowledge base, depending on the artifact's constitution or the extant landscape of theories or knowledge bases (or rather, the respective design researchers' knowledge about them). Such a situation carries the danger of the researchers over-emphasizing artifact utility without considering issues such as artifact generalizability or theoretical contributions, in order to satisfy real-world demands.

Following the metaphor of turning cycles even further, we arrive at the notions of *traction* and *friction* between each cycle. Traction exists when the researchers are able to cope with a DSR project's speed when moving back and forth between cycles. Friction occurs when one cycle turns too quickly so that researchers cannot keep up with the needs of the subsequent cycle in time. For instance, in dynamic and unpredictable contexts agile DSR states a goal of achieving quicker turning speeds (short iteration cycles) of the leftmost three cycles (cf. Section 2.2). The enhanced model in Figure 2 highlights this possibility and may help design science researchers to be aware of such dangers and to prepare for such situations beforehand. For instance, by initially reviewing literature more comprehensively including knowledge that may or may not be needed later, researchers can keep the rigor cycle turning more quickly throughout a research project. Alternatively, they can prepare to gather and store data systematically while coping with quick relevance and CI cycles and conduct a single more comprehensive but still thorough rigor cycle that covers several iterations through the design, relevance, and CI cycles after the "dust has settled".

Further, the four-cycle view allows us to integrate both artifact fitness criteria mentioned in Section 2.2. The "goodness of fit" aspect is covered at the bridge between the design and relevance cycle as it addresses the challenge of successfully adapting an artifact initially to its application context. In contrast, the evolutionary aspect of artifact fitness that covers long-term artifact adaptability rather calls for coverage between the relevance and the newly introduced CI cycle as it is usually the change in the wider contexts that drives long-term artifact fitness requirements for sustained utility. Again, a more dynamic and volatile wider context may require rapid new design generations. This will require the initial design cycles to focus greater attention on sustainable design features such as decomposability, openness, and elegance [3]. Such dynamic notions of artifact fitness also highlight the importance of design theory elements such as artifact mutability [5]. Here, the four-cycle view can help to put the rationale to consider artifact fitness in addition to artifact utility in DSR more front and center than current models.

Lastly, the four-cycle model allows the integration of the extant partial recommendations reviewed in section 2.2 more comprehensively into the underlying DSR foundations. Such integrated meta-design knowledge about DSR processes and products that can cope with high and differing turning speeds allows further research projects in volatile environments to design more useful and sustainably useful artifacts and to further grow this meta-design knowledge base.

5 Conclusion and Outlook

In this paper, we propose extending the established three-cycle DSR model with a fourth cycle that supports an improved understanding of change and impact (CI) on organizations or society that are triggered by a design artifact upon introduction into its immediate application context. Our goal is to contribute an extension to the conceptual DSR foundations to adequately reflect today's more ambitious and complex IS DSR projects. The model thus contributes to a maturing discipline that tackles current organizational and societal issues that occur in highly dynamic and volatile environments.

We conceptualize the CI cycle as the driving axle of the other three cycles and, thus, the entire DSR process. We posit that most DSR projects start due to changes in the wider environment that lead to a particular (class of) trigger(s) that, in turn, create(s) the need for a novel artifact to address a particular (class of) issue(s).

Based on the initial model proposed in this paper, we see several avenues for further research. First, research is needed to more systematically review and comprehensively integrate extant research that incorporates 'soft', organizational, or socio-technical aspects in design. Moreover, we see potential in expanding the notion of traction and friction between the cycles by likewise reviewing and integrating extant research that covers how to bridge the interfaces between any two cycles – for instance, how to deal with inherent artifact complexity and volatility. Such research furthers our overall goals of equipping design researchers for future ambitious and impactful IS DSR projects to cope with grander scopes and dynamic contexts within and outside the projects.

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