Markus Helfert
Brian Donnellan (Eds.)

Communications in Computer and Information Science 286

Practical Aspects of Design Science

European Design Science Symposium, EDSS 2011
Leixlip, Ireland, October 2011
Revised Selected Papers

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Volume Editors

Markus Helfert
Dublin City University
School of Computing
Dublin, Ireland
E-mail: markus.helfert@computing.dcu.ie

Brian Donnellan
National University of Ireland
Maynooth Innovation Value Institute School of Business
Maynooth, Ireland
E-mail: brian.donnellan@nuim.ie

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Preface

This book contains papers presented at the European Design Science Symposium 2011, held in conjunction with the Intel European Research and Innovation Conference (ERIC) 2011.

The purpose of the symposium is to bring together researchers and practitioners interested in practical aspects of design science. Design science creates and evaluates IT artifacts intended to solve identified organizational problems. Such artifacts are represented in a structured form that may vary from software, formal logic, and rigorous mathematics to informal natural language descriptions. Design science research (DSR) has become an accepted approach for research in the information systems (IS) discipline with a dramatic growth in recent, related literature. In particular, DSR holds promise as a paradigm that can establish the relevance of academic IS research for IS practice. The rich phenomena that emerge from the interaction of people, organizations, and technology need to be qualitatively assessed to yield an understanding of the phenomena adequate for theory development or problem solving.

Topics that were discussed during the event included:

- What makes projects different when using a design science approach?
- What are typical design science projects and results?
- What are the challenges and principles in a design science project?
- How can design science projects be evaluated?
- What are the advantages and limitations of following a design science approach?
- How can practitioners benefit from and participate in a design science approach?
- What is the demand for design science projects?

The European Design Science Symposium was organized in conjunction with the Innovation Value Institute, Ireland (www.ivi.ie) and the Business Informatics Group at Dublin City University (http://big.computing.dcu.ie/).

We wish to extend our appreciation to our distinguished speakers and contributors. We hope you will find the papers in this book interesting and valuable and we hope they represent a helpful reference in the future for all those who need to address the challenges related to design science mentioned above.

May 2012

Markus Helfert
Brian Donnellan

Organization

European Design Science Symposium 2011 was presented by Intel Labs Europe in association with the Innovation Value Institute and the Business Informatics Group at Dublin City University.

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Jonas Sjostrom	Uppsala University, Sweden
Jan Verelst	University of Antwerp, Belgium

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The Emergence and Initial Development of a New Design Pattern for CIOs Using Design Science

Martin Curley

Intel, Leixlip, Ireland
National University of Ireland, Maynooth
`Martin.G.Curley@Intel.com`

Abstract. This paper describes the design science process and iterative design cycles used to develop a new design pattern for Chief Information Officers (CIOs). The IT-CMF is a formal archetype of the levels and stages through which an organization traverses and evolves as it defines, implements, measures, controls and improves its IT capability in support of value creation for the organization. The paper draws upon the concept of emergence from complexity science to describe the process of emergence of the IT-CMF from seemingly unordered pieces of information and artifacts into order. The early iterative phases of rigor, relevance and design science cycles are discussed as well as the initial classification schema developed for the IT-CMF. Additionally the paper briefly discusses the role of the IT-CMF as an important design pattern for the CIO.

Keywords: Design Science Methodology, Artifacts, Complexity Science, IT Business Value, IT Capability Maturity Framework, Design Patterns.

1 Introduction

Most of the information systems research that has been carried out over the last few decades has been performed primarily from a behavioral science perspective. However there is increasing awareness of the importance of design science (Hevner and Chatterjee, 2010, Vaishnavi and Kuechler, 2008). Design Science has high potential to help fix the gap between scholarly research and practice identified by Sambamurthy and Zmud (2001). This paper describes the emergence and evolution of a new set of Design Patterns and artifacts for CIOs which developed from an attempt to transform Intel's IT organization (Curley, 2004, 2006). The approach used to drive the Intel IT transformation subsequently has been evolved into a design pattern, which has been further developed using a design science research approach coupled with an engaged scholarship (Van de Ven, 2007) and open innovation process at the Innovation Value Institute[i]. Three primary phases of design science have been executed over a decade to create a usable and useful set of integrated artifacts which has now over two hundred instances of successful adoption by global organizations.

The process of emergence is a process of coming into being, or can be thought of as the revealing of something that was previously not visible. The transition points

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between each phase correspond to micro-singularities. Singularities (Martinez, 2009) in complexity science refer to "critical points, transition points or phase transitions, when a disordered state reaches a threshold and undergoes a transformation process of self organization when previously disconnected elements or agents being able to interact in concert in an ordered pattern" (Martinez, 2009). This paper primarily focuses on the first two phases. In the context of this paper, these micro singularities refer to the creative leaps made to enable the creation of structured artifacts out of a network of information elements.

Design science research can be considered as a type of Mode 2 - knowledge creation (Gibbons et al, 1994) - where knowledge is co-created in an area which is interdisciplinary, problem focussed and context sensitive. This is typically knowledge generated by practitioners dealing with real problems in a real context, as distinct from knowledge which is generated from traditional research (called mode 1) - which is academic and based within a particular discipline (Gibbons et al, 1994). In developments in other social science fields such as management research the relevance problem has been highlighted (Van Aken 2005, Galavan et al, 2008). Van Aken (2005) proposed increasing the use of mode 2 knowledge production in management research to increase the relevance and utility of the research. Additionally, Van Aken (2005) advocated a focus on output which is field tested and grounded. The execution of the design science process used to create the IT-CMF has used an engaged scholarship approach, predominately leveraging practitioners while cognizant of an academic focus also.

2 About the IT-CMF

Organizations and their Chief Information Officers (CIOs) face significant challenges in meeting increasing demand for IT services in the face of numerous challenges such as cost pressures, complexity, demand for innovation, and increasingly the requirement to demonstrate value from IT investments. Research shows that CIOs struggle to capture and state the return from their IT investments (Alter, 2003, 2006) and that there is no all encompassing IT improvement framework (Curley, 2008; Rozemeijer, 2008) which is value focused and comprehensive across the full spectrum of IT capability activity. Using a hybrid research approach involving a design science research methodology supplemented with an initial case study, an integrated artifact called the IT Capability Maturity Framework (IT-CMF) has been researched and developed and received preliminary validation.

The IT-CMF is an archetype of the levels and maturity stages an IT capability goes through as it defines, develops, controls, measures and improves its IT capability in support of value creation for the organization. The IT-CMF is thus a design pattern which CIOs can use as a generally reusable solution in the context of their own IT capability and business environment. The IT-CMF leverages the maturity model approach adopted by the Software Engineering Institute in developing the Software CMM model (Humphreys, 1988; Paulk, 1993), but as well as focusing on process maturity also focuses on outcome maturity, i.e. what are the specific business outcomes expected at different levels of capability maturity.

The IT-CMF also leverages the concept of dynamic capabilities (Teece et al, 1994), providing a mechanism for not only developing capability but enabling reconfiguration to dynamically adapt to changing circumstances and strategy. The IT-CMF and its associated assessment instruments can act as an integrated improvement roadmap, assessment tool and improvement system for CIOs as they strive to improve IT capability in pursuit of enhancing value creation from IT.

3 The Design Science Research Approach

The primary approach followed in researching, developing and validating the IT-CMF was a design science research approach (Hevner et al, 2004; Vaishnavi and Kuechler, 2007). Design Science Research (DSR) "creates and evaluates IT artifacts intended to solve organizational problems" (Hevner et al, 2004, P77). Previous research (Curley, 2004, Curley, 2007) have identified the absence and need for an integrative CIO level frameworks, while others (Rozemeijer, 2007) have identified that although there are a 'a forest of frameworks' there are issues associated with this inventory of frameworks e.g. issues such as lack of cross process area integration. Additionally as mentioned, Sambamurthy and Zmud (2001) noted that there was gap between scholarly research and practitioners needs. The increasing pace of technology development driven by Moore's law and postulated by Kurzweil's law means there is a need for a living body of IT Management knowledge to keep pace with technological developments.

In the DSR approach for IT-CMF, an iterative step-by-step process in which artifacts and theory were generated and verified, was used with both an inductive and a deductive process in play. The primary research outputs from design science research are artifacts. The research process followed the general design cycle (GDC) adapted for design science research (Vaishnavi and Kuechler, 2007) and included the following phases; Awareness of the problem, Suggestion, Development, Evaluation and Conclusion.

4 Design Science Research Cycles

The research and development of the IT-CMF involved three parallel research cycles; Relevance, Design and Rigor Cycles (Hevner and Chatterjee, 2010) as shown in figure 1 below. The interlinking of these three primary design cycles are crucial and were often executed in parallel with multiple iterations.

The original relevance sprung from the desire to transform Intel IT in 1999, where a group was chartered with leading a team of Intel IT employees to build a transformation business plan for Intel IT (Curley, 2006). The output of that successful transformation became a nascent design pattern which was subsequently evolved and tested in the second research cycle as part of doctoral research with multiple IT executives surveyed through an executive workshop format. The output of this second phase of research served as the key input for a third phase of research in which the integrated artifacts of the IT-CMF were further evolved, refined and tested, using an open innovation consortium at the Innovation Value Institute (IVI) to develop version

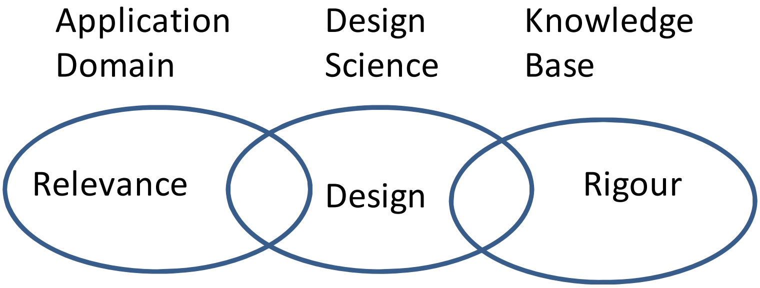


Fig. 1. Design Science Research Cycles; Adapted from Hevner and Chatterjee, 2010

1 of the IT-CMF (Curley and Kenneally, 2010). Overall the motivation of the research was to develop an integrated set of artifacts to help CIOs improve their IT capability and the value achieved from same. The three significant phases of creation/testing of artifacts which included relevance cycles, design cycles and rigor cycles are described briefly in the table 1 below.

Table 1. Phases of Design Science Research

Phase		**Relevance**	**Design Cycle**	**Rigor Cycle**	**References**
	Goal	Focus/Scope	Focus/Scope	Focus/Scope	
1	Develop solution to help Intel IT transform itself	Develop a transformation plan to transform Intel IT	Development of nascent design pattern and artifacts	Leverage known best practice frameworks and prominent academic research articles	Curley (2004), Curley (2006)
2	Share knowledge with Intel customers and develop more rigorous design to create robust integrated artifacts	Develop a set of artifacts which could potentially serve as a design pattern for CIOs	Development of core design pattern and artifacts	Extensive literature survey, best practice framework comparison and pragmatic validation with CIOs	Curley (2007), Curley (2008)

Table 1. *(Continued)*

3	Build community and ecosystem to develop a potential standard to drive change in ways organizations get value from IT	Test relevance with a broad set of CIOs.	Refinement of core design pattern and development of sub-artifacts	Built extensive knowledge base database. Continued pragmatic validation with CIOs	Curley and Kenneally (2009, 2010)

The micro-singularity that occurred between phase 1 and phase 2 was the adoption of maturity level thinking and dynamic capability thinking to organize and structure information elements. The micro-singularity that arose between phase 2 and phase 3 was the adoption of a meta-model and integrated taxonomy to enable a community to put the power of its collective intelligence and energy into deepening and extending the integrated frameworks.

In the following sections I briefly describe the three parallel research cycles.

Relevance Cycle

The relevance cycle was driven by a critical need for a framework to help CIOs coherently improve capability and value contribution from IT. The original relevance sprung from the desire to transform Intel IT in 1999 where a team of Intel IT employees had to build a transformation business plan for Intel IT (Curley, 2006). The output of that successful transformation became a nascent design pattern which was subsequently evolved and tested in the second research cycle (Curley, 2008) with multiple IT executives in multiple locations through an executive workshop format. In the third research phase - as part of the integrated research process, the integrated artifacts of the IT-CMF were first developed by more than fifty collaborating IT executives and then had pragmatic validation with over two hundred adopting organizations. A formal assessment and evaluation process was used for this pragmatic validation.

Rigor Cycle

At each phase of the Rigor research cycle, the research drew more heavily from existing academic literature and available fact base while subsequently creating and adding more knowledge to the fact base. In phase 1, where the development of the nascent design pattern the IT-CMF began, several important academic papers (Ross, 1996, Paulk 1993) informed the development of the transformation plan of Intel IT, which ultimately resulted in both a successful transformation and a nascent design pattern. Subsequent research by the author as part of his doctoral research (Curley, 2007, Curley, 2008) involved researching and referencing the available knowledge base to validate research contributions, while simultaneously deriving the artifacts from existing academic models on process theory. The development of a classification schema capturing the key components and structure of the evolving IT-CMF was a key early research deliverable which evolved to become the formal taxonomy of the IT-CMF.

As the research expanded to phase three involving more than 100 researchers/executives through the Innovation Value institute, a key integrated part of the design science process was to interrogate the fact-base, evolve/build upon it, and then add back to the fact base. A structured Wiki was used as the formal knowledge base with information and artifacts stored according to the defined taxonomy of the IT-CMF. The design science research cycle is discussed in more detail below. With each subsequent research phase the rigor associated with the process increased with multiple IT executives contributing their knowledge to different capability areas using a pre-defined IT-CMF classification schema/blueprint to enable information and knowledge to be codified and presented in a uniform fashion.

Design Research Cycle

The Takeda (1990) design cycle underpinned the general design cycle research approach that was used to research and develop the IT-CMF. Figure 2 below explains the reasoning in the design cycle as outlined by Takeda (1990).

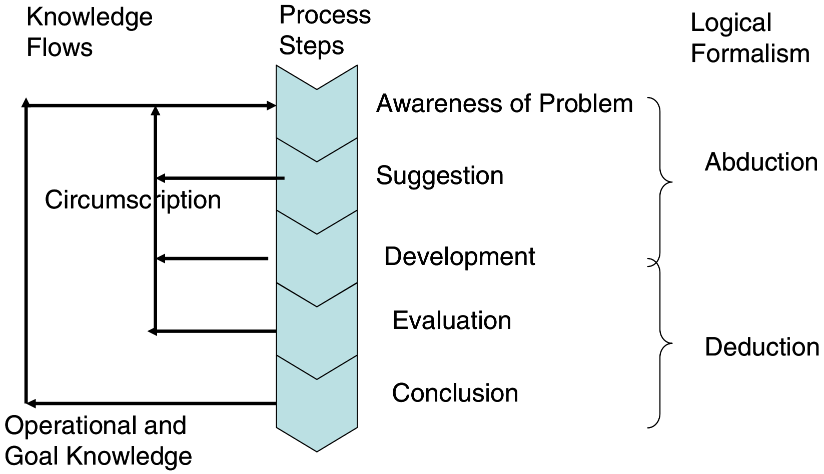


Fig. 2. Reasoning in the Design Cycle (Takeda, 2009)

In the Takeda (1990) design cycle, design begins with *Awareness* of a problem and in this context, design research is sometimes called improvement research - emphasizing the solution development nature of the research activity (Vaishnavi et al, 2004). The next step is to develop *Suggestion(s)* for the solution through abductively drawing from the existing theory and knowledge base (Pierce, 1931). These suggestions are then synthesised into a draft of the solution artifact and this is categorized as *Development* in the Takeda (1990) design cycle. The next phase is the *Evaluation* phase which is deductive. The *Suggestion*, *Development* and *Evaluation* phases are cycled through a number of times as depicted by the arrow flows marked *Circumscription* until as a satisfactory artifact is produced. This process yields both new knowledge and an artifact which is useful to practitioners.

This part of the research process also leveraged an alternating inductive and deductive theory building approach, advocated for management theory development by Carlile and Christensen (2005). Carlile and Christensen argue that the theory building process iterates through inductive and deductive phases again and again, to define theory as a body of understanding that researchers build cumulatively as they work through each phase. This alternating process is shown in figure 3 below.

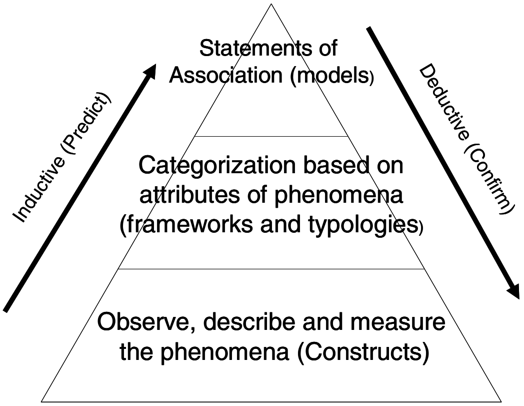


Fig. 3. Alternating Inductive and Deductive Cycles

This alternating inductive and deductive theory building approach manifested itself as a four stage near-simultaneous process which was recursively cycled through to learn, test and improve the theory quickly. The manifestation of the design science research process used in phase two (outlined previously in Table 1) is shown in the Figure 4 below, with a four stage research cycle**.**

In the early stages of this research, a case study approach was followed where the exploration and analysis of related observations at Intel IT (Curley, 2006) led to the development of an initial theoretical framework. An extensive review of the existing academic and practitioner research helped continuously improve and further validate the theoretical framework, with suggestions from academic literature and best-practices frameworks. Subsequently, the enhanced framework was then shared with executives in a workshop format for validation and capturing of practitioner insight

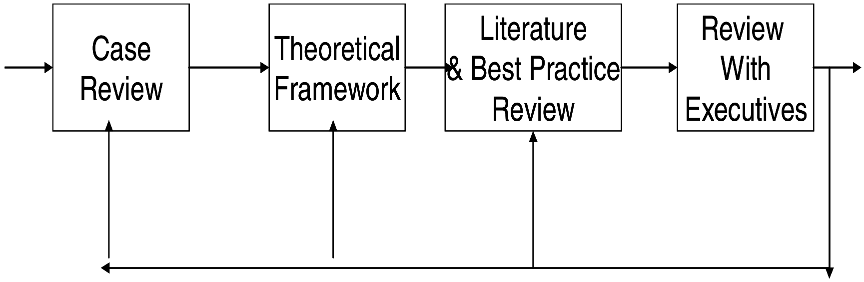


Fig. 4. Recursive DSR Process

and relevance. Findings and observations at each phase were fed-back and fed-forward to ensure continuous improvement of the framework. This parallel exploration of both academic literature, best-practice frameworks and industry insights produced a rich collection of knowledge to be leveraged to improve the framework. Based on each phases' learnings, the cycle would be repeated until a validated framework was generated.

5 Early Design Science Research Outputs

A key early research deliverable was to develop the IT-CMF classification schema and this is shown in the following figure 7. This was a key *construct* which created a conceptual vocabulary for the research. It primarily features macro processes, critical processes and associated Practices, Metrics and Outcomes which are *methods* or a record for "how-to" knowledge.

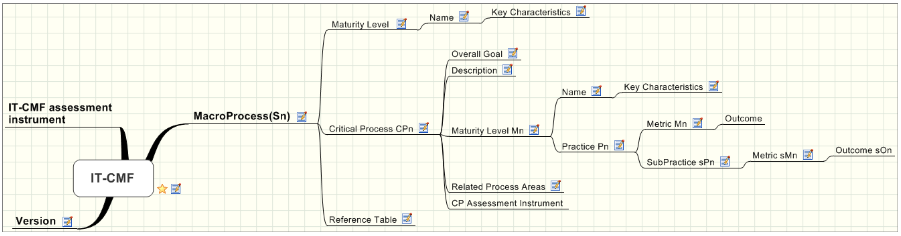


Fig. 5. IT-CMF Classification Schema

This nested set of elements together constituted the classification schema of the version of the IT-CMF which was developed in phase 2 of the research phases. For example, collections of practices, outcomes and metrics lead to the achievement of key characteristics which define a particular maturity level. The collective contribution of multiple critical processes creates a broader macro-process capability. All of this takes place in the context of IT capability being a supporter and enabler of business strategy and operations for an organization as shown in the following figure 6.

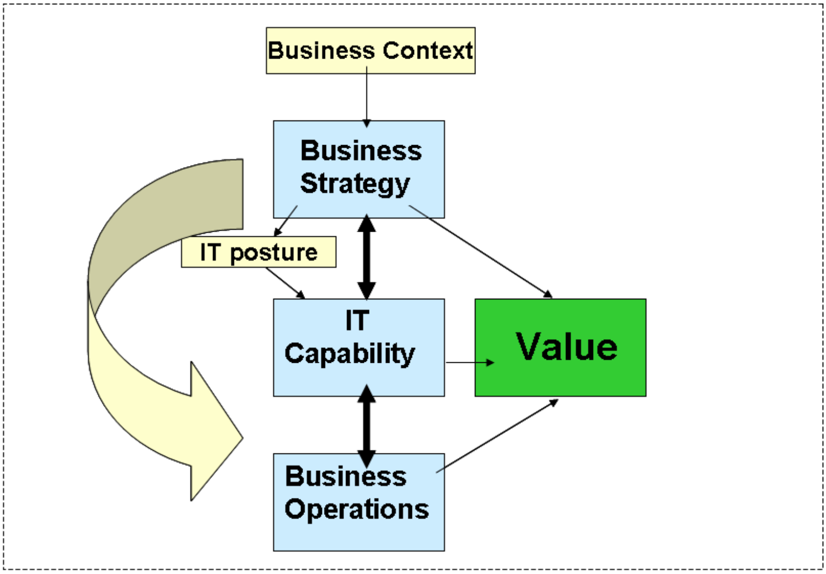


Fig. 6. IT-CMF Context Diagram

One of the most important artifacts generated in the second phase of the design science research cycle was the overall definition and mapping macro and critical processes. This is shown in the following figure and served as a key input to phase three of the research process, where broader stakeholder input was solicited through the Innovation Value Institute.

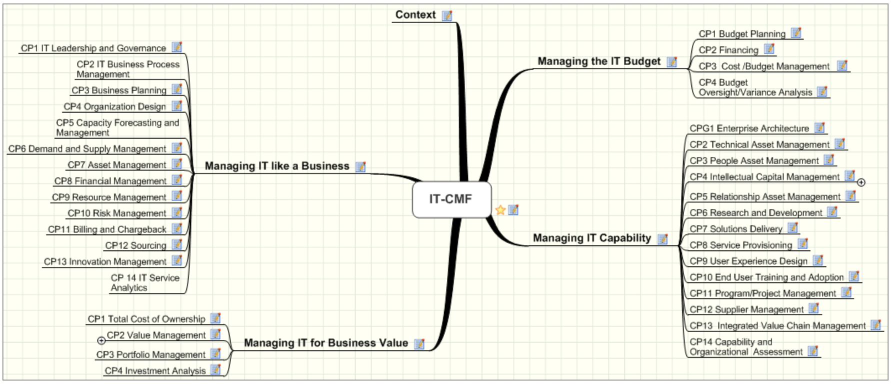


Fig. 7. IT-CMF mapping of Macro and Critical Processes

Using dynamic capabilities lens, the input and output macro-processes contain four critical processes while the capability and controlling macro processes contained fourteen critical processes each. As with all good design science research this artifact was subsequently iterated with the outcome being to reduce the number of critical processes from thirty six to thirty three during phase three of the research process.

Design Patterns and the IT-CMF

As well as the above classification schema and mapping, the method of design patterns was leveraged to produce further insight and add to the body of understanding. A core objective of earlier research work (Curley 2004, 2006, 2007) and the subsequent research of the IVI is to create, iterate and define a general design pattern that CIOs can use to systematically improve IT capability and value in the context of their own IT organization, and the business objectives/challenges they own and face - within their ongoing business context. In June 2010 version 1 of the IT-CMF was released.

A design pattern is a construct which exists in software engineering (Gamma et al, 1994) and can be leveraged in the design science research approach to build an integrative framework. A design pattern is a general reusable solution to a commonly occurring problem (Vaishnavi and Kuechler, 2004) and it is often manifested as a description or template for how to solve a problem that can be used in many different situations. Vaishnavi and Kuechler (2004)[35] specifically define patterns as a solution to a problem in a recurring context and as a general technique for analyzing a class of problems that are abstractly similar. Appleton (2000; P3) defines a pattern as "a named nugget of instructive information that captures the essential structure and insight of a successful family of proven solutions to a recurring problem that arises within a certain context and system of forces".

Also, Vaishnavi and Kuechler (2004) describe patterns as similar to, but shorter and more structured than the case studies using in business school classes, which communicate similarly complex and subtle information. A more concise definition of a pattern is provided by Appleton (2000: P3) as "a pattern is a named nugget of insight that conveys the essence of a proven solution to a recurring problem within a certain context amidst competing concerns".

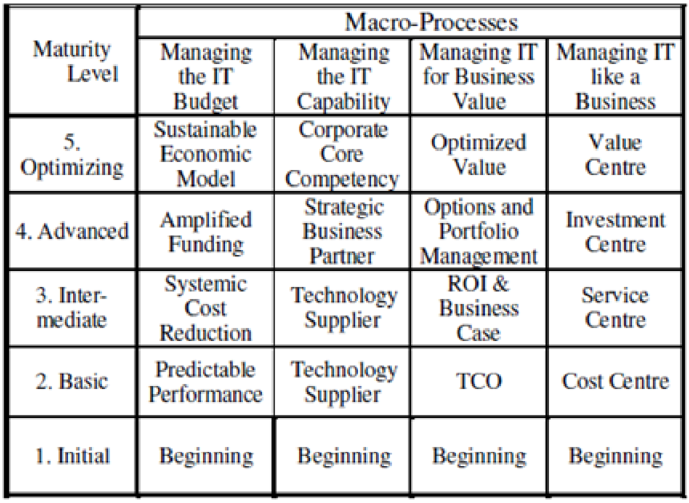
Patterns were introduced as a design concept by Alexander (1977), and the Gamma et al (1994) book on design patterns as applied to object oriented programming began to popularize the use of patterns in Computer Science. Another application of design patterns in the field of information systems was the work of Fowler (2002) in the domain of enterprise application architecture. Leveraging how design patterns are used in Software engineering, (Appleton, 2000), the goal of design patterns in Enterprise IT should be to create a body of knowledge to help IT executives solve recurring problems or seize recurring opportunities encountered in IT management. Design Patterns create a shared language and vocabulary for communicating insight and experience about recurring problems and their solutions (Appleton, 2000). Codifying the linked solutions and capturing their relationships enables the capture of a useful and re-applicable body of knowledge. (Appleton, 2000).

Design Patterns were applied to enterprise IT management in the original version of the IT-CMF (Curley, 2007). In the context of creating an integrative framework, the primary design pattern that we have created is the IT Capability Maturity Framework (IT-CMF). IT Capability can be defined as the capacity of an IT organization to complete specified repeatable actions to deliver outcomes in a defined range of complexity, context and purpose (adapted from ECSA, 2003). The spanning definition we use for IT capability is simply what IT can do for the business (Curley, 2004).

The IT-CMF as a Design Pattern

The IT-CMF consists of a set integrated design patterns manifested as artifacts (Curley, 2007; Curley and Kenneally, 2009, 2010) organized by its four macro processes: Managing IT like a Business, Managing the IT budget, Managing IT Capability and Managing IT for Business Value.

Table 2. IT-CMF Artifact



Maturity Level	Macro-Processes			
	Managing the IT Budget	Managing the IT Capability	Managing IT for Business Value	Managing IT like a Business
5. Optimizing	Sustainable Economic Model	Corporate Core Competency	Optimized Value	Value Centre
4. Advanced	Amplified Funding	Strategic Business Partner	Options and Portfolio Management	Investment Centre
3. Inter-mediate	Systemic Cost Reduction	Technology Supplier	ROI & Business Case	Service Centre
2. Basic	Predictable Performance	Technology Supplier	TCO	Cost Centre
1. Initial	Beginning	Beginning	Beginning	Beginning

Table 2 above shows one example of a key artifact produced and tested during the IT-CMF design science research process. This table which shows the four macro-processes and high level maturity paths for each process and is perhaps a good illustration of what Vaishnavi and Kuechler (2004) describe patterns as similar to, but shorter and more structured than the case studies using in business school classes which communicate similarly complex and subtle information. This artifact can be used to discuss the current and future state of IT capability in an organization and also the richness of the artifact can be enhanced by giving examples of organizations which have achieved different states of maturity. This artifact which is described more fully by Curley (2007), which communicates a potential roadmap for capability and value improvement in an organization - supported by an associated assessment artifact can be used as a closed loop improvement system for IT capability.

6 Concluding Remarks and Further Research

This paper has introduced the three phase design science process used to research and develop the initial version of the IT-CMF. It has briefly described the emergence of the IT-CMF and the iteration of linking rigor, design science and relevance cycles to create a set of integrated artifacts which can serve as a new design pattern for CIOs. Pragmatic validation of the artifacts as an integrated part of the research process has shown early value and a high early adoption rate is potentially a good measure of pragmatic validation of the artifacts developed. Additionally, Donnellan and Helfert (2010) identify the IT-CMF as a practical example of Design Science, whilst Costello (2010) argues that the IT-CMF measures up well as a candidate for a new IT Management standard.

It is hoped that ongoing development and deployment of the artifacts will contribute to further improvement of the artifacts and ultimately both pragmatic and empirical validation of the utility and value of the artifacts. Ultimately deployment and adoption of the IT-CMF could lead to a structural improvement in how organizations achieve value from IT. This is the goal of the Innovation Value Institute's ongoing research efforts.

Acknowledgement. The author would like to thank everyone who contributed to the ongoing development of the IT-CMF.

Note that as with all good Design Science Research the classification schema artifact was subsequently iterated and improved to include for example capability building blocks to group like sets of PMOs. Additionally the terms Macro Process and Critical Process were changed through the change review process to Macro Capability and Critical Capability respectively.

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Extending a Systems Analysis Method for Business Professionals

Duane Truex[1,3], Nathan Lakew[1], Steven Alter[2], and Sumantra Sarkar[3]

[1] Mid-Sweden University, Sundsvall, SE
{duane.truex,nathan.lakew@miun.se}
[2] University of San Francisco, San Francisco, USA
alter@usfca.edu
[3] Georgia State University, CIS dept.
{dtruex@gsu.edu,ssarkar3@student.gsu.edu}

Abstract. Despite having been explored, described, theorized, and measured in hundreds of IS research articles, frequent difficulties related to user participation and business/IT communication persist in relation to project management, specification of requirements, implementation in organizations, business/IT alignment, and IS failures. We report on an extension of a long term design science research project that previously demonstrated a possible path toward addressing these longstanding problems by empowering business professionals to analyze systems in business terms rather than in formalisms for IT specialists. Previous research demonstrated that most of 75 working business professionals with extensive business experience were able to use the then current iteration of a work system analysis template to analyze IT-reliant work systems in their own organizations, and to recommend improvements. The current research extends the previous efforts by evaluating natural field studies by managers taking coursework for advanced degrees in MBA and MSIS. We analyze 84 examples collected over 7 consecutive academic terms to evaluate the success of several successive versions of the design artifact, concluding that business and IS professionals are able to use the design artifact effectively and that a revised template generated better results.

Keywords: work system, work system method (WSM), design science.

1 Introduction

We use a design science research approach to extend results to date of a long-term research effort to develop the work system method (WSM) and related concepts and frameworks, an effort that will be summarized later. The original research was motivated by dissatisfaction with the seemingly common practice of putting IT at the forefront in systems analysis by emphasizing the creation of computerized artifacts by IT professionals. Creating requirements for computerized artifacts in that way may overlook problems and opportunities related to the work systems that use those artifacts. An approach that is more likely to engage business professionals emphasizes shortcomings of a current, “as is” work system and reasons why it needs improvement. The resulting

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recommendation starts with the “to be” work system, and involves much more than just improving technology that the work system uses. Our research on the development, testing, use, and refinement of WSM follows "the fundamental principle" of design science research, that "knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact" [1].

Organization of This Paper. We start by summarizing previous progress in developing the work system method. Next we use guidelines from [2] to explain how both the entire research effort and the current extension fit into the design science research paradigm. The current research shows improvement in the ability of the design artifact to support systems analysis by business and IT professionals. A qualitative analysis of a large sample from 301 natural field studies by users of WSM and written feedback from users of WSM confirms the utility of the overall approach and provide direction for future extensions.

2 Progress to Date

Over more than 15 years, Alter worked on developing a systems analysis method that can be used by business professionals for their own understanding of systems in their organizations and can support communication between business and IT professionals. (Alter [3] provides a lengthy set of references - starting in 1995 - that could not be included here due to length limitations). That research anticipated tenets of design science research that were articulated in *MISQ* by Hevner et al [2], such as relevance, testing, evaluation, and iterative improvement. The research produced a body of theory that included theories for analysis, evaluation, prediction, and design [4].

Some of the products of the research to date are summarized next. Developments specifically related to WSM are impossible to disentangle from developments involving work system concepts and related frameworks because all of these ideas were developed over time in relation to the same purpose.

Definition of Work System. In WSM the unit of analysis is a work system, a sociotechnical system (by default) in which human participants and/or machines perform work (processes and activities) using information, technology, and other resources to produce specific products and/or services for specific internal or external customers. Almost all value chain systems (e.g., systems for inbound logistics, operations, sales and marketing) and support systems (e.g. systems for procurement and human resources) are IT-reliant work systems. Information systems, supply chains, and ecommerce systems are special cases of work systems.

Work System Framework. WSM is based on two central frameworks. The nine elements of the work system framework (Figure 1) are the basis for describing and analyzing an IT-reliant work system in an organization. The framework outlines a static view of a work system’s form and function at a point in time and is designed to emphasize business rather than IT concerns. It covers situations that might or might not have a tightly defined business process and might or might not be IT-intensive. Figure 1 says that work systems exist to produce products and services for customers. The arrows say that the elements of a work system should be in alignment.

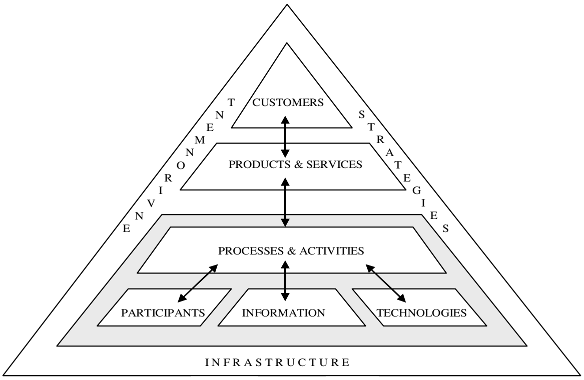

Fig. 1. Work system framework

The other central framework (not pictured due to length limitations) is the work system life cycle model (WSLC), which expresses a dynamic view of how work systems change over time through iterations involving planned and unplanned change. The WSLC represents planned change as projects that include initiation, development, and implementation phases. Development involves creation or acquisition of resources required for implementation of desired changes in the organization. Unplanned changes are ongoing adaptations, experimentation, and workarounds that change aspects of the current work system or of ongoing work system projects without separate allocation of significant project resources. WSM is designed to be used during the initiation phase, although the concepts and frameworks developed during WSM research can be used in any phase.

Work System Method. WSM is a flexible systems analysis method that starts by identifying the work system that is to be created or improved. WSM uses tools such as a "work system snapshot" to summarize the "as is" work system and the "to be" work system that will exist after any proposed changes are implemented. The natural field studies analyzed in the current research used successive versions of a work system analysis template that guided a simplified analysis process and also provided an outline of a management report. These templates were designed for use in time-limited projects in advanced MBA and MSIS coursework. Many aspects of the knowledge developed through WSM research to date were not represented explicitly in those templates because of the limited amount of time that was available both for teaching and for application. Both templates support the following sequence of activities:

- Define the system as the smallest work system that exhibits the problems, issues, or opportunities that led to the need to perform an analysis.
- Describe and evaluate the "as is" work system in whatever level of depth, and with whatever level of rigor is appropriate for the user's purposes.
- Identify additional problems, issues, and opportunities with the "as is" work system by looking at each part of the work system more closely.

- Select among possibilities for improving the "as is" work system and propose a "to be" work system.
- Justify the proposal based on the likely impact of the proposed changes.

WSM applies general problem solving to a work system rather than just an IT application. WSM is designed to be quite flexible and is usable for different purposes and at different levels of detail. . An executive can use WSM at a highly summarized level to think about whether a system-related investment proposal is actually about improving a work system (rather than just acquiring software), and whether the comparison of the "as is" and "to be" work systems convincingly implies that business performance will improve. Implementers, change agents, and work system participants can use aspects of WSM to think about how the "as is" work system operates, how well it operates, and how and why possible changes might generate better results. IT professionals can use WSM in the same type of thought process for understanding system-related situations from a business viewpoint and for communicating with business professionals more effectively.

Other Developments Related to WSM. The effort to develop WSM and related concepts and frameworks led to other concepts and frameworks that are beyond this paper's scope. Those developments include, among others: work system principles, work system design spaces, a meta-model underlying the work system framework, links between the work system framework and a service-oriented view of a work system, a theory of system interactions based on work system concepts, and a theory of workarounds based on work system concepts. (See references in Alter [3].)

3 The Current Research

The initial ideas in WSM were an attempt to distill, combine, and simplify industry experience plus ideas from many sources including the general systems, sociotechnical, and system development literature. Over many years, MBA and Executive MBA students at the University of San Francisco used successive versions of a work system analysis template to write group papers analyzing IT-reliant work systems in their own organizations. The papers from each semester revealed confusions, knowledge gaps, and other problems that led to revisions in the work system analysis outlines for subsequent semesters. For example, Alter [5] identifies pitfalls observed in 202 group papers between 1997 and 2002 and approaches that were attempted for minimizing those pitfalls. Other sources of improvements included examples in newspapers and the popular business press that illustrated omissions or confusions in a then-current version of WSM, and research journal articles that identified issues or topics not yet included within WSM.

The current research is based on a review and analysis of a sample of 84 out of 316 natural field studies produced by advanced MBA students at Georgia State University between 2009 and 2011. As reported in Truex et al. [6], which analyzed the first 75 of the 301 field studies, the deliverable was a five part management report (executive summary, background, system and problem, analysis, recommendation and justification) written based on a work system analysis template that included tables for summarizing the "as is" work system, assessing how well it operates and where problems exist, summarizing a proposed "to be" work system, and clarifying why proposed changes probably would improve performance.

The current research extends previous research. Analysis of the first 75 field studies identified a number of shortcomings that an improved work system analysis template might minimize or eliminate. We will call the template for the initial 75 field studies "Template #1," and will call the improved version "Template #2." We will use the 7 guidelines from Hevner et al. [7] to explain our efforts in the context of design science research methods and design science theory.

Guideline 1: Design as an Artifact. Hevner et al. [7] notes that IT artifacts may be constructs, models, methods, and instantiations. WSM's development to date includes artifacts of each of those types. Publications related to WSM have presented many constructs and models, have explained WSM as a method, and have described the use of specific work system analysis templates (e.g., Truex et al. [6]).

==> The current research evaluates the use of Templates #1 and #2.

Guideline 2: Problem Relevance. The lack of effective analysis methods that can be embraced fully by business professionals contributes significantly to the widely discussed user participation problem (e.g., Markus and Mao [8] ; Alter [9]). There is a growing literature about limitations of systems analysis tools for IT professionals (e.g., Dobing and Parsons [10], [11], Siau et al. [12]). The relatively rare ability of some IT analysts to engage with business professionals while using these tools in no way implies that existing methods and tools for IT professionals fully address difficulties in collaboration between most business and IT professionals. Business professionals often are at a disadvantage when IT professionals use their own methods and tools to frame the conversation, the problem, and the solution [13]. To participate on an equal footing, business professionals should have methods and tools that they can use for thinking about IT-reliant systems with or without the help of IT specialists.

==> The entire WSM research effort addresses important practical issues related to the development and use of information systems.

Guideline 3: Design Evaluation. Alter [5] identified common pitfalls in using early versions of work system analysis guidelines that were available before 2006. Truex et al. [6] evaluated the usefulness of a more recent work system analysis template and concluded that business professionals could use it successfully.

==> Iterative evaluation has been a factor in the entire WSM research program since its inception. The current research extends the previous research by using a substantially larger dataset than that used by Truex et al. [6] and by introducing Template #2 that was developed in response to results reported in Truex et al. [6].

Guideline 4: Research Contributions. Research to date in developing WSM has generated publications related to topics including the work system framework (Figure 1), work system life cycle model, work system method, work system principles, work system design spaces, and a meta-model underlying the work system framework. In addition to creating and testing specific tools, this research produced publications related to a range of concepts, theories, and frameworks. (See Alter [14]).

==> The current research produces research contributions related to creation and evaluation of a new version of the work system analysis template (Template #2).

Guideline 5: Research Rigor. The research process to date has been based on a cycle of assessing recent use of a work system analysis guidelines or templates, looking for gaps in the ideas or in the use of the ideas, seeking retrospective user comments on how WSM fit and felt, creating or improving concepts and frameworks, revising the previous guidelines or templates accordingly, and, coming full circle, testing those improvements formally or informally.

==> The current research improves the informal evaluation methods that were used previously in the development of WSM. The current research applies improved versions of the underlying work system theory and uses established means of qualitative coding, tagging, and analysis of the field studies that used Templates #1 and #2.

Guideline 6: Design as a Search Process. A variety of work system analysis guidelines and templates evolved over time through cycles that combined theorizing with a trial and error approach for developing and testing artifacts. Iterative search logic was appropriate because the initial theory and other available theories were too abstract and/or vague to support any other approach.

==> The current research continues to use a search process. Given progress to date, the search is more informed by theory than some of the initial research.

Guideline 7: Communication of Research. The development and use of WSM has been documented in over 20 papers since 1995. The many references in Alter [15] communicated a large number of results related to concepts, frameworks, analysis techniques, and various versions of WSM.

==> Additional, more extensive publications are planned.

4 Research Method and Examples of Evaluation and Iterative Redevelopment of WSM

Section 4 summarizes three ways in which we analyzed the data and demonstrates the progress in the evolution of the design artifact. First, we identify shortcomings that were addressed in improving the artifact. In section 4.2 we present the descriptive statistical results including the consistency and distributions of the data. In section 4.3, we provide examples of the reflexive qualitative data in our sample set.

4.1 Issues Revealed Using Template #1

Template #1 was used during the Summer and Fall of 2009. Based on shortcomings that were observed, we created template #2 and used it for the rest of the field studies in our sample. Template #2 and the related explanations addressed the following problems that Truex et al. [6] reported in relation to use of Template #1:

Difficulties Naming the Work System. Neal Postman (1988) said: “So in naming meaning begins.” Although Template #1 required a name for the work system nearly half of the papers did not name the work system or named it in an overly general manner that was not as informative as it could have been. (e.g., “financial accounting system” instead of “generating month ends financial statements”). Clarifications in instructions for using Template #2 included a list of typical work system names.

Confusion about the Definition of Concepts. WSM uses terms such as a customer, products and services, and processes and activities in particular ways. Better explanations of these concepts addressed a series of issues such as the distinction between a work system's customers and stakeholders such as managers and executives who care about outcomes do not receive products and services that the work system produces.

Lack of Clarity about the Desired Use a Tool Called a Service Responsibility Table. Template #1 contained a blank service responsibility table [9], which was to be used to identify customer responsibilities related to each step in the processes and activities. More than half of the initial reports reflected confusions in using this tool. Concluding that its initial form was inadequate, we eliminated it from Template #2 to focus more attention on work system performance.

Non-Attention to Column Headings. In a number of papers, entries in the cells in certain tables seemed to ignore column headings and simply used the tabular format to identify problems, issues, and recommendations, many of which made sense when read without considering the column headings. Instructions for using Template #2 were clearer about the meaning and interpretation of tables.

Problem Definition and Eventual Recommendations. Since we noticed that many recommendations were unclear using template #1, Template #2 gives more emphasis on providing a meaningful recommendation for the problems that were identified. This, in turn results in a clearer problem definition in the report. We saw that progress as we analyzed the briefings from Templates #1 and #2.

4.2 Evaluation of Improvements Incorporated into Template #2

The process for initial evaluation of improvements incorporated into Template #2 was based on the assumption that the effectiveness of those improvements would be revealed by comparing results from 3 course sections in which Template #1 was used (Spring and Summer 2009) and 11 course sections in which Template #2 was used subsequently through Spring 2011. In total we collected 301 briefings produced by 14 course sections across seven different terms. Six briefings were selected randomly from each of 14 sections to reduce the number included in the initial analysis. Five criteria were used for evaluating each of the briefings on a scale of 1 to 4: a) clarity in the identification of the work system, b) clarity of the problem definition in the management report, c) meaningfulness of the recommendations, d) internal consistency of descriptions of activities and their participants, and e) clarity in the identification of performance gaps. The 84 briefings were randomized rather than ordered chronologically to protect against ordering bias in the analysis. Each of the briefings had been read previously by one of the authors and by one or for some course sections two highly qualified research assistants. In the current evaluation, all 84 of the papers were additionally read and re-read and then coded by a highly qualified PhD candidate whose years of business experience provided sufficient background for recognizing meaningful descriptions of situations and meaningful recommendations.

The mean overall quality score for the 84 briefings was 3.40 with a standard deviation of .463 and a range from 2.2 to 4.0 Figure 2 shows the frequency distribution of scores by academic term. The scores are the sum of the five criteria for each of the briefings. The first use of Templates #1 and #2 occurred in terms 1 and 3. The average scores for the five terms other than those start-up terms were quite consistent, with a range from 3.54 to 3.73. In other words, average results for the second term in which Template #1 was used were similar to average results for most of the terms in which Template #2 was used. However a comparasion of the averages scores does not tell the full story. A fuller picture emerges from other aspects of the data including a comparison of business-focussed vs IT–focussed courses, correlations by term and comments related to the criteria.

Overall Evaluation	Frequency of scores in each term (for our sample of 84 briefing							
	-Template #1-		-Template #2-					Terms
4.0		4		1	5	3	1	
3.8		3		3	1	2	3	1- Spring '09
3.6	4	2		3		1	1	2- Summer '09
3.4	2	5		3	3	1	1	3-Fall '09
3.2	1	2	2	1	1	3		4- Spring '10
3.0	2	1	3	1	2	2		5- Summer '10
2.8	2	1	1					6-Fall '10
2.6	3							7-Spring '11
2.4	2							
2.2	2							
Number of briefings	18	18	6	12	12	12	6	
Average	2.94	3.54	3.03	3.55	3.60	3.52	3.73	
Term >>	*1*	*2*	*3*	*4*	*5*	*6*	*7*	

Fig. 2. Distribution of scores by term

The population of participants include business professionals from many management disciplines as well as IS/IT specialists. The courses were eight MBA level IS management classes (236 students), five enterprise architecture classes (55 students), and one ERP implementation and management class (10 students). Figure 3 shows overall results from all 14 sections, with emphasis on comparing scores in generalist MBA courses and scores in courses for IT specialists. Scores in both types of courses demonstrated that the students could use the template. The average scores in the MBA courses after the first term were very close to average scores in courses for IT specialists. Thus, IT specialists seemed not to have an advantage in performing this type of analysis. Stated differently, business professionals were roughly as empowered as IT professionals in using the Template #2.

Table 2 shows correlations between five criteria across the 84 briefings. All of the correlation coefficients are positive and statistically significant. The correlations may be interpreted in general as "clarity begets clarity." In particular, one fact stood out: the clearer the problem statement the better the result. The strongest correlation was between the clarity of the problem definition in the management report and the meaningfulness of the recommendation. This should not surprise anyone with experience in software development or in software project management since a key tenet of both disciplines that one cannot hit a target if one is aiming somewhere else.

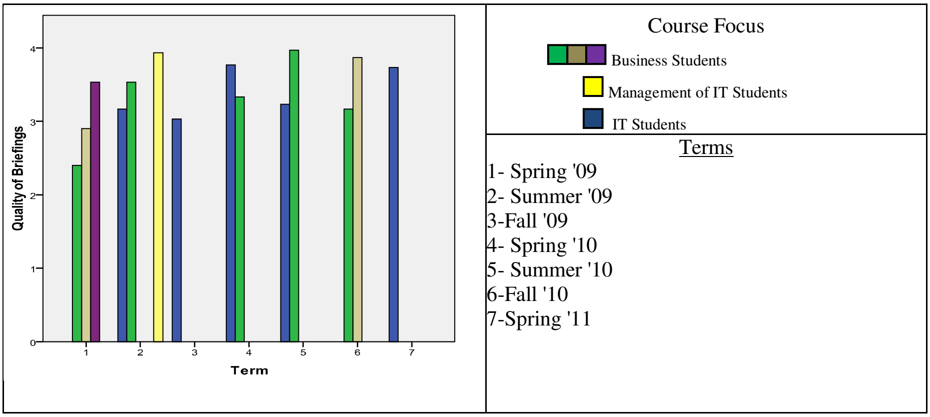

Fig. 3. Comparison of results by term for business and IT professionals

To compare results from Template #1 and Template #2, we randomly selected six briefings that used each template and counted the number of sentences that mentioned the essence of each criterion. Table 3 shows low to high ranges for Template #1 and #2 for each of the five criteria. For three of the criteria, clarity about the work system, clarity about performance gaps, and meaningfulness of the recommendations, the maximum score for Template #1 was lower than the minimum score for Template #2. In other words, Template #2 elicited substantially more clarity about the situation and recommendation than Template #1.

Table 1. Correlation of five criteria used in all 84 briefings

	clarity in the identification of the work system	Clear problem definition in the management report	Meaningful recommendations	Consistency of descriptions with activities and their participants	clarity in the identification of performance gaps
clarity in the identification of the work system	1				
Clear problem definition in the management report	.325**	1			
Meaningful recommendations	.393**	.559**	1		
Consistency of descriptions with activities and their participants	.436**	.399**	.545**	1	
clarity in the identification of performance gaps	.511**	.395**	.329**	.239*	1

** Correlation is significant at 0.01 level (2-tailed) * Correlation is significant at 0.05 level (2-tailed)

Table 2. Clarity of system description and meaningful recommendation

	Template #1		Template #2	
	Min	Max	Min	Max
clarity in the identification of the work system	7	14	16	22
clarity of problem definition in the management report	5	10	7	14
meaningfulness of the recommendations	9	13	20	25
internal consistency of descriptions of activities and their participants	4	5	3	7
clarity in the identification of performance gaps	8	11	12	16

4.3 Examples of Retrospective Feedback

Periodically, participants were asked to provide an evaluation of WSM template after completing a management briefing. For illustration we provide four examples excerpted from an IT management class. The first example illustrates a problem with Template #1 that we tried to eliminate in Template #2. (Appendix 1 was basically a one page summary that helped in focusing the rest of the Template, which went into more detail.)

> *".... Appendices 3, 4, and 5 are somewhat redundant. Information is repeated across all three appendices, which could be incorporated into one table instead. This would eliminate the need to flip back and forth between pages to cross reference information during the preparation of this analysis as well as during its review."* ***(Tagged - 309M4)…***

The next two comments illustrate that even Template #1 led to a deeper thinking about a business situation.

> *"…I think this process was extremely effective in fleshing out issues and recommendations that were apparent, but hard to articulate. After identifying the current work system compared to the work system a year ago, I'm able to propose a work system that takes what worked from both versions.... This process never let me complete and then ignore any section; it always brought new points to the surface and kept them there."* ***(Tagged – 209M12)…***

> *"… I have never thought about breaking down a process into each step and examining each step for inefficiencies. Mistakenly, I feel like I should be able to spot the inefficiencies just by thinking about the process in its entirety. This is clearly not true as I became aware of several inefficiencies that I would never have considered otherwise... I became aware of several inefficiencies that I would never have considered otherwise."* ***(Tagged – 209M16)*** …

A final example is someone who believed that the template interfered with his/her creativity, an interesting comment when an important purpose of MBA and MSIS courses is teach people to think in ways that they might not pursue on their own.

> … *However, I saw the outline as a creative constraint that guided my thoughts a little too much. I feel that coming up with an outline given less constraints would have been more useful of an academic exercise for me.* ***(Tagged – 209C06)…***

5 Discussion and Future Research

Our analysis of the use of the design artifacts, Work System Analysis Templates #1 and #2, suggests that the templates were usable by both business and IT professionals and that the second template was more effective in eliciting clearer and more extensive descriptions and recommendations. Our results confirm that it is possible to encourage greater clarity of analysis by providing a structure that allows people to articulate and share a basic understanding of the work they do and then drill down deeper in exploring some of the nuances of that work system. However, one of the shortcomings of the overall approach is suggested by the last of the reflexive statements quoted above, *i.e.,* some people may feel constrained by the design artifact.

We interpret this as follows. The work system template structure requires a user to think about certain topics in an organized and disciplined way to provide a parsimonious and cogent description of the system. The logic of the template starts with overview ideas and then drills down for more detail. It requires that people use work system concepts to articulate situational specifics that may taken for granted and are implicit in the work being done, but which need to be made explicit to have meaningful conversations about making improvements in the work system. The templates also require people to explicitly identify improvement metrics, even if only in a generalized and qualitative description. Once an improvement metric is identified and named people can then begin to consider what might be meaningful measures for those improvement criteria. The work system template should be quite natural in two ways. First it calls for descriptions in the user's native everyday work language using an almost universal business tool, an MSWord document. While it is possible to fill in the template in any order, some potential users may simply resist the discipline required to use this type of tool even though it supports coherent analysis and coherent discussions with others.

Our continuing research proceeds along several paths. We are using grounded theory methods in order to better understand the concepts that these managers used in talking about their problem situations. In addition, we intend to explore a number of issues that we observed in analyzing the current papers. Since the briefings use the concept of customer in a number of different ways (e.g., internal vs. external customer, the firm as a customer, self-service, and so on) we will review the use of the concept of customer, with special emphasis on planning and accounting systems in which the customer is the firm itself or its departments. With the widespread attention to the service economy and the importance of services in general, we also intend to explore the relative balance of production vs. service orientation in the briefings. We believe that a future Template #3 might contain a greater emphasis on service issues, and we intend to use critical instances of service or non-service orientation in the existing briefings for guidance in developing the next version.

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Design and Evaluation of Management Processes in IS: Application of a Process-Based Research Approach

Alexander Borek[1], Markus Helfert[2], Philip Woodall[1], and Ajith Kumar Parlikad[1]

[1] Institute for Manufacturing, Department of Engineering, University of Cambridge,
17 Charles Babbage Road, Cambridge, CB3 0FS, United Kingdom
`{ab865,pw325,aknp2}@cam.ac.uk`
[2] School of Computing, Dublin City University, Glasnevin, Dublin 9, Ireland
`markus.helfert@computing.dcu.ie`

Abstract. Behavioural information systems (IS) research delivers concepts and theories that are applied to IS management by practitioners. Designing an IS management process is yet far from being straightforward. Design science in IS aims at bridging this gap by providing a rigid way to bring theory into practice, which is, however, not readily applicable for designing management processes. We found a process based research approach in the operations management discipline that could provide more specific research guidelines. This paper examines and evaluates this process-based research approach from a design science perspective. Moreover, we have used the process-based research approach to design and evaluate an IS management process to test its applicability in the IS discipline. In particular, this paper discusses our experiences of applying the research approach in several in-depth action research studies conducted in the manufacturing and energy sectors.

Keywords: IS management processes, Design science, Process-based approach.

1 Introduction

Behavioural IS research provides concepts and theories that can be applied by practitioners to IS management in the form of IS management processes. Designing an IS management process is yet far from being straightforward. Design science aims at bridging this gap by providing a rigid way to bring theory into practice [1, 2]. A business process can be defined “a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action” [23]. Business processes can be further sub-divided into operational and management processes [25]. An IS management process can be defined as any management processes that has the primary goal to effectively manage the planning, design, implementation, improvement, monitoring or evaluation of information systems in an organisation.

The current body of design science literature provides guidelines that are, however, not readily applicable for designing and evaluating management processes in IS. The

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principles and guidelines require a refinement regarding how such an artefact can be built and evaluated. We have found that some concepts and approaches might be transferable from management science, where design science is also discussed and used as an alternative method to behavioural research [5, 6]. In particular, in the operations and production management discipline, a research methodology has been proposed [7] and applied successfully, e.g. [7-9], to develop and test management processes in the area of manufacturing strategy. This paper shows that this process based approach to research can be (1) transferred to the IS discipline, where it can provide useful results, and (2) that this approach fulfils key design science research principles found in the literature. The remaining paper is structured as follows: First, we review the design science literature and identify the main principles and guidelines for design science research. Then, the process based approach is described in detail and we present how we have applied the approach to develop a management process in the IS discipline. Eventually, we evaluate the research approach from a design science perspective and conclude with a discussion and by giving future research directions.

2 Key Principles and Guidelines of Design Science

With the core objective to create useful artefacts that solve complex real world problems, design science is seen as a problem-solving paradigm [1, 2]. Design science outputs are described as artefacts which are broadly defined as constructs, models, methods and instantiations (e.g. information technology (IT) systems). Many authors have discussed the relevance and research approach of design science, and emphasized that the design process and the results produced must meet certain criteria of rigor and relevance. Several guidelines have been suggested, most prominently [1]. There is also the legitimisation of the practical utility of the artefacts that relies on systematic and rigorous evaluation approaches to determine their functionality in organisations context of work, usefulness and ease of use [10].

The importance of design science is recognised in the Information Systems (IS) field since the early 1990's. At present, design science in the IS field is at the intersection of behavioural science concerned with knowledge of human behavior; IS involving knowledge of the properties of IT systems; and social sciences reflecting the respective approaches to rigour [11]. According to Winter [12], design-oriented IS research is aimed at the construction of 'better' IS-related problem solutions. Utility for practice is established as a clear and common measure of its results' relevance, but, the rigour of its construction and evaluation varies. In this paper we describe one design approach, originated from management research. We will show the legitimacy and appropriateness of this process as possible design process. Core of our argument are key design science principles, which demonstrate that the proposed process can be applied to design science research. The design science process is underpinned by several key principles, which we have summarised in Table 1.

Table 1. Design Science Principles and Literature Support

Principle	**Description**	**Selected Key Scholarly References**
1. Design as an Artefact	The development of useful artefacts is a core requirement. Artefacts include: -constructs to describe problems or solution components; -models to represent the problem and its solution space; -methods to provide guidelines for task performance; -instantiations to demonstrate utility of the artefact.	[1, 2, 10, 13-15]
2.Design Problem Relevance	DS research is problem driven, aimed at addressing the problems situated at the intersection of people, organisations, and information technology.	[1, 13, 15]
3.Design Cycle	Design cycle activities iterate between building and evaluating artefacts and are based on both relevance and rigor, focused on addressing application domain requirements, while drawing on existing theoretical foundations and methodologies in the knowledge base.	[1, 13, 16]
4.Design Research Rigor	A design requires the use of methods and analysis appropriate to the tasks at hand. The DS rigor cycle links build and evaluate activities with existing foundational theories, frameworks, artefacts, processes, methodologies, and application domain expertise in the knowledge base.	[1, 13, 16, 17]
5.Design Artefact Evaluation	Rigorous evaluation methods are required to demonstrate the design artefact's utility, quality and efficacy. Metrics are used in comparing the artefacts' performance. Evaluation approaches may include case studies, field studies, analytical methods, experimental methods, testing, or descriptive methods.	[1, 2, 13, 14, 16, 18]
6. Design Research Contributions	Contributions of DS research include: - an artefact that adds to the existing knowledge base; - design construction knowledge improving foundations; - design evaluation knowledge enhancing methodologies; - experience gained from design and evaluate activities.	[1, 2]
7. Communication and Dissemination of Research Outputs	The results of design science research should be communicated and presented in an appropriate form to the technical and managerial community.	[1, 17]

3 A Process Based Research Approach from the Operations and Production Management Discipline

A process approach [7] to research has been proposed by Ken Platts in the operations and production management discipline, which has been originally developed and tested in manufacturing strategy. The process based approach has been successfully used in various research projects in this discipline, e.g. [8, 9, 19, 20]. The approach comprises three subsequent stages.

First, the management process is designed, which needs to be grounded in theory, and based on interviews with target companies, in which the process is intended to be applied, and on interviews with consultants to learn about current practices regarding the problem that is investigated. The initial studies are not aimed at fully understanding the investigated phenomena, but should rather assist in the development of the process.

Second, the management process developed in stage one is tested and refined by application in a small number of companies (4-8 companies overall). Therefore, the involvement of the researcher needs to be considered when the process is applied, which can range from direct observation, in which the research is completely detached, participant observation, in which the researcher becomes part of the group that he observes, to the full involvement of the researcher in action research. An independent facilitator can be used in some of the studies to show that the feasibility of the process is not dependent on the knowledge and skills of the researcher. Platts advocates that especially at the beginning of this stage, it is more important to refine the process between studies to make it more robust and useful rather than being able to compare the process application between different sites by keeping the process consistent. In the later part of this stage, the process can be applied in two or more final test cases without making any changes for final testing, as done, for example, in [8]. As the goal is to test the feasibility and to refine the process in this stage, the companies for the studies should be selected to provide a wide range of different contexts. The support of the senior management should be established when this is possible. The process outline should be explained to the senior management beforehand and the results should be communicated at the end of the process. Testing of the management process is, thus, done by application of the process in different companies. The testing has the goal to "determine whether the process did provide a practical, procedural step" [7]. This is done using three main criteria: feasibility, usability and utility. Feasibility demonstrate that the process can be followed, which is done simply by applying the process. Applying the process in different industries shows that the feasibility of the process is independent of the context and applying the process using a different facilitator proofs its independence of the knowledge and experience of the researcher. Usability investigates if the process is easy to follow. Utility is the evaluation of the success of the process and the usefulness of the results for the company. Tan presents a list of sub-criteria, which are shown in Table 2 [8].

Third, a survey can be used to test the process and its wider applicability further. Platts proposes the use of a questionnaire with both users (to analyze the use) and

Table 2. List of sub-criteria for feasibility, usability and utility [8]

Feasibility	**Usability**	**Utility**
Participation	Clarity	Relevance
Availability of information	Ease of use	Usefulness
Timing	Appropriateness	Facilitation
-	-	Confidence

non-users (to find the reasons for non-adoption) to analyze their perceptions of feasibility, usability, and utility of the process. As the goal is to test the wider applicability, the hypothesis in the survey is that there are no differences in the characteristics of the users and the non-users. However, most of the researchers that have used the process approach in the past have not executed this stage, e.g. [8, 9, 21].

4 Application of the Process Based Approach to Build and Evaluate an IS Management Process

We have applied the process based approach to build and evaluate an IS management process, namely a process for Total Information Risk Management (TIRM), which enables to identify, analyse, evaluate and treat information risks[1] in an organization [23, 24].

The TIRM process aims at:

a) Understanding the risks that arise through poor information quality for the organization and financial evaluation of the business impact of information quality
b) Developing effective information quality improvement initiatives based on the identified pain points, which can involve changes in three aspects: technology, organization and people.

The TIRM process is based on the ISO 31000 risk management standard [25] and consists of five key stages: (1) communicate and consult, (2) establish the context, (3) information risk assessment, (4) information risk treatment and (5) monitoring and review, as shown in Figure 1.

The TIRM process has been built and evaluated in three consecutive research phases, as illustrated in Figure 2.

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[1] Information risk is defined in the TIRM process as the effect of uncertainty on objectives that arises from the use of information resources and their quality in an organization. It comprises information from both technical and human sources. Information quality is defined from a user perspective as the fitness for use of information, in accordance to the information quality literature [22]. It is a multi-dimensional concept with dimensions like accuracy, completeness, timeliness, security etc.

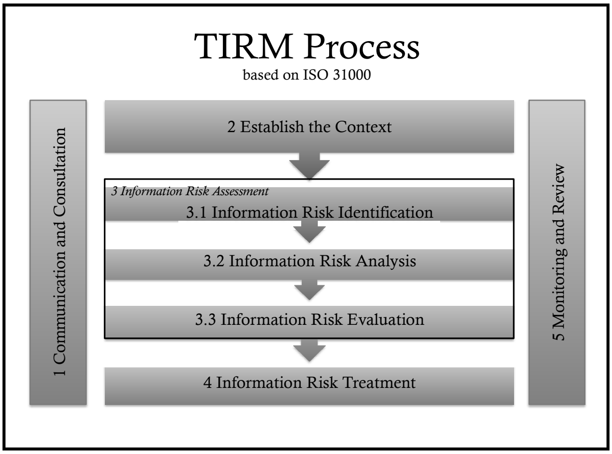

Fig. 1. The TIRM Process

The first phase was the initial design of the process on the basis of a review of the existing information quality and risk management literature and interviews with managers (operational, strategic and IT) and consultants (management and IT) about information risks in the industry.

The process was tested and refined by application in a semiconductor manufacturer, a steel manufacturer and an electrical utility company in the second phase. During these studies, we spent a considerable amount of time at the companies' sites to facilitate workshops, which were the core part of the process application. Some interviews and workshops were also conducted over telephone before and after the site visit. After each workshop, a feedback discussion took place to evaluate how the process can be improved and refined. We used the gathered feedback and the experiences and insights of the action researcher to improve the process after each application. The process has been evaluated using feedback discussions after each workshop and questionnaires at the end of the process using the three main criteria feasibility, usability, and utility. The questionnaires have been designed based on a number of sub-criteria (see Table 2) and questionnaires developed and tested as part of an existing doctoral thesis that also has used the process-based research approach [8]. So far, we have received mostly high results regarding all three evaluation criteria: feasibility, usability and utility of the TIRM process. When the feedback has been poor, we were able to identify and address the problems. Each study had a different scope of application. In case study A, we examined the local maintenance, central engineering, manufacturing IT, planning and purchasing departments. Case study B included quality management, purchasing, maintenance, sales & marketing, strategic management, logistics and planning, production and product design functions. Case study C investigated three core processes in a utility company: (1) processing new customer requests, (2) expanding the existing electricity network and (3) managing and maintaining the existing electricity network.

In the third research phase, the process was applied using an independent facilitator in an additional case study in a company that manufactures electrical industrial components. This helped us to determine that the TIRM process is not dependent on the knowledge of the researchers. In this case study, all processes were investigated that are required to manage physical assets in manufacturing, from planning and acquisition to deployment, usage, maintenance and retirement of the assets.

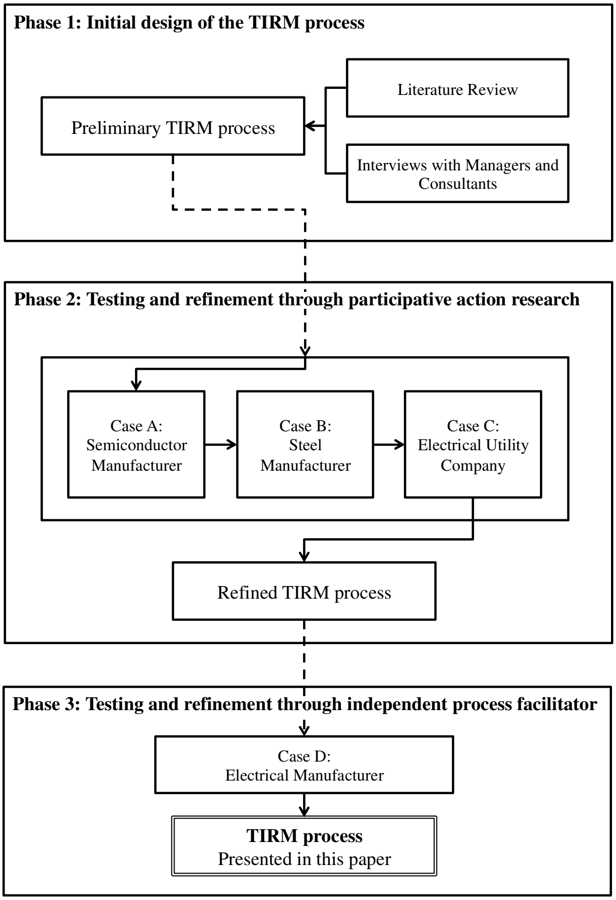

Fig. 2. Process Development

Note that for testing the wider applicability of the TIRM process, we have not used a questionnaire like Ken Platt's process approach suggests, but we have rather applied the TIRM process in different industries and contexts to test its robustness.

The TIRM process demonstrates to the IS research community that it is possible to manage information risks effectively and it provides a potential way to do this. In summary, this section has demonstrated how the process based approach can be applied to develop IS management processes and that this type of research can generate valuable contributions to the IS discipline.

5 Evaluation of the Process Based Approach from a Design Science Perspective

We have shown that the process based approach can be used for designing management processes in the IS discipline. Next, we will demonstrate that the process based approach follows key design science principles in IS. The process-based approach is, hence, discussed and evaluated in the following along the seven principles that have been set in Table 1.

5.1 Design as an Artefact

This principle demands that design science research focuses on building and evaluating an artefact in the form of a construct, a model, a method, or an instantiation [1, 2, 14]. The process based approach aims at producing a management process and produces therefore an artefact, which is a method to achieve something. In our example in section 4, the produced method has the goal to optimize existing information systems in an organisation. Moreover, as part of the process based research, the management process is applied in an organization and, thus, an instantiation is created.

5.2 Design Problem Relevance

The designed artefact should be relevant to the IS discipline [1, 13, 15]. According to Hevner et al., the objective of IS research is "to acquire knowledge and understanding that enable the development and implementation of technology-based solutions to heretofore unsolved and important business problems" [1]. The relevance of the artefact, hence, depends on the type of management process that is actually designed. It is, however, beyond any doubt that there are management processes, which are relevant for IS, e.g. a process to capture the requirements of a new system. In our example, the TIRM process examines the quality of information and helps to identify which systems should be developed or modified to solve information quality problems in an organization that have a high business impact, which allows to make more effective IS investment decisions. Moreover, Hevner et al. [1] argue that artefacts in IS can be technology-based, organization-based or people-based artefacts, which are all necessary to address problems in IS. A management process is an organization-based artefact.

5.3 Design Cycle

Design science is described as a Generate/Test cycle and is, therefore an iterative process to find a solution for a problem [1, 16]. In addition, designing an artefact necessitates knowledge in the application and solution domain. In the process based approach, a process is repeatedly applied and refined until it solves the problem. In the first phase of the process based approach when the process is initially constructed, interviews are conducted with managers to get to know the problem domain and with consultants to gain knowledge about the solution domain.

5.4 Design Research Rigor

Design science research should use rigorous methods in building and evaluation of the design artefact [1, 13, 16, 17]. Furthermore, research rigor has to be evaluated in the light of how well an artefact works and not of how well it is explained why the artefact works [13, 17]. This brings the applicability and the generalizability of the artefact into the centre of focus, which is also the primary goal of the process based approach. Applicability and generalizability is achieved by application of the designed process in a number of organisations in different industries. The TIRM process has been tested in a semiconductor manufacturer, steel manufacturer, electrical utility company and an industrial components manufacturer.

5.5 Design Artefact Evaluation

Evaluation of the designed artefact is an important part of design science [1, 2, 14, 18]. In particular, the "utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods" [1]. The requirements of the evaluation are based on the business environment. Moreover, the evaluation methods must suit the designed artefact and the evaluation metrics. Hevner et al. propose a number of criteria to evaluate artefacts: functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization and other attributes [1]. In the process based approach, the artefact is evaluated along the three criteria feasibility, usability and utility and a number of sub-criteria that can be adapted to the business context. The management process is evaluated by its application in different organizations. Feedback and insights are collected on the defined criteria during the application of the process, for example, with questionnaires and discussions with participants. Evaluation should feed back into the construction of the artefact, which is done by refinement of the process based on feedback and insights after each application.

5.6 Design Research Contributions

There are four different research contributions that design science research can have [1, 2], i.e. (1) an artefact that adds to the existing knowledge base, (2) design construction knowledge improving foundations, (3) design evaluation knowledge enhancing methodologies, (4) experience gained from design and evaluate activities. The same contributions are possible using the process based approach for design science. In fact, the example shown in this paper contributes in three ways. First, the artefact itself, the TIRM process, is a contribution to IS research as it provides an effective way to manage information risk. Second, the research shows how a management processes can be designed and, third, how it can be evaluated in IS research.

5.7 Communication and Dissemination of Research Outputs

An important part of design science research is the effective communication and dissemination of research results [1, 17]. Hevner et al. argue that research in design science has to "be presented both to technology-oriented as well as management-oriented audiences" [1]. Management processes in IS might have the tendency to be more interesting to management-oriented audiences, but are equally important to a technical audience. The TIRM process will be presented to both managerial [23] and technological-oriented research audiences [24]. Moreover, we are planning to generate a workbook for practicioners on how to deploy the TIRM process in an organisation in the near future.

6 Concluding Remarks

This paper has discussed the adoption of a process based approach from the operations and production management discipline to build and evaluate management processes in IS research within a design science environment. We have done this by explaining the research approach in detail and by applying it in the IS area to design a process for managing information risks. Furthermore, we have evaluated the process based approach from a design science perspective using common principles and guidelines of design science. As many of the current guidelines for design science research (e.g. [1]) focus on IT artefacts, we found that the process based approach can be a very useful complement that refines and adapts the design science approach to built and test management processes in IS. Further applications of the process based approach are needed to test if it is suitable for the design of other types of IS management process and to identify changes that are required. Future research should therefore aim at testing and refining the process based research guidelines and adapting them to the needs of the IS discipline. The research presented in this paper contributes to the discussion on design science methodologies and provides potential guidelines to build and test IS management processes.

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Analyzing Complex Design Processes: The Effects of Task Automation and Integration on Process Structure in Microprocessor Design*

Yohan Choi[1], B. Veeresh Thummadi[2], Kalle Lyytinen[2], and Youngjin Yoo[1]

[1] Temple University, Philadelphia, Pennsylvania, USA
`yohann.choi@gmail.com, youngjin.yoo@temple.edu`
[2] Case western reserve university, Cleveland, Ohio USA
`{Veeresh.Thummadi,Kalle.Lyytinen}@case.edu`

Abstract. Today's microprocessor design is one of the most complex and computationally intensive design processes. For overcoming the design challenges, the current chip design involves significant reuse of architectural and component designs and Computer Automated Design (CAD) tools. This begs the question how does the increased level of computer assisted automation and design coordination during chip design affect the range of design activities and their structure? In this study we examine this question by exploring the highly automated design process, often referred to as "physical synthesis" (PS) design approach to the more traditional "structured digital design" (SDD) approach. Our analysis indicates that the PS approach led to smaller and more frequent iterations while the level of iterative activity remained the same across design stages.

Keywords: Digital design, design automation, chip design approaches, design complexity.

1 Introduction

Microprocessors are the "brain of computer" [1] with the ability to perform fast basic arithmetic and logical operations. Since the invention of silicon-based computers, marked improvements in the computational capabilities of computers have been accomplished through enormous advances in hardware machinery like very large scale integrated circuits or whole microprocessor chips [2]. Over the last four decades the density and performance of integrated circuits has doubled every 18-24 months, a phenomenon often referred to as the Moore's 'Law' [3]. As a result, the chip design

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complexity has enormously increased while designers face new design challenges as they need to deliver a high quality chip in time to the market to keep up with the market expectation and competition. This has created a constant demand for design automation and integration to better manage the growing complexity of the chip design [4]. Here we would like to focus on two approaches called structured digital design (SDD) and physical synthesis (PS) with varied complexities. In the more traditional SDD approach, a designer retains a higher degree of personal control over the design by employing digital tools in each isolated design domain separately. By contrast, in PS approach, chip designers adopt highly integrated automation techniques that can significantly improve the task performance as PS augments extensively human design judgment with computer-based algorithmic design capability [7]. In this paper we surmise that the range of design activities and the structure of the design process (measured e.g. in the number of design iterations) of the two processes will be different due to the different level of design integration and automation. Moreover, it is not clear which approach is apt in a certain design situation. In order to close this gap, we specifically ask the following questions: (1) how do two distinct design approaches to microprocessor chip design – PS v.s. SDD -- influence the variation of activities carried out by the chip designers and their temporal organization? (2) how the use of automated design tools affects design processes when measured in terms of the size and frequency of iterations? Furthermore, we posit that understanding the nature and causes of such differences would provide insights of the effects of the increased design automation on design activity structure and organization in general- a lofty goal for design science research. To address these questions, we conducted a study in which we compare two design processes that each follows either an SDD or a PS approach. In the next section we review event sequencing method to examine the variation and structure of SDD and PS based design processes. Then we report the study context and followed data collection and analysis approach. Section 4 contains the details of the key findings. We conclude the paper with a discussion of key findings and future research vistas.

2 Event Sequencing as a Way of Understanding Design Routines

Recently, researchers in several disciplinary fields have devised methods referred to generally as "event sequencing" methods. These techniques are dedicated to the analysis of ordered sequences of elements, activities, or events[8-10] and were adopted in the early 90's by social scientists to study the organization of human activities such as job careers [11], or spatio-temporal behaviors as e.g. movements in cities. These analyses, though illuminating, neither attend to generative and non-linear design tasks like software or chip design, nor do they account for the presence of material artifacts in the activity, though such artifacts are inevitably embedded in design practices and affect them [12, 13]. Gaskin et. al [23] have recently proposed an extension to event sequencing methods to study variation in design activities based on the composition of design elements (hence seeking to reveal the 'DNA' of design practices). The value of the approach is that it incorporates also material artifacts into the design flow. Therefore, Gaskin et al. [14] call the method "socio-technical" event sequencing method. We adopted this sequencing method to analyze the structure and properties of design processes associated with micro-processor chip design. Our aim was to reveal differences between PS and SDD based chip design processes as to evaluate the impact of higher-level design automation. The method uses a process notation to capture a sequence of design activities. It depicts five critical elements of each design activity to form a systematic representation of design routine (see Gaskin et al 2010 for the taxonomy). Each activity therefore consists of the following elements: (1) an *actor* (roles and configurations of actors); (2) an *activity* (location and activity type); (3) an *affordance* (what do actors do with the tools); (4) a *tool,* (nature of materiality and affordance of tool); and (5) a *design object* (status of the design object in the design process and its relationship with the tool) [14]. This notation has been implemented in the MetaEdit+ Metacase software suite [15]. It enables to graphically encode design processes as they unfold in design projects. After collecting detailed process data through the interviews and archival data we can encode the process data into a visual process model. Each of the elements of the process model is then assigned a code according to their value in the design 'taxonomy' (see Gaskin et al 2010 "Sequencing Design DNA: A Set of Methodological Artifacts for Sequencing Socio-Technical Design Routines" for more details) converting the graphical sequence into a concatenated string of alphanumeric characters. We can thereby extract literal event sequence representations from the visual process description using Excel scripts. Finally, we can compute descriptive statistics from these sequences for process comparison and then analyze the process sequences using the ClustalG- a software tool to compute similarities of different sequences based on a multiple alignment method [9, 10, 16]. This can be done at the level of individual activity, or activity (sub) sequence within a project. We call this an alignment step as it detects the 'homology' or 'structural correspondence' between the two sequenced activities [17, 18]. In order to interpret these alignments visually, we generate un-rooted phylogenetic trees (a.k.a. variation relationships between the activities (see Fig.6) [19].These trees 'grow' when new types of activities are added and as a result they resemble one another less. In the case of design processes, such modifications can occur when new extraneous factors, like actors, affordances, and tools, are added to an existing activity. The branches in the tree are thus clustered based on similarity among activity sequences (i.e. similar in terms of their underlying elements). A large number of branches indicates a high degree of diversification, while a small number indicates hybridization also known as cloning [20].

3 Case Study of Physical Synthesis and Semi-automated Design Practices in a Large Microprocessor Design Center

We analyzed two design processes in a chip design that involved both PS or SDD approaches in different part of the design. We sought to find differences in the variation of activities, the size and frequency of iterations, and differences in distributions across activity types, and affordances. To this end we collected process data from a large microprocessor design development unit within a large multinational microprocessor-manufacturing firm (referred to as “Alpha”). The specific chip design focused on this study was carried out at one of Alpha’s major design centers between 2008-2010. The chip design was successful and was deemed by the interviewees as one of the most complex tasks the center had ever carried out. Overall, the project was divided into five phases covering design specification, behavioral design and physical design, broadly following the general design process of microprocessor chips. We visited the study site and conducted 16 in-depth semi-structured interviews with several block managers and designer on four occasions. The interviews used a protocol to clarify the design task, the design process, the coordination of design, and the design environment including physical design environment. The interviews ranged from an hour to several hours to collect and validate the data. The transcribed interviews were converted into a graphical process model, which underwent thorough reviews and validation with the designers. A microprocessor design is typically divided into several units or sections. Each section then is further divided into blocks as the smallest design unit. Block is typically a clearly selected set of functionality that is allocated into a specific area on the floor plan of a chip. It is, therefore, typically allocated to a single designer. Each designer typically manages about four to ten blocks depending on their complexity and criticality. We selected one functional unit block that was designed following an SDD approach and another block designed following a PS approach. These blocks were comparable in scale and complexity and overlapped in their design processes as they shared many of the same artifacts and other elements. Both designers were highly competent and were deemed by the managers of the design center as truly highly skilled chip designers. As each block was designed by the same designer throughout the whole process, we could collect detailed process data by interviewing just the main designer of that block. We followed the design associated with these blocks through all design phases. Overall, although not a perfectly controlled experiment, these blocks were selected with the idea that the main difference between the block design would be due to either following a PS approach or an SDD approach. Thus the sampling of the processes to be studied offered a possibility to conduct a sort of quasi-experiment or natural experiment[21]. To simplify the analysis, we next focus primarily on analyzing phase 2 and 3 as these are the most critical and central in the chip design. Next we will discuss briefly the SDD and PS approaches.

Structured Digital Design Approach: The SDD approach relies on semi-automated design methods where the circuit design and the physical layout are separated. In a structured digital design process, a designer draws the schematic diagrams based on a logic design and then develops a physical implementation plan by using a schematic editing tool. Since the tool does not automatically generate the schematics, the designer is required to use her own design knowledge while drawing the schematics. Therefore, the designer must have more knowledge about physical design (e.g. circuit placement and routing) than when she is using a physical synthesis approach. After drawing schematics (i.e. representation of circuit design), the designer produces layouts which are generated by a layout generating tool that takes schematic, floor plan, constraints as input and then generates layouts. An SDD approach thus uses primarily computer assisted manual techniques for carrying out the primary design activities. One advantage of this approach is that it makes custom based designs more effective. However, the downside of a structured digital design is that it takes more time and depends on the genuine efforts of designers. Furthermore, circuit design and layout design activities are separated so that the high interdependence of these activities can result in a performance problem. In general, a structured digital design approach requires a larger number of designers and more time for designing the same functionality compared to a physical synthesis approach. As a result, firms are trying to replace structured digital designs with physical synthesis designs when applicable.

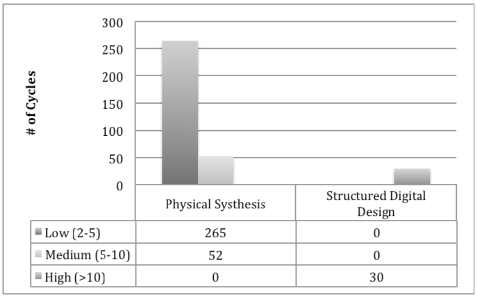
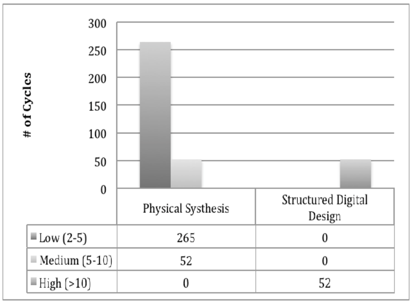
Physical Synthesis Design Approach: A PS approach uses automated synthesis tools where circuits design (i.e. generating schematics) and layout design (i.e. generating layouts) takes place simultaneously. Thus, a physical synthesis approach integrates all the physical design activities such as synthesis, placement, routing, and timing. Hence, with a physical synthesis, a considerable portion of design work is done with automated tools. The synthesis tools in the design process not only automatically convert logic design (i.e. RTL) to layout but also generate the schematics by using standardized cells from the library, which are created and stored by manual design activities (structured digital design). Designers use inputs for generating a layout such as timing, power, noise constraints, logic design, and floor plan. The layouts are iterated until all the necessary design requirements are met.

4 Research Findings

In this section, we report our findings of our analysis. In particular, we focus on the differences between design activities following a structured digital design and a physical synthesis in terms of (1) the nature and scope of iterations, (2) the variation and similarity of activities, and (3) the distribution of activity types, affordance types and object types.

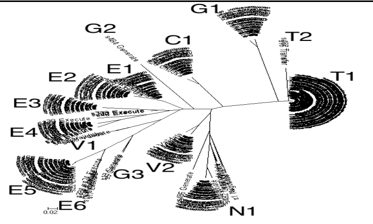
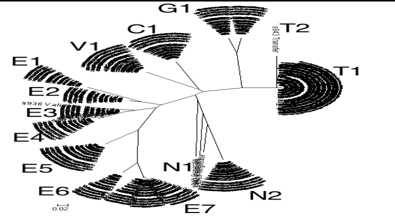
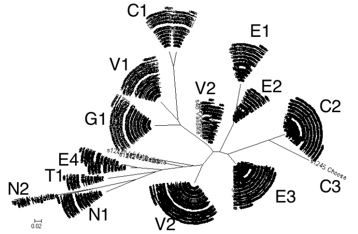
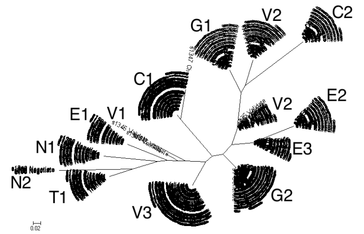
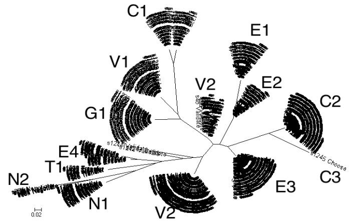
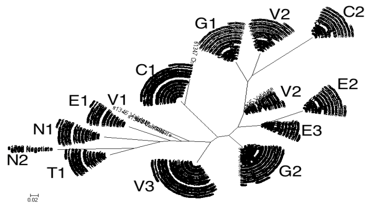
(1) The nature and scope of iterations: With both approaches, a designer first generates a layout of a block and then validates it to see if the layout meets the RTL functionality requirements. If the functionality is satisfied, the designer puts several adjoining block layouts together to check the compatibility. Until the designs meet all the requirements defined at the beginning of the design, the designer continues to generate layouts Thus, each designer tries to not only meet the functionality and physical properties of her block, but also synthesize the block as part of a coherent whole. In addition, we also observed that a majority of the iterations in these two approaches were functional iterations ("for improving the functionality") or performance iterations ("for improving the performance") rather than quality iterations ("for improving the quality by removing errors"). Lack of specific focus to quality iterations can be attributed to the fact that quality is easier to detect early on in the microprocessor design. It takes 1 to 2 weeks to generate a block layout with an SDD approach (depending on the size and complexity of the block) and only takes a day with PS approach. In addition to these daily activities, a designer with a PS approach generates a block layout at the end of each week based on many layouts generated during the week. That is, a block design with a PS approach has both daily and weekly iterations to generate a layout. In addition to this weekly pattern, the designer roll up block layouts to a section (which include many blocks) biweekly in order to check if individual blocks can be synthesized to a whole section.To analyze the differences in iteration in the two processes, we tallied the number of iterated activities and the number of iterated design objects in both processes (see Table 1). The physical synthesis had more iterations before blocks were integrated into a section but smaller iterations in terms of both number of activities and duration of iteration Furthermore, the iterations of physical synthesis iterated far more times than those of structured digital design. This clearly shows that with a physical synthesis a designer has used the automated tools that generated smaller iterations with far more frequency. In contrast, the iterations of the structured digital design approach were bigger in terms of time and length of iterations. Also, we found that the frequency of iterations with the physical synthesis was stable, while the frequency of iterations with the structure digital design approach increased as the process went on. The number iterations and size of iterations would indicate that how automated design tools influence the design process. With automated tools, these short iterations enable the PS designer to try many different options to optimize their design.

Table 1. Nature of iterations in SDD and PS approaches

(a)Granularity of iterated activities of Phase 2 in Structured Digital Design and Physical Synthesis	(b) Granularity of iterated activities of Phase 3 in Structured Digital Design and Physical Synthesis
	

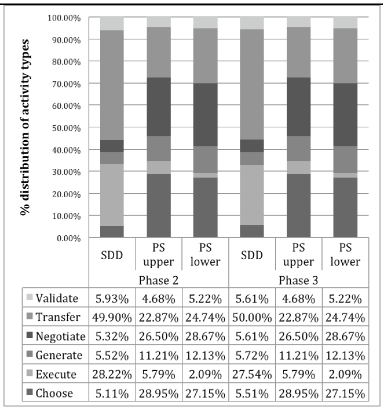
(2) The Variation and Similarity of Activities: We generated phylogenic trees of activities for each phase for both PS and SDD approach to detect the level of variance of activities across phases in these approaches. As noted above these trees grow when new types of activities are added, which results them resembling less one another. These modifications can be associated with adding new ‘extraneous’ elements into process activity like actors, affordances, tools, etc. The branches in the tree become clustered, if they are close to one another (i.e. similar in terms of their underlying elements). A growing number of splitting of branches indicates in contrast increased diversification of activities while a smaller number of splits hints at hybridization of activities [20]. When generating the trees, one of the challenges was in calculating the iteration activities with optional activities that took place as part of the physical synthesis approach iteration. These optional activities occurred when a certain design condition was met during the daily iteration. To this effect the designer generated a section-timing model only when the overall design was good enough. In order to take this optional activity into consideration in estimating the range of activities in iterations, we used upper and lower bound probabilities to capture the optional activities with the PS approach. On the other hand, the SDD approach did not involve any optional activities. The first phylogenic tree in Table 2 represents the activity cluster for phase 2 of the SDD approach. This phase had about 15 activity branches suggesting a wide range of variation of activities. Some of the branches at the lower part of the tree were very thin, indicating that these branches have fewer activities. Another interesting observation was that the tree had several branches of execute activities- overall six distinct branches. Five of these branches (i.e E1, E2, E3, E4, and E6) differed in terms of types of tools (i.e. digital or analog), number of inputs and outputs, and / or number of design objects. But E5 is different due to its design object; the design object of this branch was process planning while in the other branches it is specification. The phylogenic tree of phase 3 activities of the SDD had similar appearance to that of phase 2. It had, however, one more execute branch and a "thicker" generate branch i.e. more variation in generation activities. The six different branches of execute activities (i.e E1, E2, E3, E4, E5, and E6) differed again in terms of types of tools (i.e. digital or analog), number of input and output used, and / or number of design objects. E7 had again a different design object - process planning- while in other activities it is specification. The thick transfer branch (i.e. T1) for both phases suggests that during the design a lot of knowledge was transferred by sharing the information using digital and other tools. While comparing the Phase 2 activity trees from the PS and SDD approach using lower bound and upper bound values, we again found that both processes are heavily oriented towards execute activities. Interestingly, the PS approach, despite being an automated process, relied more on negotiation activities than the SDD. This suggests that the PS designer needed to coordinate and integrate more knowledge across design borders or that larger number of iterations created the need for more negotiations. In Phase 3, PS approach was carried out with more varied generate, validate and create activity types while SDD approach was carried out with more varied execute activity types. The phase 2 of the PS approach had about 14 branches; while the phases 2 and 3 were almost identical suggesting that the design activities across phases during PS were consistent. Also, the lower and upper bound of PS activities did not show a big difference. The upper bound trees had one additional thick generate branch, distinguishing optional activities that included mainly generate activities. The branches, except a few on the left bottom of trees, were all very 'thick'. Like the tree of SDD, the lower bound trees of PS had several executive branches (i.e. E1, E2, E3, and E4). E1 and E2 differed in terms of design objects while E2, E3, and E4 differed in terms of not only design objects but also affordance type. Likewise, the validate branches (i.e. V1, V2, V3) also differed in terms of design object and affordance type. In other words, activities are conducted for different design purposes (i.e. prototype, specification, and implementation), for these activities design tools are used differently (i.e. transformation, analysis, storage). Thus, this implies that during execution activities, designer used tools for different purposes depending on the design object given that particular design object always comes together with particular affordances. The upper bound trees had similar structure with those of lower bound, but had one more thick generate branch. This branch was due to the optional activities of PS. This implies that, if the designer was satisfied with their layout, they conducted additional generate activities over the new iterations. Once automated tool generated layout that was good enough, then the design did an additional 'creative' (i.e. generate) activity upon the layout created by the tool. Therefore, though the designer used an automated tool to come up with layouts meeting the functional requirement, the final design when she made decision, used her own knowledge conducting creative (i.e. generate) activity upon the design done by the automated tool. After analyzing the Phase 2 of the PS and SDD approaches based on lower bound and upper bound values, we observed that both processes were, as expected heavily oriented towards execute activities. The PS approach, being an automated process, relied less also on negotiation activities than the SDD.

Table 2. Phylogenic Trees

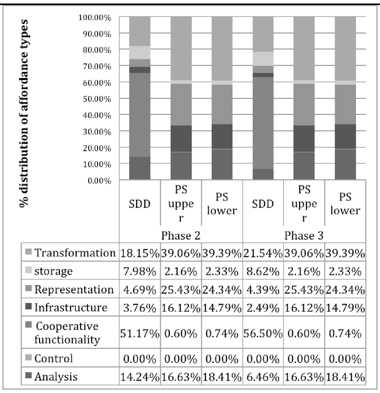
Phase	Phase 2	Phase 3
Structured Digital Design		
Physical Synthesis (Lower bound-probability -10-30%)		
Physical Synthesis (Upper bound-probability -10-30%))		
Legend: E- Execute, T-Transfer, V-Validate, C-Choose, G-Generate, N-Negotiate		

3. The distribution of activity types, affordance types and object types: Finally, we analyzed whether any differences could be detected between the PS and SDD approaches in terms of the proportions of different activities (see Table 3). We found that both approaches involved all activity types in their design process (choose, execute, negotiate, transfer, and validate). In phases 2 and 3, the SDD and PS approaches, however, had different distributions of these activity types, suggesting that there were great differences in what types of things proportionally designers do in these approaches. As expected, generate activity type was more frequent in the PS approach than in the SDD one. Despite its heavy emphasis on planning (generate) and negotiation (negotiate) activities, designers following the PS approach extensively used validate activities to test the designs constantly. This would show that though the automated tools generated layouts to meet the functional requirements the layout was still required to be validated, and the one who validated the layout was the designer rather than the tool. Therefore, the PS designer also used one's own knowledge to optimize the design. To the contrary, the SDD approach mainly relied on execute and transfer activities. An emphasis on execute can be expected in the SDD approach, as it heavily relies on generating partial solutions based on designer's evolving schematic or

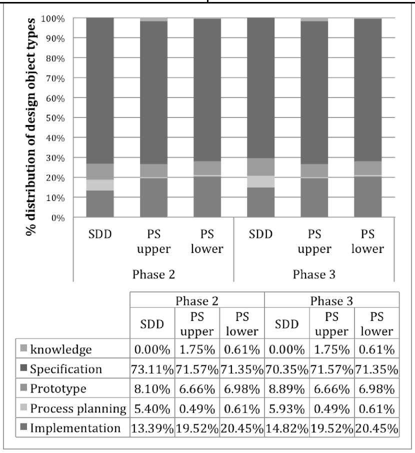
Table 3. Variations of Design Object, Affordance, Activities



	Phase 2			Phase 3		
	SDD	PS upper	PS lower	SDD	PS upper	PS lower
Validate	5.93%	4.68%	5.22%	5.61%	4.68%	5.22%
Transfer	49.90%	22.87%	24.74%	50.00%	22.87%	24.74%
Negotiate	5.32%	26.50%	28.67%	5.61%	26.50%	28.67%
Generate	5.52%	11.21%	12.13%	5.72%	11.21%	12.13%
Execute	28.22%	5.79%	2.09%	27.54%	5.79%	2.09%
Choose	5.11%	28.95%	27.15%	5.51%	28.95%	27.15%



	Phase 2			Phase 3		
	SDD	PS upper	PS lower	SDD	PS upper	PS lower
Transformation	18.15%	39.06%	39.39%	21.54%	39.06%	39.39%
storage	7.98%	2.16%	2.33%	8.62%	2.16%	2.33%
Representation	4.69%	25.43%	24.34%	4.39%	25.43%	24.34%
Infrastructure	3.76%	16.12%	14.79%	2.49%	16.12%	14.79%
Cooperative functionality	51.17%	0.60%	0.74%	56.50%	0.60%	0.74%
Control	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Analysis	14.24%	16.63%	18.41%	6.46%	16.63%	18.41%



	Phase 2			Phase 3		
	SDD	PS upper	PS lower	SDD	PS upper	PS lower
knowledge	0.00%	1.75%	0.61%	0.00%	1.75%	0.61%
Specification	73.11%	71.57%	71.35%	70.35%	71.57%	71.35%
Prototype	8.10%	6.66%	6.98%	8.89%	6.66%	6.98%
Process planning	5.40%	0.49%	0.61%	5.93%	0.49%	0.61%
Implementation	13.39%	19.52%	20.45%	14.82%	19.52%	20.45%

layout designs. We also looked at the distributions of affordances (i.e., how features of various digital tools were enacted in the design process). The distributions of affordances hint the range of capabilities that could be enacted with a tool by the designer. In general, the affordances enacted varied significantly between the two approaches. This shows that digital tools were used for somewhat different purposes during the chip design process between the SDD and PS approaches. As expected, because of the higher range of automation of activities in the PS process, the distribution of affordances were scattered more towards cooperation, transformation and storage. On the other hand, representation and analysis were more present in the SDD approach, reflecting the approach's dependency on designers' cognition and tacit expertise. In addition, in the PS approach the transformation was the most dominant affordance, while in the SDD approach transformation was relatively less frequent. This is, because the PS approach used many tools to transform the designer's design into other forms such as layout, schematics rather than doing manually those activities that are mainly done manually in the SDD approach. As the final step, we analyzed the distributions of the uses of design objects across different phases. This is represented in the percentage of specification, prototype, process planning, and implementation objects within each phase. As expected, the specification design objects were observed most frequently in both approaches. In addition, more implementation design objects were used in the PS process reflecting its heavier use of trial and error design steps.

5 Discussion and Conclusion

In this study, we asked: whether the PS and SDD approaches differ in their activities and their structuring and, if so, how? Our analysis shows that they are, indeed, different. These differences become evident in many aspects of the design activity and process structures like the size and frequency of iterations, the distributions of types of activities, the affordances enacted, and the frequency distributions of activities and design objects. We found that both approaches were extremely iterative and involved the enactment of the same set of activities repeatedly in sometimes deeply nested iterations. However, the PS approach was more deeply nested and had smaller iterations compared to the SDD one. Also, the pattern of iterations of the PS approach was stable over different phases, while that of the SDD approach was not. Thus, we tentatively conclude that designer's heavy reliance on the computing capabilities of automated digital tools in PS approach creates more *nested, small and consistent* iterations like agile software development. Our analysis of different phases using affordances, design objects and activity type revealed differences between in the SDD and PS approaches in the way they were enacted. The extent to which these approaches used different activities types remained different across different phases. However, the use of different activity types for each process appeared to be consistent across the two main phases. While the SDD approach heavily relies on "transfer" and "execute", the PS approach relies on "validate", "generate", and "choose" activity types. An emphasis on execute can be expected in an SDD approach as it heavily relies on generating partial solutions based on designer's evolving schematic or layout designs and his sharing the result of design at each step with other blocks. This also explains the heavy reliance on transfer. Surprisingly, contrary to our expectation, "generate" is more frequently observed in the PS approach than in the SDD approach. We also found that the SDD approach heavily relied on the affordance type "cooperation" more than the PS did, indicating more extensive knowledge sharing among designers. To the contrary, the PS approach enacted on affordance types such as "transformation" (to transform the design by the tools), "analysis" (to analyze the design using the tools), "representation" (to represent the designs for inspection), and "infrastructure" (to provide the support for various design activities). Finally, in terms of design objects, the specification was most frequently used for both approaches. What was interesting was that design object "process planning" was barely used in the PS approach. This is presumably due to the fact that the digital tools help conduct planning activities on behalf of designer. Instead, the designers who used the PS approach used the design object "implementation" more frequently, as her role is primarily executing the design that was done the tool. In conclusion, our analysis shows significant differences between two approaches. Even though both approaches heavily depend on digital tools, the tools are used in drastically different ways. It should be noted, however, that enactments of these routines are influenced by a large number of exogenous factors like local design culture, business environment and people, which were not accounted in our analysis. A more nuanced analysis utilizing qualitative information about the design contexts will be needed to explore the role of those external factors. Our study demonstrates also the usefulness of event sequence based analytical approaches in representing, understanding and comparing design approaches. We believe that the method outlined in this paper can provide new ways to empirically analyze and compare design approaches in scale and size not possible in the past. It thus adds a new inquiring tool to design researcher's intellectual arsenal. There is also a significant possibility to automate much of the data collection using workflow and process enactment engines enabling large scale analyses. This will allow also nearly real time analysis of the variation and evolution of design activities We are currently planning further data collection at the firm in order to follow the evolution of design activities and processes based these two approaches across several design projects. Such a longitudinal study will help us understand better how continued changes in the design method and tool support influence the structuring of design activities.

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Design Science in Action: Researching and Developing the IT-CMF

Markus Helfert[1] and Martin Curley[2]

[1] School of Computing, Dublin City University, Glasnevin, Dublin 9, Ireland
`Markus.Helfert@computing.dcu.ie`
[2] Intel, Lexlip, Ireland
`martin.g.curley@intel.com`

Abstract. Despite the increasing popularity of design science research, understanding the development of design artifacts and engagement of domain experts is still limited. Several guidelines and suggestions concerning design science research have been proposed, however combining practical utility and academic rigor can be difficult, in particular when research is co-funded by industry. In this paper we describe a design environment in the context of the development of a novel IT Management model, the IT Capability Maturity Framework. The paper illustrates an example of design science in action and explores the relation between design process and design artifacts. The contributions show how and what types of design artifacts can be developed, its benefits and challenges within a research consortium. We conclude our paper by discussing areas for further research.

Keywords: Design Science Methodology, Artifacts, Design Science Literature Review.

1 Introduction

In contrast to the increasing popularity of design science research (DSR), this paper acknowledges that relatively little has been published concerning practical usable design science processes. Based on an example, the paper addresses this paucity of published research by exploring and explaining how and what design artifacts can be achieved in practice. The research reported in this paper has been developed in the context of the Information Technology-Capability Maturity Framework (IT-CMF), a high-level process capability maturity framework for managing the IT function within an organization [4,5,6,7,8,9]. The IT-CMF has been developed within a consortium from practice and academia. The framework identifies a number of critical Information Technology (IT) processes/capabilities, and describes an approach to improving maturity for each process/capability. Based on "open innovation" principles [13], we find the design environment with the IT-CMF is particular challenging and interesting. The objective of this paper is to examine the design process within a research consortium, the Innovation Value Institute (IVI) community. In general the design process follows design science

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principles to create innovative and purposeful artifacts for the problem domain of IT Management. The artifacts are classified according to a nascent output classification schema. Furthermore, the paper focuses on the design process and how specific artifacts are designed. In this way the paper provides an example of design science in action and explores the relation between design process and design artifacts. The contributions show how and what types of design artifacts can be developed, its benefit and challenges within a research consortium

The remainder of the paper is structured as follows: Firstly we review the context and research problem, followed by a discussion on the design science research cycle with a focus on process and output. A core part of the paper focuses on the role of design within the IT-CMF and then discusses a mapping of the IT-CMF artifacts to an emerging DSR output taxonomy. We then discuss the overall design framework for the IT-CMF as well as discussing the IT-CMF classification schema/meta model. Finally we conclude with a short discussion on future research directions for this research.

2 Context and Research Problem

The research presented in this paper has been developed in the context of the IT Capability Maturity Framework, a high-level process capability maturity framework for Enterprise IT and Information Management [7,10]. It includes many separate but related processes, called critical processes (CP) concerning Enterprise IT and Information management.

In recent years much work has been done within the community on identifying, categorizing and describing these processes. Aiming to assess and improve the level of maturity of the information management processes within organizations several maturity frameworks have been developed [1]. For instance one frequently referred contribution is the Capability Maturity Model (CMM) [24].Usually the frameworks include criteria describing distinct maturity levels together with assessment approaches that will assist an organization to identify its specific maturity status. These models are in essence process improvement initiatives and are a means of assessing the maturity of an organization's ability to perform a specific process. Together with the assessment approaches some maturity models provide guidelines for improving the information management system. Maturity in this context refers to evolutionary growth in the capability to manage the information systems or IT processes [17]. More recent approaches relate to IT governance and service management, such as Cobit, CMMI or ITIL that provide reasonably comprehensive IT management descriptions [18].

The models and maturity frameworks provide valuable contributions containing best practices and experiences. Some have been developed with significant input and involvement of practitioners and researchers. There are a large number of IT improvement frameworks. However, most practical relevant approaches and frameworks are limited in providing details on how these were developed and indeed how knowledge was generated.

At the same time, many guidelines and suggestions have been proposed on how to design models and frameworks in the context of design science [14,15,16,23,25]. Similar, as a participative form of research to understand complex problems, Van de Ven [30] as well as Mathiassen and Nielsen [21] describe the principle of engaged scholarship. In this form, producing knowledge is more penetrating and insightful than when researchers work alone. Livari and Venable [19] discuss also Action Research in relation to Design Science. However, many discussions are often on an abstract level with limited insight on the practicality of the design research process and possible design outputs. This observation with the published work underpins the importance of our research with a view to practical aspects of design science presented in this paper. In the case of the work within the Innovation Value Institute stakeholders from six different communities were represented that included industry technology suppliers, enterprise IT executives, public sector IT executives, analysts, Chief Information Officer associations and academic researchers.

3 Design Science Cycle: Process and Output

The development process of the IT-CMF can be seen as elements of an Design Science-oriented research process by which we develop artifacts [3,15,29]. DSR "creates and evaluates IT artifacts intended to solve organizational problems" [15:77]. Two basic activities can be differentiated in DSR: build and evaluate where building "is the process of constructing an artifact for a specific purpose" and evaluation "is the process of determining how well the artifact performs" [28:254]. Brattleteig [2] draws attention to the emerging emphasis in Design Science as a systematic approach to design, making the design activity itself a scientific activity. He contrasts it with 'scientific design' in industrial design that is based on scientific knowledge. Furthermore, while there is no widely accepted definition of DSR, Livari and Venable [19] define DSR as a research activity that invents or builds new, innovative artifacts for solving problems or achieving improvements, i.e. DSR creates new means for achieving some general goal, as its major research contributions. In this view the development process of the IT-CMF can be characterised as Design Science-oriented research process.

The design activity can then be seen as a discipline aimed at developing knowledge about the processes of giving form, about the processes of creating ideas, and about the design process as it proceeds from idea to design result [2]. The research approach is an iterative step-by-step process by which artifacts and theory are generated and verified, with both an inductive and a deductive process being used. Becker et al. [1] for instance have described an example design process in detail. Our research process within the IVI community follows the general design cycle adapted for design science research and included the following phases [29]:

- Awareness of the problem
- Suggestion
- Development
- Evaluation
- Conclusion.

In DSR the primary output of the research activity are artifacts. Thus, developing innovative artifacts is a central activity in Design Science [11]. Typically artifacts in DSR can be in the form of constructs, models, methods or instantiations [20,28]. Thus, the result of design science research in IT is, by definition, a purposeful artifact created to address an important organizational problem. Some aspect of the artifact must be an original contribution to the existing knowledge base of the application domain. Artifact originality is a defining characteristic of DSR which makes the new artifact an innovation to the field of application. In DSR artifacts are innovations which define the ideas, technology, practices, products and services through which the conception, analysis, design, codification and use of IS can be accomplished to deliver value [15]. March and Smith [20] proposed four general outputs for design research, constructs, models, methods and instantiations. As Rossi and Sein (2003) and Purao (2002) added a fifth output to this list better theories are sometimes added [26, 27]. The later output has been discussed as a separate design phase [20], and we have decided not to include in our discussion. The output types are shown in Table 1 below.

Table 1. Design Research Outputs

Output	Description
Constructs	The conceptual vocabulary of a domain
Models	A set of propositions or statements expressing relationships between constructs
Methods	A set of steps used to perform a task – how to knowledge
Instantiations	The operationalization of constructs, models and methods

4 Design within the IT-CMF

This research is being undertaken in conjunction with the Innovation Value Institute (www.ivi.ie). IT Management is being investigated using a design process with defined review stages and development activities based on the DSR guidelines advocated by Hevner et al. [15]. During the design process, researchers participate together with practitioners and subject matter experts within research teams to capture the knowledge and views of key domain experts. Catering for constraints often faced when working in collaboration with practitioners, and individual expertise a design science oriented research process has emerged within the community. Within the design process, IT processes are assigned to a certain design stages that are illustrated in Figure 1. The design process for the IT CMF is divided into four phases separated by stage reviews with key deliverables at each stage. As indicated in Figure 1 at phase 1 references relating to the artifacts are consulted and expanded with input from group of key opinion leaders, subject matter experts, industry and academic literature. At phase 2 comparisons are made with artifacts in industry frameworks and industry best

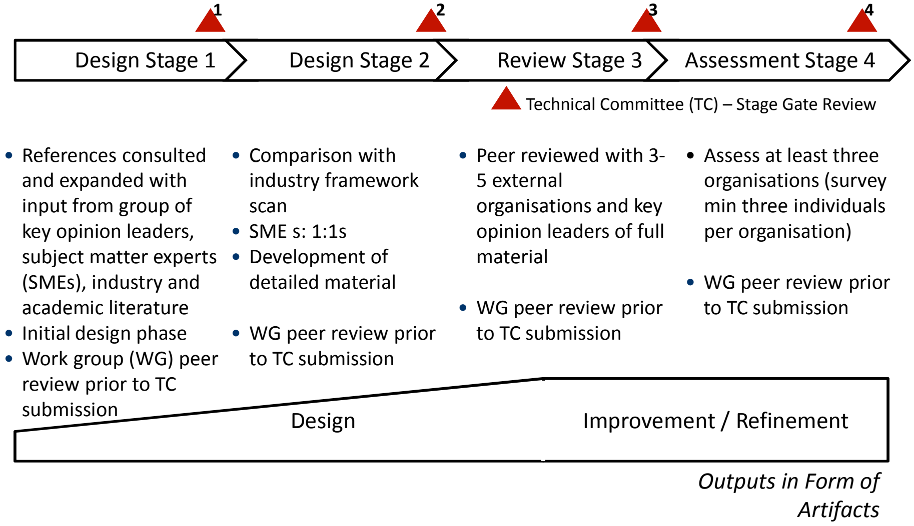

Fig. 1. IT-CMF Design Process (adopted from Innovation Value Institute)

practices. At phase 3 the artifacts are reviewed with 3-5 external organisations and key opinion leaders. At phase 4 the artifacts are exercised through field experiments in at least three organisations.

In Table 2 we have summarised the main outputs in form of Design Artifacts. The table is categorised according to Table 1.

Table 2. Mapping of Artifacts to DSR outputs

Design Science Output	Examples IT-CMF
Constructs (the language to specify problems and solutions - with)	• Templates for CP Definition & Interdependencies • Glossary • The IT Capability Context Diagram • The IT-CMF classification Schema
Models (the representation of the identified problems and future solutions - what)	• Descriptions for a particular CP and models • The IT-CMF control loop • The IT-CMF integrated maturity states • The IT-CMF individual maturity states per macro-process • The IT-CMF critical process listing • Individual CP CMF`

Table 2. *(Continued)*

Methods (the procedure how to solve these problems and develop the future solutions)	• Descriptions of transitions to increase maturity • Assessment Approach • Macro-process PMOs (Practices, Metrics, Outcomes) • Critical-process PMOs • The design/research process can also be viewed as a method to design artifacts
Instantiations (the physical conversion as proof-of-concept of the prior artifacts - use)	• Assessment tool (software) • IT-CMF Development environment • Macro-Process Key Characteristics • Critical-Process Key Characteristics • IT-CMF Assessment Instrument • Individual CP assessments

5 Research Dynamics: Design Framework for IT-CMF

Figure 2 illustrates the relationship between the design process and design artifacts, adapted to the design and application process. The meta-model or classification schema facilitates a consistent and concise method, which in turn allows for their application in a goal oriented, systematic and repeatable fashion. According to Gutzwiller [12] activities are the construction of tasks which create certain results. These activities are assigned to roles and the results are recorded in previously defined and structured specification documents. The techniques comprise of the detailed instructions for the production of the specification documents. Tools can be associated with this process. The resulting result documents are based on a meta-model that describes the information model of the results (see Figure 3 below). Results are then applied to organizational contexts by adapting the result documents. The approach forms three elements: Design process, result documents and the adaption/application to organizational contexts.

In order to operationalise the design process and design artifacts, we developed a meta model describing the results in form of a maturity model for a critical process within the IT-CMF. This helps to ensure consistency among different CP descriptions (result document). The IT-CMF meta-model, presented in Figure 3, contains important elements of the IT-CMF maturity model. The meta model complements the development process as well as the process of applying the maturity model within various organizational contexts.

Each process within the IT-CMF is supported by a set of documents, which include for example references, descriptive examples, publications and core presentation slides. Furthermore each process contains a set of capability building blocks (CBBs) that describes the key capabilities to achieve the expected result of the process. Associated

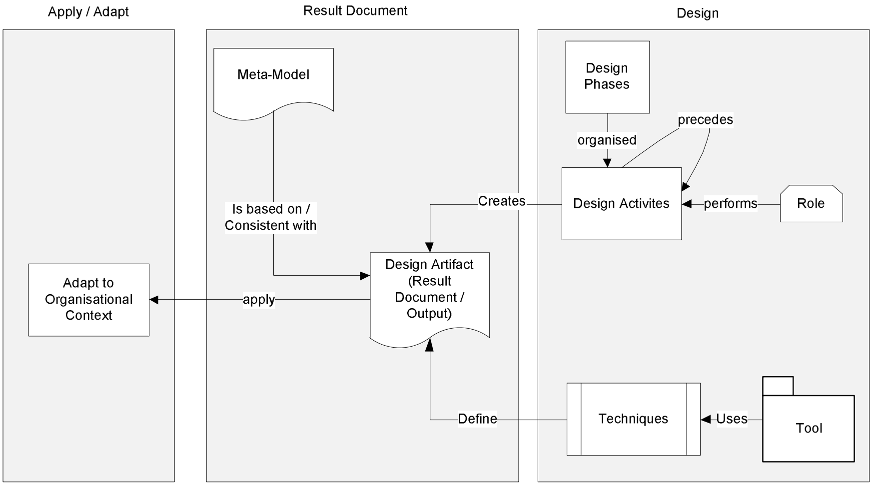

Fig. 2. Design Framework of the IT-CMF

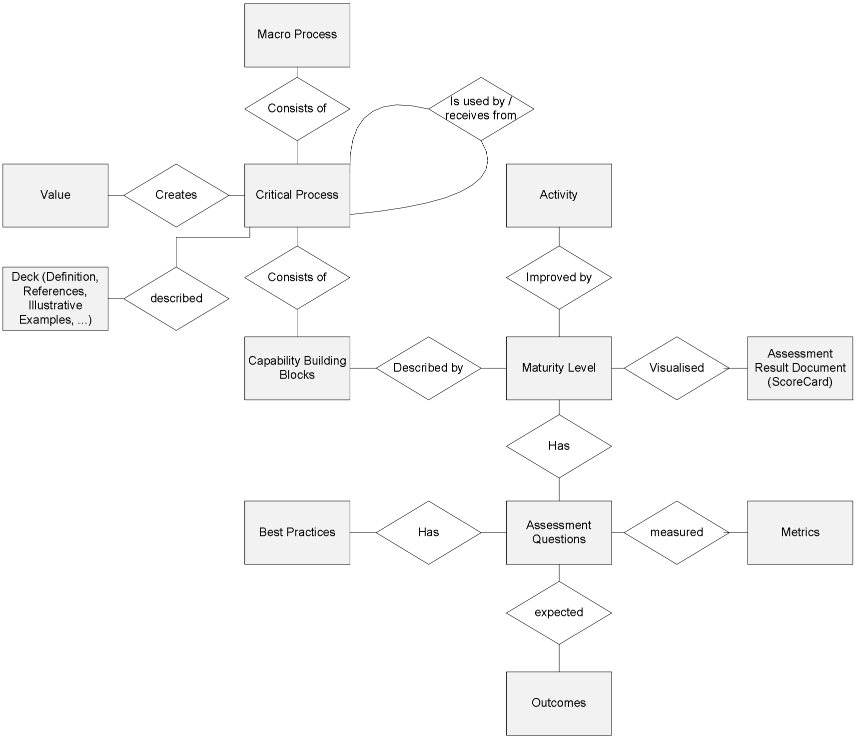

Fig. 3. IT-CMF Meta-Model

with each CP is a maturity profile referring to the level of value and assessment elements describing maturity practices, metrics and outcomes. Different levels of maturity define maturity profiles for each CBB that assigned with activities represent the details of the transformation from one maturity level to another. These transformation activities in fact represent an improvement process along the maturity profile.

Application of the CMF within Organizational Contexts

Once developed and evaluated, the maturity models for processes can be applied to various organizations. Important aspects are (1) the adaption of the model to organizational characteristics, (2) the assessments of the maturity of CBBs as well as (3) providing guidelines for improvements. In this regard the IT-CMF maturity model can be considered as providing models in form of state descriptions (e.g. CBB maturity levels and assessment techniques) and methods elements in form of guidelines and activities to improve the current situation. In the context of Design Science the first aspects can be described as a model perspective describing various maturity levels (states) of organizations whereas the second aspect describes guidelines to improve the current situation of organizations in form of method components [22].

6 Concluding Remarks and Further Research

The work presented in this article describes the design process and artifacts in relation to developing the IT Capability Maturity Framework with the Innovation Value Institute. We presented the guiding principles of Design Science and refered to engaged scholarship. Furthermore we described the design process together with a meta-model for describing key components of the IT-CMF maturity model. In addition we summarized the application of the IT-CMF to organization contexts, and discussed both model and method components of the IT-CMF.

Although our research provides a valuable contribution for other Design Science work, the research in this article could only provide an overview and the general design process. Indeed in our further research we aim to detail the design steps and together with evaluation approaches for assessing the quality of design artifacts. Another route for further research is the further development and improvement of the IT-CMF. Additionally we plan to use a behavioral science research approach to compliment the pragmatic validation approach of DSR as the IT-CMF artifacts are deployed across specific organizational contexts. The research will help specifically provide information on the value of deploying the developed artifacts and the value accrued from raising maturity levels. As presented, the principles of design science and engaged scholarship have illustrated the benefits and thus will assist us in our future work on the IT-CMF.

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Detailed Design Science Research and Its Impact on the Quality of Design Artefacts

Łukasz Ostrowski

School of Computing, Dublin City University, Glasnevin, Dublin 9, Ireland
`Lostrowski@computing.dcu.ie`

Abstract. Based on reviewing foremost literature, this paper discusses various design science research methodologies and related to them case studies. I have identified common activities that may create an outline of a reference model for design science. The model will apply to a design step activity in any design science methodology. I also present my assumptions, based on structured interviews, that the current abstract level of design science methodologies may cause poor quality of content of its artefacts. As for the measurement of quality, I discuss representational information quality dimensions. The contribution of the paper is to relate design sciences theories with research activities by providing a design science process oriented framework. My observations indicate that it will help improve the quality of design science artefacts.

Keywords: Design Science Methodology, Systematic Framework, Design Science Literature Review, Information Quality Dimensions.

1 Introduction

Over the last years design science (DS) research has received increased attention in computing and information systems (IS) research [1,2]. It has become an accepted approach for research in the IS discipline, with dramatic growth in recent, related literature [3,4].

Design science focuses on creations of artificial systems. It addresses research through the *building* and *evaluation* of artefacts designed to meet identified business needs [5] . Understanding the nature and causes of these needs can be a great help in designing solutions; however, design science does not limit itself to the understanding, but also aims to develop knowledge on the advantages and disadvantages of alternative solutions [6]. Literature reflects healthy discussion around the balance of rigor and relevance [5] in DS research, which reflects it as a still shaping field [7,8] .

In this paper I discuss current work on design science methodologies. I observed that numbers of proposed methodologies for design science increased in recent years. These methodologies proposed various models. These models contain steps, which invoke certain activities. However, these methodologies do not provide much detail on implementation of the activities. My aim is to investigate the activities further and construct a reference model based on them. The reference model will connect

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directions of design science theories with its practical application. Such a model will state how and in which order to conduct the activities.

Mostly, I concentrated on common activities that occurred across various DS methodologies in a step in which an actual artefact is being created/produced/developed. I found it as one of the least explained step across proposed design science models. Some researchers refer to the step as build [9], design & development [10], design solution [11], or develop (construction) [12]. For the purpose of this paper I refer to it as the construction step. I observed that current DS methodologies do not provide much detail on how to conduct such a step. Upon conducting structured interviews with IS researchers, I identified it as potential risk for DS artefacts. Lack of details in the construction step may cause poor quality of the content of the artefact. I propose representational information quality dimensions as the measurement of the quality.

The paper is organized as follows. First, following Offerman's [11] claim that not many guidelines are provided in IS literature on the construction step. I conduct DS literature review focusing on related case studies, which give more insight into activities that are used in that step. After analysing findings I propose main activities for a reference model, which will create the outline of the construction step. The reference model can be applied regardless of chosen DS methodology. It refers to the construction step as opposed to a specific DS methodology. By activities, I mean tools, methods, and/or actions taken by researchers to gain sufficient knowledge in order to create/produce/develop an artefact. It's worth noticing, that these activities, even actually used, were not mentioned in the selected methodologies, but Offerman's [11]. Next, I present, that DS methodology in practice is still too general to be rigorously applied. This issue could be observed in the quality of content of artefacts. Then, I introduce representational information quality dimensions as measurement of quality. An example of a survey that uses these dimensions is presented. Finally, I discuss further research on the reference model, its positive impact on the quality of the content of artefacts, and further work.

2 Methodology and the Reference Model

Methodology is the philosophy of the research process which "includes the assumptions and values that serve as a rationale for research and the standards or criteria the researcher uses for interpreting data and reaching conclusion''[13] .

Views and recommendations on the DS methodology vary among papers, e.g. [14,15,10]. One set of guidelines, by Hevner [5] , has been widely cited. However, there are concern with their high-level and lack of specificity [12]. Just few papers revealed a few instances of the actual application [16] .

Thus, though generally highly regarded and widely cited, DS methodological guidelines from the precursors Hevner [5] and Walls [17] are seldom 'applied', suggesting that existing guidelines and methods are insufficiently clear, or inadequately operationalized - still too high level of abstraction [10]. Alturki [12], inspired by Winter [8] stating that there was a "lack of a commonly accepted reference process model for DS research", structured DS Roadmap to guide researchers across DS. In my opinion, this is the most comprehensive collection of design science theories to date. I understand his work as a combination of most, hitherto known, DS models. However, descriptions of activities that are needed to conduct steps in such models were only briefly mentioned. I define this combination as horizontal – combining steps without getting into lower levels, where activities are carried out, to construct one common model. As a result his Roadmap indicates directions and milestones for design science research.

On the contrary, I try to focus on the construction step, and identify activities of it, which are mentioned in various models across design science methodologies. Then I construct a model based on those activities. As a result I detail the construction step, and offer an additional layer to design science. The model can be seen as a reference model that can be applied to any DS methodology, where the construction step occurs. I call this a vertical approach (as opposed to the horizontal one). I combine activities of construction steps from various design science methodologies to build a model that decomposes the construction step by creating an additional sub-level of it. In other words, I concentrate on identifying activities that may take DS research methodology (i.e. the construction step) from high level of abstraction to more standardize and practical one.

This different approach requires examining DS methodologies individually. Alturki's Roadmap [12] offers combination of most DS methodologies, but their description is missing. Gathering information on what activities were used in those proposed methodologies involves examining them based on the official publications. In addition, some DS methodologies focus on development of artefacts for specific aspects of IS [18,3]. Having this in mind, DS literature review of the construction step could not be based on Alturki's work. However, it was used as a reference to check numbers of identified DS methodologies.

The main source of conceptions for the various design science methodologies was existing DS literature. I used the systematic literature review [19] approach, beginning with the most cited papers - e.g. Hevner [5], March [9], gradually reaching towards other relevant publications, and paying particular attention to related special issues and specialist conferences. Closer attention was paid to papers largely methodological, as well as articles that are methodological in part only. Through that process, 40 key articles were identified from which a glossary of DS-related concepts and definitions was compiled.

Those articles revealed four main streams in DS, illustrated in Table1. It can be observed that roots of DS reached out for methods of systems development life cycles at its first shaping stages. Later, when DS methodologies started being introduced, I noticed that some researchers' proposed methodologies for IS artefacts represented combinations of DS and other research paradigms as well. For example, action design research[18], which combines design and action research. Those examples were classified as variations of design science methodologies.

Even though there were different DS methodologies, a common agreement on their outcomes were reached. Researchers define the DS outcome as an artefact, in form of a construct, model, method, and an instantiation[9,5]. Researchers understand artefacts as "things", i.e. entities that have some separate existence[28]. Constructs are defined as "concepts" and "conceptualizations" [9]and "vocabulary and symbols"[5]. These

Table 1. Four streams in DS

Systems Development Life Cycle	*Design Science Theory*	*Design Science Methodology*	*Variations of Design Science Methodologies*
Archer [20]	Walls [17]	March [9]	Baskerville [14]
Takeda [21]	Markus [22]	Purao [23]	Carlsson [3]
Nunamaker [24]	Gregor [25,26]	Hevner [5]	Sein [18]
Eekels [27]	Goldkuhl [28]	Cole [29]	
	Pries-Heje [30]	Vaishnavi [31]	
	Venable [32]	Peffers [10]	
		Offerman [11]	
		Alturki [12]	

constructs are abstracted concepts aimed for theorizing and trans-situational use. “Conceptualizations are extremely important in both natural and design science. They define the terms used when describing and thinking about tasks” [9]. Models are not conceived as abstract entities in the same way as constructs. “Models use constructs to represent a real world situation – the design problem and its solution space…” [5] “Models aid problem and solution understanding and frequently represent the connection between problem and solution components enabling exploration of the effects of design decisions and changes in the real world.” [5]. A method is defined as “a set of steps (an algorithm or guideline) to perform a task” [9]. An instantiation is a prototype or a specific working system or some kind of tool [28]. Most researchers agreed on those form of artefacts (e.g. [33,12]); however, the methodology to achieve them varies [18,14] .

I observed that researchers (e.g. [31,34]) clearly pointed out to the *construction* step as the one where the artefact is formed; however, without giving much detail on how to approach it. My observation was in line with Offerman’s [11] claim that not many guidelines were provided on construction step in IS literature. Having learnt that, I decided to extend the research area to DS case studies, which were used to validate those proposed methodologies.

Upon distinguishing construction steps from various design science methodologies (Table 2), I reached for activities. I looked for undertaken activities in relevant case studies. Then analysed these activities in regards to the source from which information on artefacts was gathered. I observed that two main streams could be distinguished: relevant literature and collaboration with practitioners from the field, in order to construct artefacts.

My search indicated, that in 78% of all case studies, researchers gathered relevant information from literature and practitioners from the field. The rest 22% focuses mainly on relevant literature. Just practitioners as the only source of information did not occur. By literature review I understand activities that lead to review the critical points of current knowledge and/or methodological approaches on a particular topic (e.g. the seeking solution). It may be seen as preparation, gathering knowledge, or

Table 2. Construction steps of artefacts

Papers	*Step to build artefact in DS*
Offerman [11] , Goldkuhl [33]	Design solution
Peffers [10]	Design and development
Vaishnavi [31]	Development
Hevner [5]	Design as a search process
Carlsson [3]	Review extant theories, knowledge and data
Alturki [12]	Design (Construction)
Baskerville [14]	Declarative search for specific solution
Sein [18]	Building, Intervention and Evaluation

building foundation on which the artefact is being constructed. Collaboration with practitioners reveals that the act of designing does not occur in isolation. It is a living process engaging practitioners from the field. The bilateral construction of an artefact falls within the scope of engaged scholarship presented by Van de Ven. [35] . The level of engagement may depend on the nature of seeking artefacts. Mostly, researchers contacted practitioners by organising focus groups, structured interviews, or surveys.

These two main activities withdrawn from DS literature may state a core for a construction step model. Such a model could be seen as a reference model to any DS research methodology. It's a reference model because it takes into account only common activities from various design science methodologies. Some activities that were not considered might still be crucial for the purpose of certain methodology. Nevertheless it brings together activities that were spread across and existed in practical usage of design science, but roughly mentioned and describe in their methodologies. As a result I see that the model applies to the construction step in majority of various design science methodologies and fills out the gap between the design science methodology and the actual activities carried out (Figure 1). However,

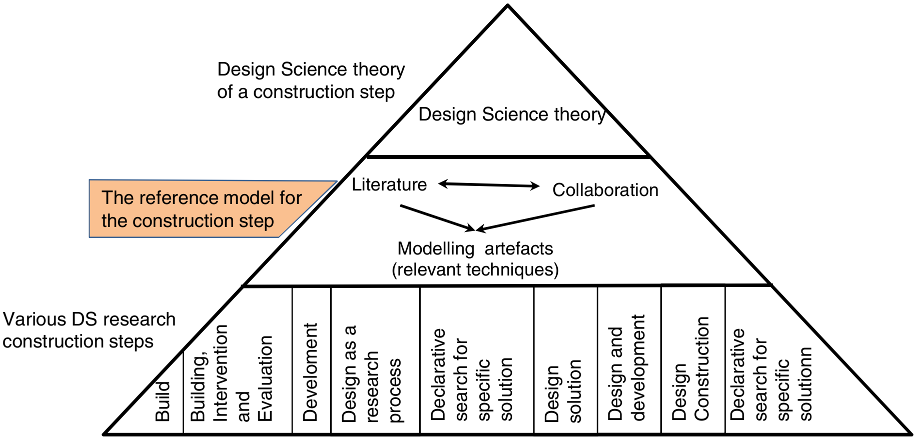

Fig. 1. Place of Reference Model in DS

these activities are already conducted intuitively by IS researchers. The aim is to standardize it into a right level. I believe that structuring these activities will provide the necessary rigour, and the lower abstract level of design science. The reference model will provide description of activities and indicate an order which they should be undertaken in construction step regardless of used DS research methodology.

The double arrow of the reference model on Figure 1, between the literature and collaboration, indicates that information gathered from one source should be confronted with the other. In the sense, how the theory from literature is actually used in practice, and how the best practice reflects theory. As doing so, the gathered information can be double checked and its relevance to the artefact become more solid. Because of the general character of the reference model, it will play role of facilitator guideline rather than solution adviser for certain artefacts.

3 Design Science Methodology in Practice

In the previous section I presented two main activities that play a crucial role in designing an artefact. They are: conduct of a relevant literature review and engagement with practitioners from the field. In this section I present these activities in practice, and which design science methodology is adaptable by IS researchers. In addition I discuss pragmatic application of the reference model. I arranged a several structured interview [36] sessions with researchers from a consortium. They were conducted for a period of 3 months.

The researchers work concentrate on producing an artefact that will cover most of IT management processes which are central to IT organizations, and are defined for a particular domain within it. The artefact already contains many IT management processes, which are categorized in four macro processes within a high-level overarching process. Some of them take inputs from and provides outputs to other processes. Therefore researchers are divided into working groups whose goal is to produce one IT management process. This is the artefact that each working group produces following DS methodology. The community of the consortium is comprised of university-based academic researchers and industry-based practitioner-researchers drawn from over 40 companies located throughout the world. I believed that the comprehensive work being done in there would give me reliable insight of Design Science paradigm in practice.

3.1 Case Study

The case study consisted of structured interviews. In this case data was collected by the author of the paper. Interviewers read the questions exactly as they appeared on the survey questionnaire. The choice of answers to the questions was often fixed in advance, though open-ended questions also occurred [37] . The order in which questions were asked of respondents was standardized. This way, the questions were always answered within the same context.

I was able to contact researchers, responsible for 5 different artefacts, who shared the research experience. My questions regarded how they approach design science research in the work environment; share knowledge between working groups and each other; and what difficulties occurred with design science methodology.

I found that all groups followed the Design Science methodology provided by Peffers [10] . However, I observed that this methodology only showed direction of the research, advising what the proper sequence of steps was rather than guiding or stating indicators on how to do these steps. This led to different perception of how to do design science in each working group. Since some produced artefacts are inputs for others, the different perception could cause differences in quality of artefacts. The expected requirements might not be met. If that happened, a working group would have to adjust an artefact before they start working on their own one. That could lead to inconsistency, and a misinterpretation of the artefact. In addition, each working group had determined their individual milestones, which impeded communications between groups. Sometimes, waiting for other group to reach the right milestone delayed other groups' work.

Some groups focused mainly on best practices, relying on their own experience and known best practice. Others did not know if the found literature was sufficient. On the other hand some academic researchers provided a wide and comprehensive knowledge from literature, but the seeking artefact was lacking in application aspects. These interviews revealed that following Design Science methodology is possible to produce artefacts. At the end, each working group developed artefact that showed utility [5]. However, the current abstraction level of design science gave the researchers too much flexibility, caused unstructured approach to their artefacts. As a result, some artefacts might not provide as good utility as they could have. Combining those artefacts into one, that would cover all IT management processes as the consortium planned, will take much more time than expected.

I believe that if the reference model was available, the work would be carried out more smoothly at the consortium. The artefacts would be easier to combine and work with. This is because the reference model offered a structured way of constructing artefacts at the low operational level. The researchers would not be struggling with defining activities and their orders. If all artefacts were constructed in the same balance between rigour and relevance [5] , combining and analysing them would cause less misinterpretation. With the reference model would be easier to track progress. In addition the information provided by artefacts would be more even, but what would be the quality of the information, and how to measure?

The artefacts by providing solutions to problems show their utility [5]. Utility is judged by practitioners regarding the seeking problem. The problem I observe is how to measure the quality of the content of the artefacts, which is a subjective matter. The next section deals with this issue.

4 Information Quality Dimensions for Design Science Artefacts

In previous section I presented that there are still some issues regarding construction of design science artefacts. I claimed that the current abstraction of design science methodology may lead to artefacts of poor information quality. I introduced a reference model, which will standardise the construction and improve the quality of artefacts. In this section I present information quality dimensions that can be used to measure the quality of design science artefacts.

The goal of design science artefact is to produce utility with respect to a constituent community [5]. For IS researchers, the constituent community are the practitioners. Research must address the problems faced and the opportunities afforded by the interaction of people, organizations, and information technology [5].

Practitioners' problems and opportunities refer often to revenue increase or costs reduction through the design of an effective business solution. The design of organizational information systems plays a major role in enabling effective business processes to achieve these goals [5]. Since artefacts meant to be solutions to these goals, they should comply with, and be perceived through dimensions of information quality.

Information quality is defined as information that is fit for use by data consumers [38], consumers in our case are the practitioners. Information quality is a very broad field extensively developed over last two decades. Because of its magnitude I decided to reach only for one facet in the discussion. The utility of artefacts is a subjective matter. According to users' expectations, users evaluate the extent to which information products (i.e. the artefacts) are fit for the intended use. Since subjective standards and expectations vary from person to person, each user will generate an individual opinion [39] . To integrate and standardise these opinion I reached for representational information quality [38]. It uses subjective assessment methodologies [40] such as surveys, and interviews to measure information quality by information consumers (i.e. practitioners) [41] .

Representational information quality concerns whether the information is presented in an easily interpretable, understandable, concise and consistent way. Table 3 illustrates measuring items for each dimension.

Table 3. Information quality dimensions and their measuring items

(Sources: Ge, 2008)

IQ Dimensions	Attributes of Items		
Interpretability	Interpretable	Without inappropriate language and symbols	Readable
Ease of understanding	Easy to understand	Easy to comprehend	Easy to identify the key point
Consistency	Consistent meaning	Consistent structure	Presented in the same format
Concise	Concise	Compact	

With these dimensions I can assess DS artefacts to see whether their utility, if granted, carries some flaws that may cause poor information quality. Problems with information quality are often costly, easily pervasive, and disastrous [39] . Therefore, I believe if DS artefact can score high in respect to information quality dimensions, it will support its utility to use of the information (the solution) provided [38].

I predict that consortium's artefacts will show limitations if these dimensions were applied. Two things let me make such an assumption. First, differences in some artefacts were brought into my attention by consortium's researchers during the structured interviews. Second, the current abstraction level of design science, that was used, was not enough to ensure the right balance between rigor and relevance in the artefacts development process. Therefore the quality content of the artefacts should vary. These would favour my assumption that the current abstraction level of design science leads to poor quality information of its artefacts. I believe that a solution to the poor quality artefacts is the reference model, which tends to narrow and level down design science methodology.

5 Conclusion

In summary, I observed that literature and collaboration with practitioners play an important role in constructing/producing/developing an artefact. Based on these two activities I proposed the reference model. Constructing such a model, will narrow and detail the current abstraction level of design science. I discussed that the current level may cause poor quality of the content of artefacts. I suggested that the quality of the content may be measured with representational information quality dimensions. However, most of my efforts will be focused on developing the reference model. Later I will validate it through the information quality dimensions. I am interested if the current abstraction level of design science caused the poor quality of content of design science artefacts. In addition, if the reference model increases the quality.

My future work involves conducting the survey and continues working on the reference model. I use these dimensions in a survey to measure the quality of content of consortium's artefacts. The survey will be conducted among researchers, postgraduate students and potential end users of the artefacts. Data will be collected by means of a web-based system and a paper-based questionnaire. The web-based system will be hosted on my university server. The paper-based questionnaire is used for the postgraduate students and researchers in the university. The participants of the questionnaire are invited to complete the survey on site. The paper-based questionnaire is used to increase the response rate of the survey.

In terms of measurement, based on the observations of McKinney [42] and Lee [43], I use an 11-point Likert type scale. The number 10 is labelled as "Extremely good", while 0 is labelled "Not at all", and 5 is labelled "Average". Most items in the survey will be formulated as "how is the artefact <Attributes of the Item>?" For example, "How is the artefact ease to understand?" The artefacts will be attached to the questionnaire. However, some aspects of the artefacts will not be disclosed because of some intellectual property regulations.

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Evaluation Patterns for Design Science Research Artefacts

Christian Sonnenberg and Jan vom Brocke

University of Liechtenstein, Fuerst-Franz-Josef-Strasse 21
9490 Vaduz, Principality of Liechtenstein
`{Christian.Sonnenberg,Jan.vom.Brocke}@uni.li`

Abstract. Artefact evaluation is regarded as being crucial for Design Science Research (DSR) in order to rigorously proof an artefact's relevance for practice. The availability of guidelines for structuring DSR processes notwithstanding, the current body of knowledge provides only rudimentary means for a design researcher to select and justify appropriate artefact evaluation strategies in a given situation. This paper proposes patterns that could be used to articulate and justify artefact evaluation strategies within DSR projects. These patterns have been synthesised from prior DSR literature concerned with evaluation strategies. They distinguish both ex ante as well as ex post evaluations and reflect current DSR approaches and evaluation criteria.

Keywords: Design Science Research, Evaluation, Artefact, Patterns.

1 Introduction

Design science research (DSR) in information systems comprises of two primary activities: build and evaluate (cf. [1]). Although the evaluation of DSR artefacts as well as of design processes is regarded as being "crucial" [2, p. 82] much of the contemporary information system DSR work focuses on the build activity. Moreover, while design researchers could choose from a rich set of available evaluation methods frequently applied in the information systems (IS) or computer science (CS) discipline, current literature on DSR provides little guidance about how to choose strategies and methods for evaluation in DSR [3, p. 1]. Only recently some initial frameworks have been proposed to help articulating and selecting DSR evaluation strategies [3], [4]. However, the current body of knowledge provides only rudimentary means for a design researcher to select and justify appropriate artefact evaluation strategies in a given situation.

It is the aim of this paper to identify DSR evaluation patterns that can be observed within the DSR literature based on a synthesis of related work. These patterns shall inform design researchers in both the computer science as well as the information systems discipline. Retrospectively, different design activities have been emphasized in the past by both the CS or IS community. While computer scientists focus more on the build activities and technological rigor, IS researchers aimed at understanding the impact of IT artefacts on organizational elements (thus emphasising evaluation

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activities). Design science as a research paradigm integrates both perspectives [5]. The patterns proposed in this paper serve to guide design researchers from either the CS or IS discipline to structure and justify their DSR evaluation strategies.

The paper proceeds as follows. The next section reviews related work on evaluation in DSR by (1) discussing the general structure of a DSR process, (2) presenting sets of DSR evaluation criteria, (3) and describing existing DSR evaluation frameworks. The paper then synthesizes the related work and presents selected DSR evaluation patterns. The paper concludes with a summary of the findings and an outlook on future research.

2 Related Work

2.1 DSR Methods and Implied Evaluation Strategies

To date, a variety of approaches for conducting design science research have been proposed which basically imply a process that includes two high level activities: *build* and *evaluate* [1]. A prominent example of such a DSR process is provided by PEFFERS ET AL. [6]. Their DSR methodology has been synthesised from prior DSR process proposals by other authors in the field and is depicted in Fig. 1.

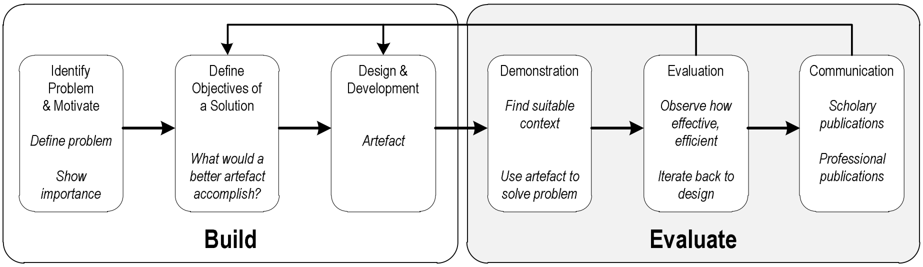

Fig. 1. Build and evaluate activities within a DSR methodology [cf. 6]

What can be seen from Fig.1 and what is also a typical assumption of other DSR processes is that evaluation activities occur ex post, i.e. after an artefact is constructed [3]. In particular, existing DSR methods are characterised as “stage-gate-models” [7], explicitly separating evaluation activities from build activities and even emphasising the build activities over evaluation activities [7]. This separation implies that technological rigor is valued more than organizational relevance [cf. 7].

As a response to these shortcoming SEIN ET AL. [7] propose a DSR method that suggests to conduct build and evaluate activities concurrently to immediately reflect the progress achieved and to trigger artefact revisions early within a design process. The concurrent evaluation accounts for the fact that artefacts “emerge” through the interaction with the organizational context as well as through design interventions, i.e. through reflection and learning activities [cf. 7].

The patterns proposed in this paper also account for the emerging nature of DSR artefacts. They also reflect common DSR evaluation criteria as well as existing frameworks for structuring DSR evaluation strategies. Both, evaluation criteria as well as evaluation frameworks will be presented in the following sections.

2.2 Artefact Evaluation Criteria

Evaluation in DSR aims at determining the progress achieved by designing, constructing, and using an artefact in relation to the identified problem and the design objectives [cf. 8], [1]. To systematically show if such a progress is achieved evaluations should be guided by *evaluation criteria* [cf. 8]. Table 1 below lists DSR evaluation criteria proposed by March & Smith [1].

Table 1. Evaluation criteria for DSR artefacts [1]

	Construct	Model	Method	Instantiation
Completeness	X	X		
Ease of use	X		X	
Effectiveness				X
Efficiency			X	X
Elegance	X			
Fidelity with real world phenomena		X		
Generality			X	
Impact on the environment and on the artefact's users				X
Internal consistency		X		
Level of detail		X		
Operationality			X	
Robustness		X		
Simplicity	X			
Understandability	X			

While this set of DSR evaluation criteria is considered being comprehensive [8], however, the proposed evaluation criteria are not independent of the artefact type under consideration. Aier & Fischer [8] suggest criteria that are independent of an artefact type and particularly apply for evaluating design theories. These criteria are [8]: *utility*, *internal consistency*, *external consistency*, *broad purpose and scope*, *simplicity*, *fruitfulness of further research*. These criteria can be mapped to at least one criteria proposed in [1] (see [8]). Another set of evaluation criteria is proposed by Rosemann & Vessey [9]. Their criteria set aims at particularly ensuring the relevance of a DSR artefact, i.e. if an artefact is applicable in practice. The considered criteria are: *importance*, *suitability*, and *accessibility* of an artefact [9].

When choosing evaluation criteria a design researcher should pay attention to balance the interests of practitioners and researchers [cf. 8] which is a central aim of design science research. E.g. practitioners are interested in the applicability and usefulness of an artefact (relevance) whereas researchers are interested in the validity of the artefact and thus aim at structuring their evaluations appropriately in order to ensure rigour in the process.

2.3 Frameworks for Structuring DSR Artefact Evaluation Strategies

According to PRIES-HEJE ET AL. [3, p. 4] little work addressed the choice of strategies and methods in DSR evaluations. As a response to this identified gap they propose a framework to help researchers building evaluation strategies (normative application) or explicating unstated evaluation strategies in existing DSR literature (descriptive application) [4]. Their framework distinguishes evaluation strategies along three dimensions: (1) *what to evaluate* (design process or design product), (2) *when to evaluate*, and (3) *how to evaluate*.

Regarding the "*when*" dimension PRIES-HEJE ET AL. [3, p. 6] emphasise that "evaluation is not limited to a single activity conducted at the conclusion of a design-construct-evaluate cycle". Typically, evaluations in information systems and in particular in design science research can be conducted at two points in time relative to the artefact construction [7]: (1) *ex ante* where artefacts are evaluated prior to their implementation or actual construction, and (2) *ex post* where artefacts are evaluated after they have been designed and constructed [3, p. 5]. Depending upon how a design researcher chooses to define an actual artefact the ex ante – ex post distinction could possible slide [3].

Besides the point in time an evaluation is considered a design researcher must also decide *how* to evaluate an artefact. Referring to the work of VENABLE [8], PRIES-HEJE ET AL. [3] identify two primary forms of evaluation approaches in DSR: *artificial* and *naturalistic* approaches. Artificial evaluation judges an artefact in a "contrived and non-realistic way" [3, p. 4]. They hold that artificial evaluations (in [4] this is referred to as *evaluation against research gap*) are unreal. As a consequence, results gained through artificial evaluations may not be applicable to real use and thus have to be complemented by naturalistic evaluations which are conducted within an organization. Naturalistic evaluations are critical to ultimately proof the artefact's utility for practice [2] and thus have to be part within any DSR project.

However, it has been criticised that existing DSR methods envision naturalistic evaluations late in the research process and do not account for the fact that artefacts emerge through interaction with organizational elements [7]. Moreover, existing DSR methods provide only limited guidance on how to incorporate the organizational context into evaluations and what organizational elements should be reflected. Stemming from the IS evaluation literature, SUN & KANTOR [10] propose to structure evaluations according to the "realities", i.e. organizational elements, considered. They refer to a "three-realities" paradigm that encompasses (1) *real users*, (2) *real systems*, and (3) *real problems* as evaluation realities. Moreover, they consider three levels of granularity at which the results of using an information system may be judged: (1) *individual item retrieved*, (2) *task completion*, and (3) *impact of the completed task on the motivating goal* of the individual or organization.

Artefact evaluations could incorporate the organizational context both partially or "entirely". Naturalistic evaluations (in [4] this is referred to as *evaluation against real world*) reflect all realities and involve real users using real systems to accomplish real tasks in real settings [3, p. 4].

Another, more general framework has been proposed by CLEVEN ET AL. [4]. In addition to the "what", "when" and "how" dimensions they consider further dimensions (12 in total), e.g. "artefact focus", "artefact type", "ontology", "epistemology", "reference point", or "function of an evaluation". The purpose of their framework is to explicate relevant dimensions (referred to as design variables by the authors, cf. [4]) to structure and configure DSR artefact evaluations and design processes. For an explanation of these additional dimensions we refer to the work of [4]. Compared to the work reported in [3] the framework explicitly lists evaluation methods, however, these are not classified, e.g. into observational, analytical, experimental, testing, or descriptive methods (like in [2]), or into artificial or naturalistic evaluation methods like in [3]. Furthermore, guidelines are missing with regard to how, and why to use a particular method. The patterns proposed in this paper shall provide such guidance for researchers.

<table>
<tr><th>Dimensions</th><th colspan="60">Characteristic Values</th><th>Source</th></tr>
<tr><td>Time</td><td colspan="30">Ex Ante</td><td colspan="30">Ex Post</td><td>[3]</td></tr>
<tr><td>Ontology</td><td colspan="30">Realism</td><td colspan="30">Nominalism</td><td>[4]</td></tr>
<tr><td>Epistemology</td><td colspan="30">Positivism</td><td colspan="30">Interpretivism</td><td>[4]</td></tr>
<tr><td>Perspective</td><td colspan="15">Economic</td><td colspan="15">Deployment</td><td colspan="15">Engineering</td><td colspan="15">Epistemological</td><td>[4]</td></tr>
<tr><td>Position</td><td colspan="30">Externally</td><td colspan="30">Internally</td><td>[4]</td></tr>
<tr><td>Function</td><td colspan="15">Knowledge Function</td><td colspan="15">Control Function</td><td colspan="15">Development Function</td><td colspan="15">Legitimization Function</td><td>[4]</td></tr>
<tr><td>Artefact Focus</td><td colspan="20">Technical</td><td colspan="20">Organizational</td><td colspan="20">Strategic</td><td>[4]</td></tr>
<tr><td>Artefact Type</td><td colspan="12">Construct</td><td colspan="12">Model</td><td colspan="12">Method</td><td colspan="12">Instantiation</td><td colspan="12">Theory</td><td>[4]</td></tr>
<tr><td rowspan="5">Method</td><td colspan="30">Artificial</td><td colspan="30">Naturalistic</td><td>[3]</td></tr>
<tr><td colspan="15">Assertion</td><td colspan="15">Laboratory Experiment</td><td colspan="15">Case Study</td><td colspan="15">Field Study</td><td rowspan="4">[4]</td></tr>
<tr><td colspan="15">Simulation</td><td colspan="15">Field Experiment</td><td colspan="15">Action Research</td><td colspan="15">Survey</td></tr>
<tr><td colspan="15">Criteria-based Analysis</td><td colspan="15">Theoretical Argument</td><td colspan="15">Ethnography</td><td colspan="15">Phenomenology</td></tr>
<tr><td colspan="15">Mathematical Proof</td><td colspan="30">Prototype</td><td colspan="15">Hermeneutic Methods</td></tr>
<tr><td>Realities Considered</td><td colspan="20">Real Task</td><td colspan="20">Real User</td><td colspan="20">Real System</td><td>[10]</td></tr>
<tr><td>Level of Evaluation</td><td colspan="20">Item Received</td><td colspan="20">Completed Task</td><td colspan="20">Impact of Task Completion</td><td>[10]</td></tr>
</table>

Fig. 2. Framework synthesis of DSR evaluation strategy dimensions

The morphological field in Fig.2 synthesizes the frameworks proposed in [3] and [4] and also reflects the "three-realities" as suggested in [10]. It shows the dimensions that have been considered being relevant for DSR artefact evaluations by other authors. In particular, a design researcher might choose from the dimension set to structure and configure particular evaluation strategies [cf. 3]. Since individual dimensions and their characteristic values could be correlated some configurations might emerge "naturally" in a given evaluation context. Such configurations can be generalized into *DSR evaluation patterns*. The next section presents selected patterns that reflect DSR processes structures, evaluation criteria, and evaluation strategies.

3 Evaluation Patterns

3.1 General DSR Evaluation Pattern

It has been criticised that current DSR processes strictly sequence build and evaluate activities and particularly envision the evaluation of an artefact late in the process (see discussion above). The DSR evaluation patterns described below address this limitation and aim at accounting for the emergent nature of DSR artefacts.

Fig. 3 below shows a cyclic high level DSR process including the activities *problem identification*, *design*, *construction*, and *use*. Furthermore, Fig. 3 suggests that each DSR activity is followed by an evaluation activity. Depending on when an evaluation occurs, *ex ante* as well as *ex post* evaluations are distinguished. Ex ante evaluations are conducted *before the construction* of any artefacts, ex post evaluations occur *after the construction* of any artefact [3].

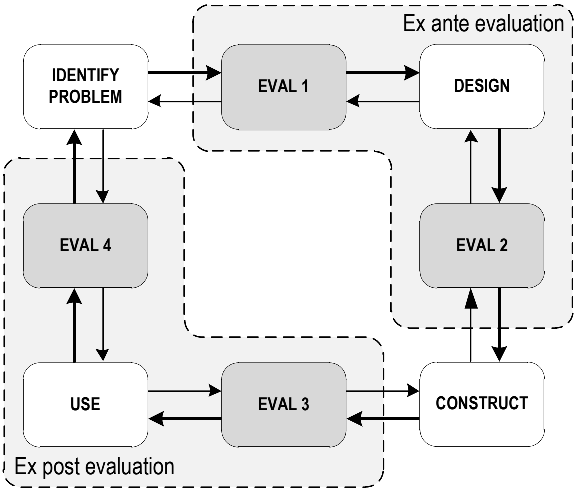

Fig. 3. Evaluation activities within a DSR process

The DSR process in Fig. 3 indicates that there are feedback loops from each evaluation activity to the preceding design activity. Overall, these feedback loops together form a feedback cycle that runs in the opposite direction as the DSR cycle.

The evaluation activities in Fig. 3 have been given generic names. Depending on the context and the purpose of an evaluation within the DSR process different evaluation methods or patterns [cf. 11] could be applied when conducting individual evaluation activities. Moreover, individual evaluation activities could be combined to form composite evaluation patterns. In this case the evaluation activities are highly integrated. An example of such a composite pattern is the Action Design Research method proposed by [7] that links build and evaluation activities by means of principles. Such composite patterns are not discussed here. Instead, the nature of the generic evaluation activities depicted in Fig. 3 is discussed below.

Eval1 Activity

The evaluation of the problem identification activity serves the purpose of ensuring that a meaningful DSR problem is selected and formulated. It should be demonstrated whether the envisioned design problem is important for practice, is novel and thus represents a research gap, or results from the inability of existing artefacts to accommodate a new environment or context. The following methods could be applied:

- Assertion
- Literature review (identify critical issues studies, research gaps, or existing artefacts)
- Review practitioner initiatives
- Expert interview (not listed in Fig. 2)
- Focus groups (not listed in Fig. 2)
- Surveys

All methods finally serve to justify the engagement in a DSR project. Thus, the pattern pertinent to the Eval1 activity is termed *Justify*.

Eval2 Activity

The evaluation of the design activity result serves the purpose of showing that an artefact design ingrains the solution to the stated problem. Since the artefact has not yet been constructed and thus not been applied this evaluation is artificial. Possible design criteria pertinent to this evaluation activity are *feasibility*, *accessibility*, *understandability*, *simplicity*, *elegance*, *completeness*, or *level of detail*. The following methods typically apply to this activity:

- Assertion
- Mathematical proof
- Logical reasoning
- Demonstration – Ex ante
- Simulation
- Benchmarking [cf. 11]
- Expert interview
- Focus group

The patterns pertinent to the Eval2 activity can be termed *assertion*, *demonstration*, *simulation*, and *formal proof*. The first two patterns are discussed in more detail below.

Eval3 Activity

This evaluation activity serves to initially demonstrate if and how well the artefact performs while interacting with organizational elements. In this activity, some inferences on the utility of an artefact could already be made. Since this activity links ex ante as well as ex post evaluations of an artefact it is central for reflecting an artefact design and thus to initiate and inform subsequent iterations of the artefact design activity (see feedback loop in Fig. 3). Both artificial, as well as naturalistic evaluation methods can be applied here. Thus the "realities" considered here may comprise subsets of "real tasks", "real system", and "real users". Prototypes are frequently used at this stage. Possible design criteria may comprise *feasibility*, *ease of use*, *effectiveness*, *efficiency*, *fidelity with real world phenomenon*, *operationality*, *robustness*, or *suitability*. The following methods could be applied

- Demonstration with prototype
- Experiment with prototype [cf. 11]
- Experiment with system [cf. 11]
- Benchmarking [cf. 11]
- Surveys
- Expert interview
- Focus group

The patterns pertinent to the Eval3 activity can be termed *prototyping* and *experimentation*. Prototyping will be discussed below.

Eval4 Activity

This evaluation activity result serves to ultimately show that an artefact is both applicable and useful in practice. Also, researchers might want to theorize on the design principles underlying the artefact. Only naturalistic evaluations will be applied here, i.e. the organizational context is reflected by means of all "three realities" (see discussion above). Possible design criteria pertinent to this evaluation activity are *applicability*, *effectiveness*, *efficiency*, *fidelity with real world phenomenon*, *generality*, *impact on artefact environment and user, internal consistency*, or *external consistency*. The following methods typically apply to this activity:

- Case study
- Field experiment
- Survey
- Expert interview
- Focus group

The patterns pertinent to the Eval4 activity can be termed *case study*, *field experiment*, *survey*, or *applicability check*.

The results of this evaluation activity might stimulate further iterations through the DSR process depicted in Fig. 3. Subsequent iterations may refer to the same or an adapted problem statement. It is also possible that while the problem might not change the purpose and thus the applied evaluation criteria of subsequent evaluations (Eval1, Eval2, Eval4, Eval4) may change. This could be required if a DSR project should be adapted to stakeholder needs that have not been addressed within previous iterations through a particular DSR process.

Below, selected patterns will be presented: the "*assertion*" pattern, the "*demonstration*" pattern, and the "*prototyping*" pattern. These patterns have been selected here for two reasons: (1) they support the justification of artefact designs and trigger the revision of design decisions early in the process, and (2) they very frequently occur within DSR literature, however, their appropriateness within a given design context has been reflected only very rarely.

Evaluation patterns pertinent to the Eval1 and Eval4 activities respectively have been discussed extensively in related work on research methods. What has not been provided so far is that the applicable patterns have been positioned and contextualized within a DSR process as depicted in Fig 3. In this regard our paper provides a contribution as it locates applicable evaluation patterns within a DSR process. The pattern descriptions discussed below are structured according to their *intent*, the *context and applicability*, *description*, *implications*, and *examples* [cf. 11].

3.2 The "Assertion" Pattern

Intent

Make an *informed argument* [cf. 2] about why the artefact design is superior and will work in a given situation.

Context and Applicability

The researcher has formulated a problem statement or specified an artefact design according to some previously stated design objectives. The researcher wants to show that his approach or his design is superior compared to previous approaches or artefact designs. The researcher has prepared a rudimentary test case but did not justify why his data might be "representative". The researcher might also have a theoretical model that informed the artefact design and thus expects the artefact design to work as predicted or prescribed by the theory.

Description

1. Specify the problem or artefact design (formal language, diagram, text).
2. Describe an instance of a business problem.
3. Provide a *test case* or *theory*.
4. Demonstrate how the artefact is expected to work given the specified constraints and data set.

Consequences

The researcher might provide a sound motivation of why an artefact design is expected to solve a particular business problem. However, providing an informed argument is considered being a "weak example favouring the proposed technology over alternatives" [12, p. 26]. Assertions are potentially biased since the goal is not to understand the difference between alternative designs but to demonstrate that an artefact design is superior [12]. Assertions are the weakest form of validating an artefact and should be avoided except for motivating the design of an artefact.

Examples

1. A study reported in [12] found that among the papers that have been analysed in the computer science discipline predominantly make use of assertions to validate their solutions. A representative generic example of an assertion used in computer science is provided in [12, p. 30]: "Use the tool to test a simple 100-line program to show that it can find all errors."

3.3 The "Demonstration – Ex ante" Pattern

Intent
Demonstrate that an artefact design embodies the solution to the identified business problem and works in the context of an artificial setting.

Context and Applicability
The researcher has specified an artefact design according to some previously stated design objectives. The problem statement as well as the artefact design do not allow for formally proving the correctness of the artefact design. No prototype has been constructed so far. The researcher might want to demonstrate that the design properties of the artefact allow for solving the business problem or even the class of problems of which the concrete business problem represents an instance.

Description

1. Specify the artefact design (formal language, diagram, text).
2. Describe one or more instances of a business problem.
3. Construct a *test case* or *analytical example* by providing relevant input data and constraints.
4. Provide justification for the constraints and data values.
5. Demonstrate how the artefact is expected to work given the specified constraints and data set.

Consequences
The researcher may show that the artefact design already embodies a solution to the identified business problem. It is also expected that exercising analytical examples may trigger design revisions early within the design process as the researcher may identify inadequacies [cf. 11]. The use of standardised test cases or test cases that have already been applied by others may strengthen the significance of the evaluation results.

Examples

1. CHEN [13] (taken from [11]) provided a description of his entity-relationship model and the associated diagrammatic technique and demonstrated its use by means of an example.

2. vom Brocke et al. [14] synthesised accounting constructs and business process management constructs into a process-oriented accounting model. They demonstrated how their accounting model could serve to provide information on value generation in business processes by means of an example that has already been presented in other publications by other authors.

3.4 The “Prototyping” Pattern

Intent

Implement an artefact design as a generic solution to demonstrate the artefact’s suitability [5].

Context and Applicability

The researcher has specified an artefact design according to some previously stated design objectives. The artefact design is operationalizable and the researcher could provide an implementation of the solution by means of a prototype (individual software, new module or service within a given system). The researcher might want to demonstrate that the artefact works in practice and solves the identified business problem, i.e. it is feasible. The researcher might want to see how the artefact interacts with organizational elements, i.e. “real tasks”, “real users”, or “real systems”.

Description

1. Specify the artefact design (formal language, diagram, text).
2. Provide an implementation according to the artefact design specification. Construct a *test case* or *analytical example* by providing relevant input data and constraints; or select a “real task” in an organization.
3. Select “real users” if prototype is applied within an organizational context.
4. Use the prototype.
5. Assess whether the tasks could be solved as intended by using the prototype.

Consequences

The researcher could show that artefact design and its corresponding prototype are suitable to solve the particular business problem. The researcher could also identify unintended effects of an artefact as they emerge in the interaction with other organizational elements [cf. 7]. In fact, prototyping is regarded as an adequate evaluation method for DSR artefacts [5]. A design researcher could already apply naturalistic evaluations in order to capture the organizational context and infer on the artefacts usefulness before it is actually used within an organization.

Examples

1. Lee et al. [15] defined a method for generating and managing business process design alternatives and they also provided a software prototype to support the use of this method. The prototyping considered a “real task” and “real users”.

2. SONNENBERG ET AL. [16] specified a domain specific language (DSL) for creating and documenting business models along with a prototypical modelling tool. Their prototyping considered a "real task". The purpose was to show that their DSL was expressive and receptive of modelling problems that could theretofore not be solved or could have been solved by means of very complex solutions if not modelled with the presented DSL.

4 Conclusion

Current design science research literature provides little guidance on how to structure artefact evaluation strategies. This paper addresses this shortcoming by presenting DSR evaluation patterns. These patterns have been synthesised from the DSR literature and reflect the structure of DSR processes, DSR evaluation criteria, as well as existing DSR evaluation frameworks. The paper positions the identified evaluation patterns along a general DSR process and distinguishes both ex ante as well as ex post evaluations of DSR artefacts.

While the formulation and presentation of evaluation patterns aimed at supporting design researchers, the presented set of patterns is by no means expected to be complete. Further research is required to specify additional patterns as well as to explicate possible interdependencies between evaluation patterns. This could also contribute to define higher order composite patterns that could be used to even distinguish between different types of DSR research processes and generic evaluation criteria pertinent to such generic research process types.

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Design Research in Search for a Paradigm: Pragmatism Is the Answer

Göran Goldkuhl[1,2]

[1] Department of Management and Engineering, Linköping University, Sweden
[2] Department of Computer & Systems Sciences, Stockholm University, Sweden
goran.goldkuhl@liu.se

Abstract. Design research (DR) is an emergent research approach within information systems. There exist demands to clarify the meta-scientific foundations for this approach. Different responses to these demands are made. There exist attempts to position DR within interpretivism and critical realism. Some scholars have suggested pragmatism as an appropriate paradigm base for design research. This paper has taken pragmatism as a candidate paradigm and it has investigated and elaborated the epistemological foundations for DR. Different epistemic types of DR are identified using a pragmatist perspective. Design research is also related to four aspects/types of pragmatism: Local functional pragmatism (as the design of a useful artefact), general functional pragmatism (as creating design theories and methods aimed for general practice), referential pragmatism (focusing artefact affordances and actions) and methodological pragmatism (knowledge development through making).

Keywords: design research, information systems, research method, pragmatism.

1 Introduction

There is a growing interest for design research (DR) within the information systems (IS) community. This is an interest for the explicit notion of design research (or design science). There has been a great interest for design oriented research within IS for long time, although it did not receive such label ("design science") until mid 90'ies [1]. Within the DR tradition, Nunamaker et al [2] is considered a seminal paper, but this paper does not even use the terms design research or design science; instead it uses the term "systems development research". There has during the IS research history been many research endeavours comprising the design and construction of information systems. Of course, the introduction of concepts like and design research, design science and design theory has put a lot of focus and emphasis on design research as an acceptable and viable research approach in IS.

There are many important contributions here. The basic conceptualisation of design research made by [1], [3] and [4] has given legitimacy to this research approach. Design research is contrasted to natural/behavioural science (as a standard view of science). In [3] seven normative principles are presented for the conduct of a proper

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DR project. An important aspect of DR is the concept of design theory. There are several views presented concerning constituents and functions of a design theory [5], [6], [7], [8], [9], [10] and [11]. There exist proposals concerning how to conduct DR in terms of process models [12], [13] and [14]. These proposals go beyond the basic division of DR into build and evaluate [1], [3]. Different views on evaluation in DR have been presented in [15]. Differentiations are made between artificial and naturalistic evaluations and between ex ante and ex post evaluations of design process and design product.

Several contributions within the cited literature above do not make a clear distinction between artefact design and the creation of abstract knowledge results. There exist some publications that describe the interaction between design practice and theorizing activities within DR [8], [11], [16] and [17]. It seems important to acknowledge the dialectic relationship between theorizing and artefact design; i.e. the contribution of abstract design knowledge to the design practice and the contribution of empirical data from design practice to theorizing.

There are obvious similarities between design research and action research and there are several scholars who have investigated relations between these two research approaches [13], [18], [19], [20]. Several scholars identify resemblances [18] and [19], while others identify differences and argue to keep them apart [20]. There are approaches to merge DR and action research together [13].

There are several scholars who claim that the *scientific foundations* for DR are *unclear* [14], [21], [22], [23] and [24]. Purao states [21, p 1]: "…the scientific foundations underlying this critical area of the IS field — design research — have remained largely undeveloped. …Over the years, in spite of important writings about design research … philosophical underpinnings of this form of research have been largely unexplored. Without adequate scientific foundations, research in the technology of information systems … continues to be a lost child still searching for its scientific home".

The main foundation of DR seems to be the seminal work by Simon [25] on "the science of the artificial". This involves the study of shaping and using artefacts. This dichotomist view of artificial vs. natural world seems to be a very important basis for design research. This is acknowledged by most (if not all) DR scholars, although some objects to a narrow-minded artefacts-centred approach of DR and ask for a broader socio-technical view [14], [26], and [27].

There are some responses to the demands for a clearer paradigmatic foundation for design research [21], [24] and [28], although these do not make any clear positioning within an established research paradigm. Niehaves [23] attempts to position DR within an interpretivist paradigm. Carlsson [14] attempts to position DR within critical realism. None of these attempts give however clear epistemological grounds for the prospective, normative and useful nature of design knowledge.

Hevner et al [3, p 77] give an indication that DR has *a basis in pragmatism*: "Philosophically these arguments draw from the pragmatists … who argue 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". This argument seems adequate but it can however not be seen as sufficient for finding a paradigmatic home for DR. Some further elaboration is made in [29]: "Pragmatism is a school of thought that considers practical consequences or real effects to be vital components of both meaning and truth. Along these lines I contend that design science research is essentially pragmatic in nature due to its emphasis on relevance; making a clear contribution into the application environment". There are scholars who agree that DR should be positioned within pragmatism [18] and [30], but no deeper paradigm analyses are presented. Hovorka [27] suggests a pragmatist perspective when conducting DR, which seems important but the epistemological foundations remain unsettled.

This paper is a response to the quest for a paradigmatic basis for design research in IS. It takes pragmatism to be a proper basis for DR and tries to elaborate suitable epistemological foundations for DR. In this respect it continues the earlier work in this direction made by [3], [18], [27], [29], [30] and [40]. *The purpose of this paper is thus to investigate and elaborate pragmatism as an appropriate research paradigm for IS design research.* This is a conceptual paper investigating and explicating epistemological grounds of IS design research within pragmatism.

2 Design Research and Pragmatist Epistemic Types

2.1 Knowledge of what-is

Design research is contrasted to (traditional) natural/behavioural research [1] and [3]. A traditional research view is oriented to "what-is". It tries to describe and explain patterns of cause and effect. The main epistemic forms are descriptions and explanations. These are the dominant epistemic forms in positivism. Even if interpretivism is contrasted to positivism (with an orientation to interpretation and understanding), it seems that the basic epistemic attitude is also to reveal "what-is". An empirical field is taken-for-granted as already existing and available for inquiry. Theorizing means, in such traditional views, building knowledge about the world as it already exists; figure 1.

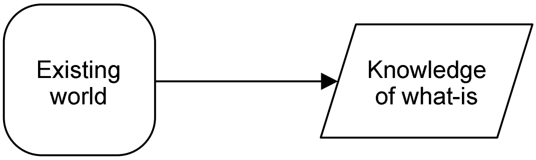

Fig. 1. Knowledge of the world as-is

2.2 Knowledge of to-be

Pragmatism is not only concerned with "what-is". There is also a knowledge orientation to a world that might become ("to-be"). Dewey [31] describes this in an eloquent way: "An empiricism which is content with repeating facts already past has no place for possibility and liberty". Pragmatism sees knowledge as the way to improve action and existence [31]. This means that knowledge should not only describe the past (as patterns of cause and effect), but also be used in a constructive way to contribute to change and improvement. This implies other complementary epistemic forms besides description, explanation and understanding.

Foundational in this pragmatist attitude is a search for what might be; an exploration into social and technical potentials and opportunities. Epistemologically this can be called *prospective knowledge* (knowledge about the possible). There are several other epistemic forms that complement this prospective orientation which will be described below. The pragmatist aim for prospective knowledge should not be mixed up with forecasting, i.e. a mere prognosis about a coming future. The pragmatist attitude is to intervene into the future with the purpose to construct a better world. The world "to-be" is not only a possible world in the pragmatist vein; it is also a desirable world (figure 2). The relation to values and goals is thus obvious. Dewey [31] writes "If we form general ideas and if we put them into action, consequences are produced which could not have been produced otherwise. Under these conditions the world will be different from what it would have been if thought had not intervened. This consideration confirms the human and moral importance of thought and of its reflective operation in experience". There is always a choice of what changes we aim for and this choice is based on *values* explicating what is considered desirable. In pragmatism, a prospective knowledge orientation is accompanied with a *normative* concern. Prospective knowledge (the possible) walks hand-in-hand with normative knowledge (the desirable).

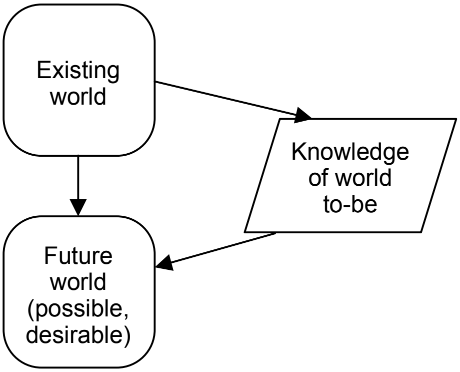

Fig. 2. Knowledge of to-be

Lee & Nickerson state [30, p 4], when writing about pragmatism as a basis for DR: "The practical consequences of interest to pragmatism include not only truthfulness (e.g., whether the predictions or other observational consequences of a scientific theory are upheld by actual observations), but also the usefulness and moral rightness of a belief, idea, concept, plan, decision, policy, design, etc. Pragmatism elevates or restores usefulness and moral rightness to the same level of importance as truthfulness". The concern for utility and usefulness is acknowledged by several DR scholars (e.g. [3]) when making references to pragmatism. However, the normative concern in pragmatism (as an explicit reasoning about a multitude of values) should be equally acknowledged [30] and [32]. Rescher [32, p 175f] emphasises this: "a pragmatism…that cares not just for the *efficiency* of means but for their *appropriateness*, which is a matter of combining a whole range of evaluative factors not efficiency and effectiveness alone but also their broader normative nature".

In IS design research, truth (as justified theory) and utility (as artefact effectiveness) are related to each other as "two sides of the same coin" [3, p77]. It seems necessary to move beyond this metaphorical account. In what ways are truth and utility related? What kinds of epistemic forms are represented? Truth is a fundamental feature of scientific explanations; i.e. the descriptions of cause-and-effects patterns follow conducted observations. Utility is however not described as an epistemic feature. Utility is talked about as the artefacts' effectiveness in solving problems; thus a feature of the artefact. If we convert this to an epistemic level it can in principal be described as *means-to-ends* descriptions. The artefact and its features are seen as means to the desired ends of a use-situation. A means-to-ends description is a cause-to-effect description where the effect is considered as valuable [6]. This means explanations that are "married to" normative statements. Means-to-ends descriptions should 1) be correct (have truth value), 2) comprise effects/ends that are considered desirable and 3) thus express usefulness of means. Means-to-ends accounts are thus "the coins" with the "two sides" of truth and usefulness. Such descriptions of means-to-ends have a *prescriptive force* [6]. They tell what one ought to do. If one aims for a certain end (a desired use situation), then one should arrange certain means (establish an artefact with certain features). Such means-to-ends accounts will thus follow a clause with this principal form: "*attribute of artefact will contribute to value in use*". It is important to add that usually we are not working with one single artefact attribute and one single use-value. There may exist many attributes and many use-values and thus many-to-many relations between these. It is also important to add that there may be conflicting values and that there needs to be trade-off decisions between artefact attributes.

Essential in pragmatism and in design research is that the search for a possible and desirable world is not only a question of conjectures. A pragmatist and design researcher is not only guessing or proposing what might be, but he/she also tries *to install it through action*. It is a process of "knowing through making" [21, p 14].

2.3 Knowledge of from what-is to to-be

Essential in design research is to consider the introduction of new artefacts as *responses to problems and needs* in human practices. A new type of artefact is considered as a solution to a perceived problem. This calls for an understanding and description of problems; the as-is world as a starting point for the design process. However, this as-is description should not be seen as a neutral and value-free account of an existing world. The whole process of going from problems to design and use can be conceived in terms of *pragmatic inquiry* [33]. The existing as-is is considered as a *problematic situation* that needs to be settled through an inquiry comprising observation, evaluation, reasoning and intervention.

The inquiry mode of investigation implies an *evaluation* that goes beyond mere observation and description. A diagnostic mode is applied towards the existing situation in order to reveal problems. Evaluation means judgement and judgement entails explicit or implicit criteria. Goals and values (i.e. normative knowledge) play important roles in evaluation and the establishment of an appropriate cognitive base for generation of design ideas. Evaluative knowledge portrays the world but adds a diagnostic dimension. Evaluative knowledge can be *critical* (when clarifying problems, obstacles and threats) or *appreciative* (when finding strengths and other positive resources). Descriptions and conceptualisations of existing phenomena and patterns of cause-and-effect are included as parts in the evaluative knowledge.

Viewing design research in terms of pragmatic inquiry means the conversion of a problematic situation into a satisfactory one through artefact design. The designed artefact (founded in elaborated knowledge) is a response to the problematic situation. The background situation with elicited evaluative and normative knowledge is a basis for generation of design ideas and their implementation in new artefacts. Proposed artefacts (with certain attributes) should be generated based on background problems and goals. The prospective artefact should thus be grounded in descriptions of *extant problematic situations* and *anticipated positive use-situations* [16].

Design research should not stop with design ideas. They need to be realised in gaugeable artefacts. In DR there are different degrees of implementation, use and evaluation [3] and [15]. In some DR endeavours researchers build a prototype and stop with this. Prototypes function as a proof-of-concept [2], [24] demonstrating the feasibility of the design ideas. Some limited evaluations might be possible to perform on prototypes. A more comprehensive approach implies implementation in full-scale production systems and use-tests in real situations.

Evaluation of designed artefacts (and their features) in limited or real situations will contribute with empirical grounding. The hypothetical means-to-ends knowledge will be transformed into corroborated prescriptions. Such prescriptions may thus express the relation between attributive knowledge (of artefact features) as means to the ends of desired effects in use-situations. So far in the discussion, the focus has been on design as product (artefact features). To this, it is necessary to add a complementary focus on the design process and procedural guidelines for this. It might be possible and desirable to state a prescriptive chain from *procedural guidelines* via *artefact features* to *desired use-situations*.

2.4 Epistemic Types in Design Research: A Summary

As claimed above, there is a spectrum of different, but related, epistemic types in design research. This epistemic spectrum corresponds better with pragmatism than positivism, interpretivism or critical realism. Knowledge about the world as-is is limited to description, explanation and understanding. These epistemic types are not rejected in pragmatism. They are useful as starting points for knowledge development of a world to-be. However, to create knowledge about new possible states of the world, as is done in DR, other epistemic types are also needed.

It is appropriate to group the DR knowledge into three blocks which have sequential relations between each other. The sequences of these blocks should not be seen as strictly linear in the development of them, but rather as an iterative and dialectic manner. The three blocks of DR knowledge are (given their epistemic types):

1. *Evaluative background knowledge* of problematic situations, including conceptualising, explanatory, appreciative and critical knowledge.
2. *Prospective* and *normative knowledge* about possible artefacts.
3. *Prescriptive knowledge* about design procedures and artefact features contributing to stated use values (means-to-ends); this includes attributive and normative knowledge and is based on explanatory and evaluative knowledge.

Pragmatist epistemology helps us to clarify the different epistemic types of design research:

- Evaluative knowledge (making diagnostic judgements)
- Critical knowledge (diagnostic when disclosing problems, obstacles)
- Appreciative knowledge (diagnostic when finding positive resources)
- Conceptualising knowledge (categorising the world; giving definitions)
- Explanatory knowledge (stating cause-to-effect relations)
- Prospective knowledge (stating a possible world; suggesting artefact features)
- Normative knowledge (stating what is desirable, i.e. values and goals)
- Prescriptive knowledge (expressing means-to-ends relations)
- Attributive knowledge (characterising and clarifying properties of objects)

3 Design Research and Four Kinds of Pragmatism

3.1 Four Kinds of Pragmatism

There are many aspects of pragmatist epistemology. Lovejoy identified thirteen different kinds of pragmatism in a classical article [34]. Rescher [32] describes, in a more modern account, several kinds of pragmatism. Within IS research, Goldkuhl [35] has identified three kinds of pragmatism:

- Functional pragmatism
- Referential pragmatism
- Methodological pragmatism

These three kinds of pragmatism follow three types of relations between knowledge and action. Functional pragmatism means knowledge *for* action; that a knowledge item contributes to (improved) action. Referential pragmatism means knowledge *about* actions; that knowledge is formulated in terms of actions. Methodological pragmatism means knowledge *through* action; that knowledge is created through action. A differentiation is made between two types of functional pragmatism [35]. Local functional pragmatism means the knowledge contribution to a specific local practice. General functional pragmatism means that the knowledge contributes to "general practice". These four kinds of pragmatism will be used below in order to further clarify the epistemological foundations of IS design research in pragmatism.

3.2 Local Functional Pragmatism

It is imperative in IS design research to create an IT artefact that contributes to problem solving in a practice setting. This is stated as the first DR guideline in [3]. The artefact in itself is a local practice contribution [35]. In the perspective of local functional pragmatism, it is thus the artefact that is the core contribution. However, there is knowledge accompanying the artefact. In order to create the artefact, it is necessary to make inquiries into problematic situation, as stated above in section 2.3, and corresponding to guideline 2 (about problem relevance) in [3]. This evaluative knowledge will also be a possible contribution to local practitioners enhancing the understanding of their practice. The design process will probably comprise different kinds of models and sketches describing the artefact and its argumentative base. Such design knowledge might also be useful for the local practitioners. Design research demands evaluation; cf. guideline 3 (about design evaluation) in [3]. Evaluations that clarify the usefulness of the designed artefact might also be of value to the local practice.

3.3 General Functional Pragmatism

Even if it is stated as imperative in the DR literature to produce an artefact, this does not make it a science. It is necessary to create abstract knowledge that has value beyond local practice [16]. However, such abstract knowledge should not be aimed only for the research community. In the perspective of general functional pragmatism, such knowledge should be useful for practitioners belonging to different practices. Cf. DR guideline 7 in [3] concerning communication to different stakeholder audiences.

The DR process should generate abstract design knowledge which can take different forms. The genuinely prescriptive character of such knowledge was described in section 2 above: Proposed characteristics of artefacts are means for arriving at certain use-values. Design theories are seen as essential contributions from design research [5], [6], [7], [8], [9], [10] and [11]. Such theories can contribute to design practices in different ways. There are theory propositions focusing on either the design process or the design product.

Methods and design frameworks are sometimes included in design theories. However they can be seen as separate cognitive artefacts with a more obvious prescriptive and practical function than a design theory. There is a long history of developing and using methods within IS. Methods contribute with guidelines and modelling notations and other elements to the design of IT artefacts. They are typical examples of knowledge for action.

3.4 Referential Pragmatism

In referential pragmatism there is a demand for knowledge stated in action terms. This follows the action doctrine in the sociological school of symbolic interactionism: "the essence of society lies in an ongoing process of action - not in a posited structure of relations. Without action, any structure of relations between people is meaningless. To be understood, a society must be seen and grasped in terms of the action that comprises it" [36, p 71].

Translated to IS design research this means that we should make actions clear together with conditions, results and effects of action. We should conceptualise the world as chains of actions and artefacts (i.e. processes and products). The performer of actions (either humans or artefacts) should not either be dismissed from the analysis.

In section 2.3 above there was a demand for explicating artefact characteristics as contributions to values in use-situations. Such artefact features can in an explicit action-theoretic perspective be seen as affordances. An affordance is an existing feature in the environment that can be used for human action; a perceived and factual action possibility [37]. This means that features of IT artefacts are considered as affordances for human action [38].

Design theories and methods should thus make actions and artefact affordances as explicit as possible following the principles of referential pragmatism.

3.5 Methodological Pragmatism

In a pragmatist perspective knowledge is developed through a continual interplay between action and reflection. Action is not limited to observation; intervention in the world is pivotal for development of new knowledge. The idea of design research to build artefacts has a high resonance with methodological pragmatism. Design ideas are elaborated and then tried out through realisation in artefacts. The continual interplay between build and evaluate is an essential trait of DR. A pragmatic inquiry comprises exploration and experimentation as knowledge development strategies. Personal experiences from the construction of artefacts drive the knowledge development. Knowledge through making [21] as a basic idea in DR is methodological pragmatism!

4 Conclusions

Pragmatism is a research paradigm that is concerned with knowledge for action and change. It is explicitly objecting to a mirror view of knowledge [31] and [39]. Knowledge is developed to better cope with the world. Knowledge development is conducted through inquiry processes starting with problematic situations. Judgement and evaluation are essential parts in inquiry. The purpose of knowledge is to improve existence through action [31]. This calls for knowledge that points to a better and possible world and useful ways to reach this improved state. Questions of utility and effectiveness are in pragmatism always accompanied with questions of appropriateness of ends. The search for normative rightness through exploration of different values is essential [31], [32]. In pragmatism, there is dialectic relation between knowledge and action. Knowledge is a means for action and change. But also the other way around, action and change are means for knowledge as ends [41], [35].

Essential traits of design research can best be justified within the epistemological foundations of pragmatism:

- The focus on utility and usefulness and contribution to practice
- Knowledge development through building and intervention
- Problematic situations as a starting and driving point for inquiry and design
- The search for what is possible and desirable
- Going beyond description; aiming for prospective, normative and prescriptive knowledge

Pragmatism has earlier been suggested by several scholars as an appropriate paradigm for DR [18], [27], [29], [30] and [40]. Earlier discussions have, however, been rather limited with a focus on relations between truth and utility [28], [29]. Pragmatism is correctly a paradigm for utility and the search for practical consequences. But pragmatism comprises much more than this. *Normative issues* with explicating and selection of *values* are essential in pragmatism [30], [31], [32]. Knowledge development through *inquiry* is seen as prototypical [33]. This involves observation, evaluation, reasoning and intervention. It is important to move beyond a restricted view on pragmatism as only issues of utility.

The claim in this paper is that *design research has found an appropriate paradigm home in pragmatism.* This should not be interpreted as ruling out other paradigmatic influences. For example, a basic interpretive stance is appropriate to combine with pragmatism. An investigation of a problematic situation as a basis for a design endeavour should be conducted with a search for multitude of socially constructed meanings. One example of an operationalisation of pragmatism is Symbolic interactionism [36], which can be seen as fusion of pragmatist and interpretivist thinking. The pragmatist attitude of blending what ever works together should be acknowledged [42].

It is not only a question of positioning DR paradigmatically in an adequate way. *Pragmatism helps to sharpen design research* in different ways. The clarification of different epistemic types is important. From an epistemological point of view it is not sufficient to describe results from DR in terms of different artefacts as constructs, methods, models and instantiations [1], [3]. The character of different knowledge items is necessary to specify in ways that have been done in section 2 above. Some steps have been taken in this paper to clarify pragmatism as a research paradigm for design research in IS. Future research should take further steps. The relation between inquiry and design should be further investigated. In a spirit of action orientation, there is also a need for exemplifying the paradigm analysis through case illustrations.

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Creating a New IT Management Framework Using Design Science

A Rationale for Action and for Using Design Science

Martin Curley[1], Jim Kenneally[1], and Ralf Dreischmeier[2]

[1] Intel Corporation / NUI Maynooth
{Martin.G.Curley,Jim.Kenneally}@Intel.com
[2] Boston Consulting Group
Dreischmeier.Ralf@bcg.com

Abstract. As Information Technology continues to evolve in an accelerated fashion, it appears that the evolution of associated enterprise IT management practices and standards to harness IT's ever growing potential for business value is lagging. This paper outlines a rationale for the creation of a new IT Management framework, motivated by the current lack of an existing integrating Chief Information Officer (CIO) framework which addresses all of the important processes the CIO needs to manage in order to improve capability and create more value from IT. The paper summarizes an inventory of existing IT frameworks, their utility and possible limitations. The authors discuss the development and adoption of an emerging new approach - the IT Capability Maturity Framework (IT-CMF). Research and development of the IT-CMF used a Design Science research approach coupled with open-innovation and engaged scholarship to develop an integrating value based framework for CIOs. The paper also discusses the research governance process used to oversee the engaged scholarship research.

Keywords: Design Science, Design Pattern, IT Business Value, IT Capability Maturity Framework, IT Management Framework.

1 Introduction

We are moving quickly to a world where information technology underpins much of our global business infrastructure and indeed many aspects of our increasingly global society. And yet as the computing and communications technologies which underpin this advance very quickly, many of the enterprise IT organizations which develop and operate the IT infrastructure and corresponding services are creaking under many pressures. There is no single integrated enterprise standard for designing, operating and supporting this increasingly integrated global computing and communications environment, particularly from a value perspective. In the face of a rapidly changing business and technological vista, many IT organizations are being asked to deliver both substantial cost-savings and business value. This is a very difficult challenge, especially when there is additional pressure from rapidly changing business environments and

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urgency for IT-enabled business innovation. In parallel the pace of technology development continues to accelerate with ever more powerful computing and communications products coming onto the market driven by Moore's law. It appears that many CIOs struggle to convert this latent potential into measured business value.

On the one hand, Chief Financial Officers (CFOs) are often challenging CIOs to take cost out of IT, while CEOs on the other hand are asking CIO's to "show me the money", i.e. to demonstrate the value that IT is generating. Whilst this is already a challenge in itself, CIOs also have other challenges to manage. In particular, managing increasing demand for IT services in firms which often translates into additional workload for the IT organization (Andreessen, 2002). More IT is often a productivity driver particularly in times of recession. However, often, the CIO is asked to deliver this productivity with flat or even declining IT budgets. But not all challenges are purely financial. Within increased business uncertainty there is an increased need for adaptability and agility whilst sustainable IT is becoming a real business requirement also.

Additionally new challenges were introduced by legislation such as Sarbanes-Oxley, which significantly increased the compliance workload on IT organizations. Also with rising energy prices, the cost of supplying power to computers is starting to approach or sometimes exceed the capital cost and increase significantly the total cost of ownership (TCO) of computing. Thus we find that, CIOs are now facing a variety of efficiency challenges.

However, CIOs do not just have to deal with efficiency challenges; they are now facing effectiveness challenges also (Curley, 2004). Increasingly, CIOs have to deal with multidimensional security threats as a common problem because of the dynamics of IT enterprise infrastructures. Consequently, CIO performance is often part-measured on how they can effectively avoid IT systems security threats. These security challenges draw attention to the dual roles of the CIO: the defensive role to ensure business continuity and an offensive role for the business as a whole, which requires accountability to strategic goals and actions, or, helping drive innovation. In parallel CEO's are turning to CIOs as a source of inspiration and a delivery mechanism for innovation. In this context, some business researchers advocate that in the future, CIO may stand for Chief Innovation Officer (Baldwin and Curley, 2007) Westerman and Curley (2008). Figure 1 shows a representation of some of these CIO challenges delineated by efficiency and effectiveness.

There are often complaints about the IT organization's agility with legacy infrastructure and applications that can inhibit an IT organization's ability to deliver new services in an agile fashion (Bharadwaj, 2000). In today's competitive business environments, agility and speed of market entry of products or services is becoming a very strong focus for many businesses. Indeed as the IT/Software intensity of many products (e.g. automobiles) continues to increase, IT is often hardwired into the very fabric of the products and services a company delivers. And perhaps, complexity management is the most difficult challenge CIOs have to deal with in daily operations. As technology development continues to accelerate ahead driven by Moore's law, it appears that the gap between the management practices used to

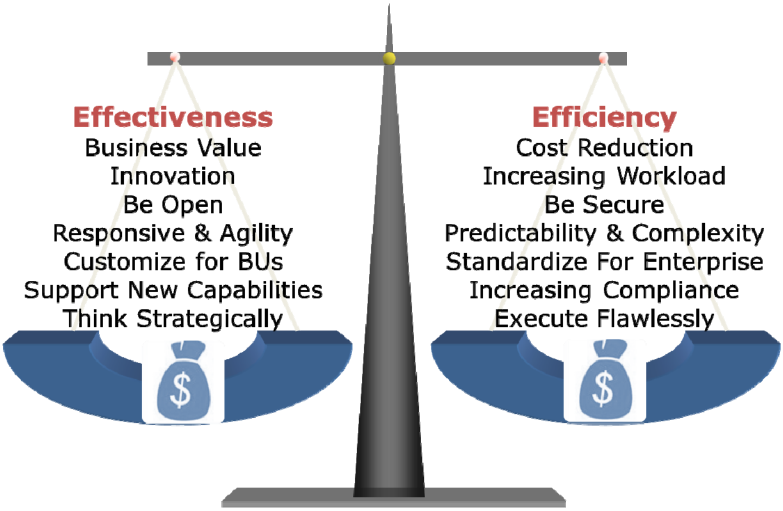


Fig. 1. CIO Challenges

manage that technology and the technology itself continues to increase. Sambamurthy and Zmud (2000) noted that there is a growing gap between scholarly research and the need of practitioners.

The diversity of challenges that CIOs encounter, together with the fast pace of change of the technology industry that underpins IT, makes the environment in which CIO works very demanding one. Despite the existence of numerous frameworks there appears to be no single CIO playbook or integrated framework available to help CIOs navigate these difficult challenges. Many CIOs have to make up their own guidelines and frameworks on the go. This 'juggling' is required continuously with CIOs often in reactive mode struggling to deliver 99.999% availability rather than being proactively focused on enabling business growth through IT. While many IT frameworks exist many of these are targeted at IT practitioners such as Program/Project managers and software development (CMMI), Service Engineers (ITIL) and not at the CIO.

2 New Measures for Success

In the past, IT organizations measured success primarily in terms of their services, for example, higher availability and service-level agreement compliance. Today IT organizations are being driven to expand their success metrics, to include those related to improving the bottom line, for example, increased revenue, improved time-to-market for products, increased market share, factory capital purchase avoidance, and measured improvements in employee productivity (Curley, 2004). As a result, IT organizations need to reduce their costs while simultaneously working with business to apply standard metrics and, methods for forecasting and measuring realized IT business value. Such practices help with identifying previously unrecognized payoffs for IT spending, while actively measuring the ongoing value contribution of IT. A strategic partnership between IT managers and business executives is key to realizing business value.

Strategic alignment between IT and the business is a crucial factor in business value generation (Henderson and Ventrakaman, 1999). Good strategic alignment implies a virtuous circle, that is, a positive bi-directional relationship between IT and business strategy. Importantly, business strategy depends upon robust IT Capability, and IT, which in turn, supports the business strategy. Alignment should be measured not only by the extent to which IT supports the business, but also by the extent to which business strategy capitalizes on IT capabilities. Tallon, Kraemer, and Gurbaxani (2000) produced two interesting findings that: close alignment between IT and business strategy is beneficial; it increases the payoff from IT investments. And more perplexing, increasing alignment beyond a certain point led to a decrease in payoffs from IT investments, primarily due to a loss in agility and flexibility. Indeed, this could mean, IT innovations must be accompanied by innovation in business and management practices.

In a survey of 420 IT professionals reported by Cosgrove (2001), over 48% of those surveyed claimed that their largest IT initiatives were not directly linked with their own organization's business strategy. This strategic dissonance between business strategy and IT spending can seriously impact the financial performance of the business. Effective IT management and planning practices can help move IT and business strategy. A deeper level of alignment can be achieved by validating the IT organization's performance against the firm's values.

3 Why a New Framework?

In the face of diverse challenges there is an increasing interest from IT executives in the utilization of more formal process methodologies. As IT increases in maturity, pressures that have significant impact on the business for reliable performance and improved efficiency, effectiveness and value also grow. Thus, CIOs are applying process methodologies to help stabilize IT and operations (Cameron, 2005). Cameron notes that the traditional home-grown process methodologies of IT organizations are being replaced by more standard approaches such as ITIL and Six Sigma (Motorola, 2008). Process improvement approaches are popular because of the belief that the quality of a system or organization is highly influenced by the quality of processes used within it.

However, without an integrating framework and methodology focused on value, CIOs can quickly find themselves under pressure as they are aware that even if they deliver the next Customer Relationship management or Enterprise Resources Planning solution exquisitely, it will only keep them or their company in the game. In addition, it appears there is a continuing structural problem in the IT profession and industry around managing the returns from IT investments. Few, if any CIOs surveyed by the authors could state the average and aggregate return from their IT investments.

In the context of the many existing frameworks, Rozemeijer et al (2007) mention three important points. Firstly with the growing number of frameworks covering different domains of IT, the coherence between the domains has been somewhat neglected. Secondly that despite the individual domain expertise the overall picture which is needed to deliver end-to-end services across domains has received very little attention in the development of frameworks. Thirdly that most frameworks focus on the relationship between processes within a certain domain, with just a few covering most domains; and even if they do, they lack integration and are too high level to add value. They argue that effective IT service management can only be achieved when both the cohesion of processes within a domain and the inter-domain dependencies are understood. However, even this is not enough as IT service management is only a component of an overall IT capability required to deliver value to an organization. As an example, in typical Enterprise IT many other processes are required beyond IT Service Management such as Innovation Management, IT Governance and Enterprise Architecture.

It would be very useful if CIOs had a high level design pattern (i.e. a generally reusable solution) to the commonly recurring problem of managing IT for business value.

4 The Value of a Framework

Frameworks are important in that they provide a way to consistently, concisely and coherently communicate both strategies and tactics. Often the strategies and tactics can be complex and their interrelationship and connectivity even more so – a well-crafted framework can be a very powerful tool for communication, execution and resultant evaluation of strategies and tactics. Frameworks are also important in that they share information, helping other executives avoid having to discover and learn already existing knowledge and solutions themselves.

Our spanning definition of a framework is that is an extensible structure for describing a set of concepts, methods, technologies and other changes necessary for managing and delivering a value driven IT capability, based on an integrated set of enterprise IT processes (adapted from CERN (2006)). Frameworks can be thought about as a conceptual model used to help understand, tackle and solve difficult issues, often with competing forces. Additionally, frameworks provide a mechanism that guide users through a proper order of steps, applications and data via a common interface (Cern, 2006).

When frameworks incorporate assessment instruments they provide the ability to compare changes over time, helping identify if particular interventions have had a desired effect or not. Increasingly benchmarking, particularly in IT is becoming more and more important and a common framework used across an industry can provide a vocabulary and consistent set of variables to enable benchmarking across parameters such as budgets, capabilities, processes, outcomes, value delivered etc. An additional reason for using a framework is that the half life of stable organizations seems to be decreasing with organizational change a frequent response to organizational or environment changes. Having a framework and indeed capability which is guided by the framework can mean more consistency and stability of both purpose and capability through the ebb and flow of organizational change.

5 The Maturation of IT Capability

We can define IT capability simply as what IT does for a business and capability comprises the people, processes, and technology resources to complete specific objectives. A core goal of management (and associated control theory) applied to a capability is to create conditions of sustainability, controllability, predictability, (Salman and Younis, 2005) and by extension value contribution. When the IT Capability has achieved these conditions it should be in a position to contribute in an optimal fashion to value creation. In the formative stages of an IT capability much of what gets done is attributable to resources and in particular people (Christensen and Overdorf, 2000) – this is unless an out of the box application which already has digitized processes for managing the IT capability is available. Over time as people repeat recurrent tasks, processes become defined (unless the organization has the foresight and knowledge to define up front what the processes are and the related inputs and outputs). As business strategy becomes better understood by the IT organization, the values of the firm become important and IT people make decisions based on what is important driven by company strategy or what is implicitly or explicitly defined by company strategy. Thus there is an evolution of the IT capability, starting from ad hoc use of resources to well defined processes and visible values as defined by IT Governance. Ultimately when resources, processes and values coalesce this could be defined as maturation of capability and indeed culture. (Christensen and Overdorf, 2000). An integrating framework which provides step by step guidance of how to improve could accelerate the journey to maturity.

6 Why a Living Framework or Body of Knowledge?

The half-life of IT Management practices is short as the pace of technology continues to accelerate. Figure 2 provides a graphical illustration of the perceived growing gap between technology potential and management capability. This can often be evidenced by the many failed or cancelled IT programs in both public and private sectors.

Kurzweil's (2001) law of accelerating returns predicts ever faster pace of technological development with the interplay for example of Moore's and Gilder's law and the mass collaboration and brain amplification it allows, creating a vortex of creativity. Given the pace of change, it is important not to have a static framework but one that is not only continuously evolving but also has the ability to be updated with new best practice. As mentioned, Sambamurthy and Zmud (2000) noted there was a growing gap between scholarly research and contemporary practice. IT executives need a living framework and associated body of knowledge to be able to practice

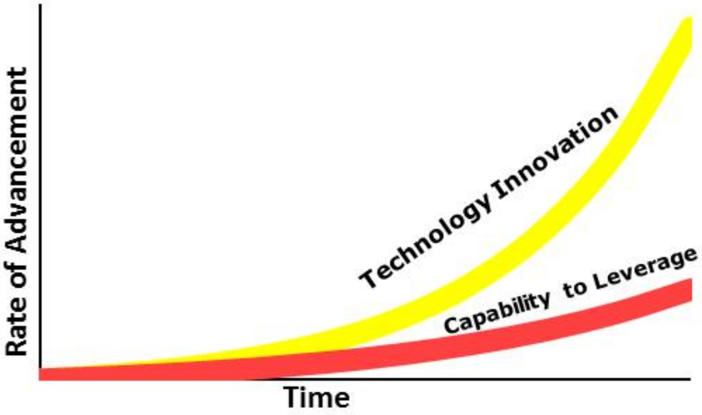


Fig. 2. Rate of advancement in technology innovation outpacing management capability

efficiently and effectively. The use of WIKIs and other collaboration and knowledge tools hold great promise in acting as repository for a global body of knowledge for the IT executive.

7 Existing Frameworks

A review of existing IT Management frameworks reveals that there is a plethora of frameworks for IT management already in existence. While all of these add value and offer advice and guidance a number of central issues emerge following the review of these:

- Comprehensiveness: few if any frameworks cover the full scope of an IT organization or its capability
- Validation: there is often a lack of theoretical, empirical or pragmatic validation
- Language: there is no shared vocabulary across the existing frameworks requiring frequent context and vocabulary switching depending on the problem domain.
- Value: A core issue is a lack of value focus or origination
- Static nature: many frameworks have no ability to be updated in near real-time with long revision cycles the norm

In order for a framework to help the CIO in an integrated way, it should cover most, if not all the process footprint of the Enterprise IT organization. The idea of being value-based is equally critical, as this is one of the critical measures upon which CIOs' performance is increasingly measured. Finally, it is important that frameworks are validated to give confidence to practitioners to invest in the adoption of the framework. Each adoption of a framework requires energy, resource and money to be invested, and needs to be considered carefully.

Given the rate of innovation of information technologies, it is possible that a framework relevant at one time, might be irrelevant at another time with different technologies. This means, framework comprehensiveness must also include "temporal comprehensiveness". Thus a framework that is relevant for management in a current state or environment, must also be designed to evolve with the organization or business context over time. A key concept of an integrative framework is that it is “evolvable”, being continuously revised to cover the current and future process footprint of the modern Enterprise IT organization. (Stack, 2007)

There are many IT management oriented frameworks in significant use in organizations today and the authors have identified an inventory of over one hundred and fifty frameworks that seem relevant in this area. Some of the frameworks are widely adopted, implemented and provide significant value. However, none of the frameworks fully address comprehensiveness, validation, value-based focus and dynamic nature the authors have identified.

Each individual framework has unique qualities such as formats, information and process features, and recommendations which makes a comprehensive quantitative and qualitative analysis difficult. This is expected to some extent, because frameworks are also unique to the environments in which they are designed, for example COBIT (Control Objectives for Information Technology) has a heritage of audit and risk management and hence builds on this particular perspective. What becomes a problem is a prescriptive framework that falls short in evolving with organization context and time, to include other important details that reflect the reality of dynamic interplay of the organization practices, processes, outcomes and measures of performance. Many of the frameworks reviewed cover particular focus areas in great depth but are lean in focus in others.

A preliminary analysis of existing frameworks showed that while a wide range of focus areas were covered, the most frequent were project management, quality management; resource management and IT service management. Of these frameworks the IT Information Technology Infrastructure Library (ITIL) is one of the more widely adopted (OGC, 2008). ITIL is a set of techniques and concepts for helping manage IT infrastructure, development and operations. Microsoft Operating Framework, MOF (Microsoft, 2008) has gained significant traction in IT operations organizations. It focuses on a subset of the ITIL libraries. COBIT (ISACA, 2007) is another framework which is adopted widely. Its focus is in information security and auditing domains. An extension of COBIT, called VALIT (ISACA, 2008) aims to extend the risk management and security focus into the domain of value management. CMMI (SEI, 2003) is often used for software development and project management practices in IT organizations. The IT Service CMM (Niessink, 2005) applies a maturity approach to the IT service Management aspect of IT and it is appears to be used quite widely in the Netherlands and neighboring countries.

However, a wider review of over 150 frameworks shows that no single framework covers the entire footprint that a CIO managing an enterprise IT function has to deal with or possess a dominant value focus. Against this backdrop, a list of key processes/capabilities required to manage enterprise IT was developed using a design science approach by the authors and used as a reference to assess the comprehensiveness of existing frameworks. To evaluate domain coverage, each framework was scored on a 33-point scale – the scoring scale was a super-set of areas derived from reviews of current framework domain areas, academic theory and IT practitioner input/relevance from industry. Each framework was given a total score out of a possible maximum of 33 points. This is represented by the Y-axis on Figure 3.

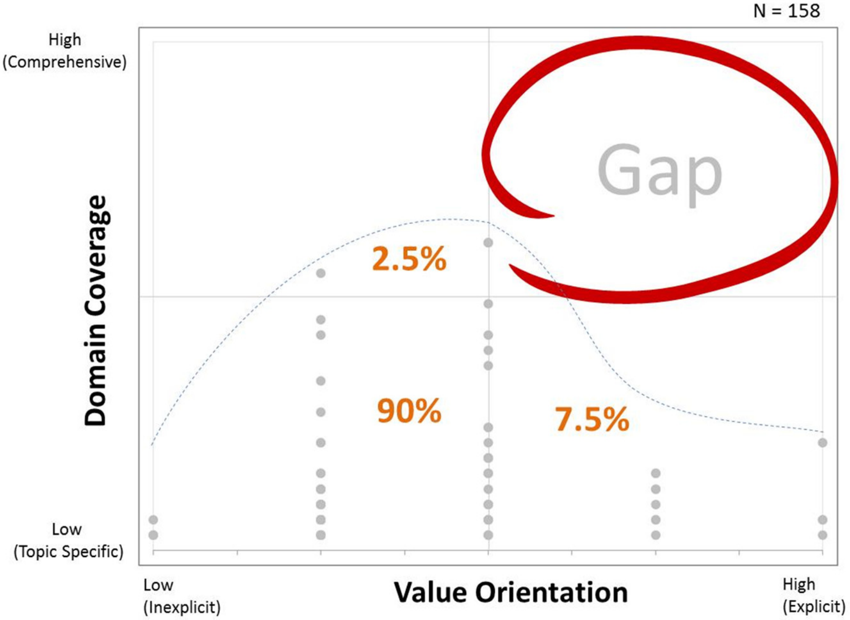


Fig. 3. Evaluation of reviewed approaches

A second review of each framework was conducted to assess how they address the economics and value focus, as required more and more from IT and business executives. Each framework was scored on a maximum 4-point scale, representing how pervasive value focus is contained throughout each approach – which is represented on the X-axis in Figure 3. While this analysis may oversimplify some of the complexity contained within some frameworks – it does help reveal some overall trends. What becomes most apparent is the overall lack of breath and value focus by many of the reviewed approaches, with 90% of the frameworks analyzed falling into the lower-left quadrant - covering a sub-set of processes which need to be managed by the CIO and offering limited value representation. 100% of the reviewed frameworks fall under the broken blue line – illustrating that there is a need for a management framework which comprehensively covers the entirely of enterprise IT function and is tightly coupled with value outcomes for the business i.e. decision-making focus from a business value delivery perspective.

From this analysis, it appears that no one framework comprehensively covers the landscape of management capabilities required to successfully run an IT organization to deliver firm-wide business value. Many times, CIOs have to build their own 'Frankenstein' approaches, harvesting various bits from other approaches to build a DIY framework that will help them deliver the right kind of value to their firm. These Frankenstein building activities invariably leads to many issues including CIOs continuously re-inventing the wheel, trying to make the often incompatibility of differing approaches work together, and the steep-learning curve required across the harvested approaches. Figure 3 provides a key context which drove the development of the IT-CMF.

8 Value Based Frameworks

Many value-based frameworks have paid little attention to the business process or evolving best practices. For example, The Working Council for Chief Financial Officers Report (CEB, 2003) on improving the yield of IT, usefully shares best practices in the area covering IT business case, enterprise-wide investment coordination and continuous portfolio management. However beyond this, the Report does not extend linkage to the IT process landscape.

Furthermore, Information Systems (IS) scholars voting for the most influential papers in the IS field ranked a list of exemplary IS research papers discussed in the Handbook of IS Research (Whitman and Woszczynski, 2003). The follow up analysis of more than 40 of these ranked papers failed to yield a single paper which had the words value or IT Business Value in their titles. These results could indicate both a paucity of the quality of research in this area or this is an indication that researchers did not prioritize the papers by relevance to the intended subject area under analysis and voting. On the other hand, it could also mean that at the time of the analysis of the ranked list of papers and voting, IT business value was not a topical research area. Interestingly Bannister and Remenyi (1999) argue there is a saturation of IT evaluation methodologies, however too often, managers have to fall back on instinct in IT investment decision making. Following a review of IT value-based management methods, Veith et al (2007) reached the conclusion that there is no existing method suitable for assessing the business value created by IT assets.

Despite the existence of all the "best practice" frameworks and scholarly research papers available, many CIOs struggle with trying to optimize the value delivered from a given IT spend in a company. Weill (1992) suggests that different organizations will realize different levels of value from the same level of spend. One of the major reasons why CIOs can fail to realize sustainable value from their IT investments is the lack of an integrative framework or model to guide them in dealing with the complexities of heterogeneous challenges that the business environment brings. Another reason is the fact that there are few systematic guidelines to help firms measure IT value (Mooney et al, 1995). Tradeoffs are required to continuously evolve the IT capability in an organization while delivering ongoing value.

Without an astute framework, CIOs have to take on-spot decisions, often trying to integrate different management frameworks and models as they deal with the very difficult challenges. Many of the existing best practice frameworks have features that compete. These competing features and lack of interoperability among frameworks can lessen an enterprise's potential to extract the potential from any one of these approaches especially when they are simultaneously applied at different hierarchical levels and across different organizational functions.

All this supporting material and evidence leads to an argument and logic which says that there is no single integrated framework which can meet the multiple demands of the CIO struggling to improve IT capability whilst managing different challenges. The evidence supports the need to develop a coherent integrative value-based process framework based on processes and maturity lenses that CIOs can apply effectively when dealing with the uncertainty of business challenges and ultimately, one that develops the strategic logic to improve their IT capabilities for the pursuit of value creation. The IT Capability maturity Framework (IT-CMF) is our proposed solution to this need and prior research has created a foundation and wireframe for this work (Curley, 2004), (Curley, 2006), (Curley and Kenneally, 2009, 2010).

9 Building an Integrative Framework Using Design Science

In recent years there have been several philosophical debates on ways to conduct IS research (for example interpretivism versus positivism) with the main focus of such debates being on the epistemologies of research (for example Klein and Myers, 1999). Two important paradigms which characterize research in Information Systems are behavioural science and design science. While behavioural science has dominated the 20th century IS research, design science research is becoming more mainstream. A fundamental goal of design science in Information Systems Research is utility – that is that the artifact is useful in addressing a real world problem or challenge.

The design and specification of an artifact and the assessment of its utility, in comparison to other existing or competing artifacts, is an integral component of design-science research (Hevner et al, 2004). Furthermore Hevner et al (2004) distinguish between the core goals of the behavioural-science paradigm compared to a design science paradigm. They argue that the goal of the behavioural science paradigm is to find *what is true* whilst the design-science approach's goal is to find *what is effective*. Hevner et al (2004) also posit that utility relies on truth but that the discovery of truth may actually lag the application of utility. This may particularly be true in the field of IS where the speed of change means that often theoretical research lags real world practitioners' needs (Sambamurthy and Zmud, 2002).

Typically the design process of an artifact is a sequence of activities that produces the design artifact. The evaluation of the artifact then provides feedback information and a better understanding of the problem and the design process to help improve the quality of the artifact. This build and evaluate loop is typically iterated a number of times before the final design of the artifact is completed (Markus et al, 2002). The goal is not only to add to the knowledge base but also to provide an artifact that is applicable to a real world challenge (Hevner et al, 2004). It is important also to note that the developed artifact should continue to be developed post the research, taking into account changes in the ongoing environment and responding to new insights. This of course supports the concept of a living framework.

However using Design Science on it's own would be insufficient to develop a integrating framework and it was combined with an open innovation and engaged scholarship approach to provide the scale, capacity and diversity of knowledge inputs to create an integrating framework.

10 Researching and Designing the IT Capability Maturity Framework

In 2006, the Innovation Value Institute (IVI) was established by Intel and the National University of Ireland, Maynooth (NUIM) to create a consortium which could build such an integrative framework using open innovation. Intel and NUIM were quickly joined by the Boston Consulting group as steering patrons and subsequently more than fifty other organizations joined to share their knowledge and IT practice experience. The research and development of the IT-CMF was underpinned by a design science research approach supported by engaged scholarship approach (Van de Ven, 2007) which help provide a route to address key challenges in the information systems field by engaging practicing executives and experts in the research process.

Design Science Research "creates and evaluates IT artifacts intended to solve organizational problems" (Hevner et al, 2004, P77). The research approach is an iterative step-by-step process by which artifacts and theory are generated and verified, with both an inductive and a deductive process being used. While behavioral science has dominated the 20th century IS research, design science research is becoming more mainstream. A fundamental goal of design science in Information Systems Research is utility – that is that the artifact is useful in addressing a real world problem or challenge. IVI addressed utility by integrating a pragmatic validation approach as a key part of the research process as well as measuring the value of utility through the level of early adoption by leading organizations. The IVI leveraged an open innovation approach with IT executives from many companies working with select academics to research and codify the IT-CMF.

In the development of IT-CMF the use of a common taxonomy and recursive logic to enable an evolving approach to evaluate maturity of a particular IT critical capability was important. In terms of engaged scholarship the primary research contributions to the development of the IT-CMF were made by working IT executives. Leveraging a design science process the IT-CMF was explicitly designed to cover, as much as possible, the entire IT capability footprint that a CIO needs to manage in order to optimize the value contribution from IT. And perhaps more importantly, IT-CMF was positioned and developed as an evolving framework which makes it capable to capture and represent new processes as they emerge.

The research artifacts and theory are manifested as a framework called the IT Capability Maturity Framework (IT-CMF) which is a formal archetype of the levels and stages through which an organization traverses and evolves as it defines, implements, measures, controls and improves its IT capability in support of value creation for the organization. A key early task in the research process was to develop a classification schema or meta model to ensure development of an integrated model which was constructed using a common set of vocabulary and formats.

A key concept in the development of the IT-CMF is that of a design pattern. A *design pattern* is a construct which exists in software engineering (Gamma et al, 1994) and which was leveraged significantly in the IVI design science research approach. A design pattern is a general reusable solution to a commonly occurring problem (Vaishnavi and Kuechler, 2007) and it is often manifested as a description or template for how to solve a problem that can be used in many different situations. Vaishnavi and Kuechler (2007) specifically define patterns as a solution to a problem in a recurring context and as a general technique for approaching a class of problems that are abstractly similar. Appleton (2000; P3) defines a pattern as "a named nugget of instructive information that captures the essential structure and insight of a successful family of proven solutions to a recurring problem that arises within a certain context and system of forces".

An outline of the overall design science research approach utilised for the development of the IT-CMF is described in Table 2, using the guidelines provided by Hevner et al, (2004).

A goal in researching and developing the IT-CMF was not to 'reinvent the wheel', but to complement the fundamental elements of existing frameworks to extend and fill the gaps where no best practice model currently exists and create a common vocabulary and language for IT capability and improvement management. The IT-CMF consists of a set integrated design patterns manifested as artifacts (Curley, 2007; Curley and Kenneally, 2009, 2010). An example of one of these artifacts is shown in the Figure 4 below and this describes the list of critical capabilities required to manage enterprise IT.

Table 1. Design Science Research Approach

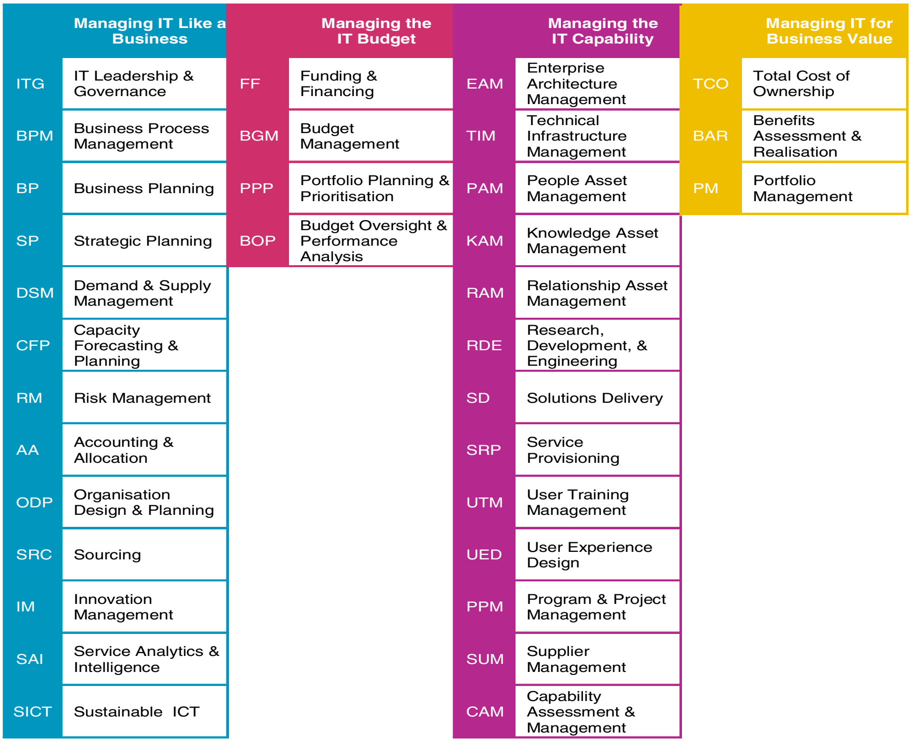
DSR Guideline Description (Hevner et al 2004)	**Approach taken**
Guideline 1: Design as an Artefact -	The overarching IT-CMF Classification Schema provided the Construct and conceptual vocabulary for the research process. From there, each working-group collaborated to define for each area of the IT-CMF, a set of critical capability definitions, maturity curves and capability building blocks (categorised as Models) and improvement practices (Methods). Organisational maturity assessment tools and library of practices to improve maturity were developed and codified as instantiations in an online capability assessment and improvement tool

Table 1. *(Continued)*

Guideline 2: Problem Relevance –	Hevner (2004) defines a problem as the 'differences between a goal state and the current state of a system'. As outlined in earlier sections, organisations often struggle to deliver business value from Enterprise IT, even with the plethora of current frameworks available – none seem to address this issue. With worldwide spending to be around 1.3 trillion dollars annually (IDC) – this is a very real issue for companies.
Guideline 3: Design Evaluation -	Evaluation began with simplified conceptualizations and representations for each of the domain areas. Through an iterative cycle, working-groups defined various IT artefacts to aid management within each area. The evaluation provided continuous feedback, initially based on Descriptive evaluation method (using informed argument and scenarios with subject-matter-experts) and then moving to Observational evaluation (using case studies/pilots at organisations). IT artefacts evaluated in terms of completeness, consistency of format, clarity of concepts, usability, fit for purpose, performance, and reliability.
Guideline 4: Research Contributions –	The contributions from this research are the development and use of a portfolio of defined maturity paths, assessment and improvement approaches required for Enterprise IT to deliver business value.
Guideline 5: Research Rigor –	Formal working groups are overseen by a Technical Committee which used a multi-stage research process to research and develop the IT-CMF. Pragmatic validation was used on an iterative basis to continuously improve the artifacts developed. Additionally the over-arching framework for the IT-CMF approach is grounded in the well debated Dynamic Capabilities (Teece) approach. The research work provides IT artifacts to assist companies manage their IT capabilities for better business value outcomes.
Guideline 6: Design as a Search Process	The master blueprint of the IT-CMF was defined through observations from Enterprise IT transformations, an extensive review of existing frameworks, academic literature and executive/practitioner input. This pattern was iterated until a valid framework was generated. As working-groups defined the individual artefacts within each critical capability area, they performed subsequent reviews of related literature, industry whitepapers and conducted expert interviews with identified academics and practitioners. Furthermore, as each IT artefact is continuously iterated, where the appropriateness of the IT artefact is evaluated within the context it was deployed within. Subsequent updates are applied if warranted by a central Technical Committee when feedback is evaluated from multiple deployments.

Table 1. *(Continued)*

Guideline 7: Communication of Research -	This DSR work provides clear information on how to systematically improve their IT capabilities. Through the open-innovation approach, ongoing forums and bi-annual conferences where academia and practitioners can share perspectives and latest developments plus suggestions for future research. The digitization of the IT-CMF specification, integrated assessment instruments and other artifacts is greatly assisting the diffusion of the IT-CMF. Formalized training and certification on the application of IT artefacts are offered by designated bodies to a global audience to ensure IT artifacts are implemented and used within an appropriate organizational context. These activities enable practitioners to take advantage of the benefits offered by the artifact and it enables researchers to build a cumulative knowledge base for further extension and evaluation.



	Managing IT Like a Business		Managing the IT Budget		Managing the IT Capability		Managing IT for Business Value
ITG	IT Leadership & Governance	FF	Funding & Financing	EAM	Enterprise Architecture Management	TCO	Total Cost of Ownership
BPM	Business Process Management	BGM	Budget Management	TIM	Technical Infrastructure Management	BAR	Benefits Assessment & Realisation
BP	Business Planning	PPP	Portfolio Planning & Prioritisation	PAM	People Asset Management	PM	Portfolio Management
SP	Strategic Planning	BOP	Budget Oversight & Performance Analysis	KAM	Knowledge Asset Management		
DSM	Demand & Supply Management			RAM	Relationship Asset Management		
CFP	Capacity Forecasting & Planning			RDE	Research, Development, & Engineering		
RM	Risk Management			SD	Solutions Delivery		
AA	Accounting & Allocation			SRP	Service Provisioning		
ODP	Organisation Design & Planning			UTM	User Training Management		
SRC	Sourcing			UED	User Experience Design		
IM	Innovation Management			PPM	Program & Project Management		
SAI	Service Analytics & Intelligence			SUM	Supplier Management		
SICT	Sustainable ICT			CAM	Capability Assessment & Management		

Fig. 4. Example Artifact from the IT-CMF, List of critical capabilities (CCs)

11 Governance for Design Science, Engaged Scholarship and Open Innovation

A key governance mechanism for managing and assuring quality of the Design Science and engaged scholarship research process at IVI was the establishment of a cross-organization technical committee (TC). The technical committee which was staffed by key leaders from a variety of organizations as well as Academics provided a body for review of research and discussion of the development and approval of the IT-CMF and its artifacts. The Technical Committee of IVI was charged with oversight for the development of the IT-CMF and to review and guide research and content development efforts of various workgroups of IVI. The TC used a stage approval process which was developed to ensure consistency and quality of research – a summary overview is shown in the Figure 5 below.

The research unit of IVI was a Workgroup (WG) which generally consisted of domain experts from industry working with Academics to research and develop artifacts associated with a specific process area. Approvals by the Technical Committee at each stage of the process were reached by consensus with workgroups (WGs) based upon clear deliverables set forth at each stage (refer to Figure 5 for summary). For each TC review stage, WGs leveraged an approved set of Blue Print templates which contained content guidelines and governance usage principles that would lead a WG to building various artifacts for each CC. In addition, content creation processes were defined to allow workgroups understand the most effective method to build and iterate these blueprints. Workgroups (WGs) consisted of industry, practitioner and academic subject-matter-experts working on developing a set of artifacts for each of the critical capabilities of the IT-CMF. Each WG was staffed with individuals playing different defined roles including Chair, Facilitator, Participant/Contributor, Reviewer and External Expert. Workgroup members researched, developed, shared and inventoried artifacts using a wiki website, enabling a form of distributed mass collaboration and open innovation.

The research process leverages the concept of open-innovation, originally proposed by Henry Chesbrough (2003). In a world of widely distributed knowledge, and rapidly advancing technology, companies cannot afford to rely entirely on their own expertise. Chesbrough advocates companies should seek to tap into knowledge and expertise outside their companies, make the best use of both internal and external knowledge, companies do not have to originate research to benefit from it. In fact the research process employed by the IVI went beyond this to what might arguably be called Open Innovation 2.0 (Samelin et al, 2011) where players from the entire ecosystem are involved in the Innovation Process. The working-group model used to develop the IT artefacts which led to version 1.0 of the IT-CMF, represented over 60,000 hours of contribution across 50+ companies – drawn from multiple industries in both public and private sectors. The development process is a combination of mass research collaboration and open innovation - where collective action occurs with large numbers of people working independently on a single project, facilitated by its modular nature. The modular architecture of the project is maintained by the

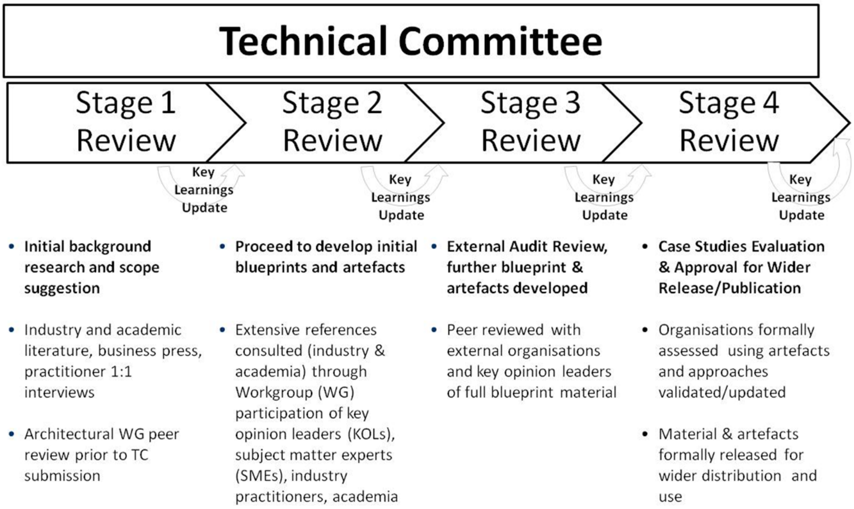


Fig. 5. IVI Technical Committee Stage gates

overarching IT-CMF Classification Schema provided. Modularity enables a mass of research to proceed in parallel, with different teams, allowing different "blocks" to be easily integrated, facilitating decentralised open-innovation that all fits together. The mass research collaboration approach differs from mass cooperation, in that the research acts taking place require the joint development of shared understandings within the working-groups to define and iterate IT artefacts. Conversely, group members involved in mass cooperation needn't engage in a joint negotiation of understanding, they may simply execute instructions willingly.

Throughout this research and content development process, shared understandings were allowed to occur, allowing artifacts to be documented, iterated and shared within and beyond these workgroups with wider audiences. The exit criteria for the final stage 4, required workgroups to test the validity of their developed artifacts in a real world application - through assessment of the artifacts' utility at a number of different organizations. A standard assessment process was developed for WGs to follow, ensuring consistency in application of artifacts and learnings from assessments. The TC Content Review Process was rigorously enforced and moving through each of the stages was not a foregone conclusion – often WGs were denied progression to the next stage due to failure to meet the required exit criteria – in this case, WGs would be requested to resubmit after further development of the content and artifacts. When comments of the TC were relatively minor in nature, WGs often were granted approval to progress but were required to feed-forward these learnings into successive iterations. Once IT artefacts were Stage 4 approved, continuous evaluations and updating of the artefacts occurred through a closed loop feedback system post each deployment or set of deployments – to iterate artefacts if required based on utility.

12 Early Industry Adoption of the IT-CMF

Standards are seen as well known models of excellence and authority, and are most often used as a basis for comparison providing a reference point against which implementations can be evaluated. A technical standard is often published as a formal document which defines agreed and often interoperable methods, processes, practices and other technical criteria. There are of course multiple paths to becoming a standard, through the formal standards' bodies or through broad scale adoption. Industry adoption of an emerging framework, process or method is often a good indicator or predictor of its utility and potential for future standards.

Tracking the adoption rate of the IT-CMF can be informative of its utility and industry demand. Since IT-CMF's version 1 release in summer 2010, within its first 18 months of release nearly 350 assessments have been executed.

The adoption rate of the IT-CMF v1.0 has outperformed adoption rates of some existing IT standards, with some existing approaches taking as much as five years to reach the same assessment rates the IT-CMF attained in its first year after v1.0 release. The initial global demand for the IT-CMF can be considered a proxy indicator of its utility.

The IT-CMF is designed to be uniquely integrative and value-based. Amongst its key strengths, the IT-CMF presents clear business focus, namely the business value returned from IT investments. It strives to articulate this value in monetary terms, such as revenue growth and profitability. Because its emphasis is on business value, IT-CMF helps to broaden and clarify the CIO view beyond the traditional paradigm of operations and services provisioning. It provides an easy to understand systems perspective beginning with a management process, financial inputs, an IT production engine and finally outputs delivering business value. A recent external examination of the IT-CMF has validated its potential (Costello, 2010) and compared the IT-CMF favorably to ten criteria required to form a new standard for IT management.

Working collectively with industry and academia the IVI plans to continue to further research and develop the IT-CMF to make it a useful and valuable framework and standard which can help all organizations exploit the ever increasing power and potential of evolving computing and communications capabilities.

13 Conclusion

In this paper the authors have described the rationale for developing a new comprehensive and value based CIO level framework. Our research identified that while there were many frameworks which were useful and were adopted there was no one single CIO level framework which was both comprehensive in terms of process coverage and value based. The paper has also briefly described the design science research approach supported by engaged scholarship and open innovation used to research and develop the new framework (the IT-CMF). Early adoption trends of the IT-CMF by very credible and successful global organizations demonstrate both utility and usability of the research output from the IVI consortium. There is however, much more research needed to be done in particular validating the benefits of the adoption of the IT-CMF as well as continuously updating the living body of knowledge which underpins the IT-CMF.

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Exploring the Relationship between Design Science Research and Innovation: A Case Study of Innovation at Chevron

Jack Anderson[1], Brian Donnellan[2], and Alan Hevner[3]

[1] Chevron Corporation, USA
jack.anderson@chevron.com
[2] National University of Ireland Maynooth, Ireland
brian.donnellan@nuim.ie
[3] University of South Florida, USA
AHEVNER@usf.edu

Abstract. What is the relationship between design science research and innovation? Our industry-academic collaboration poses this intriguing question and suggests a context and an experimental design for its study. We wish to understand the synergies between the active research areas of DSR and innovation by exploring their overlapping concepts and identifying unique ideas in each that have the potential to inform the other. We present a case study of an actual innovation process in Chevron as a source of empirical data for the exploration and subsequent analysis of how the application of DSR guidelines might inform the practical implementation of innovation processes.

Keywords: Design Science Research, Innovation, Case Study Research, Artefact, Evaluation.

1 Introduction

In business and industry, innovation is the catalyst to growth. Continual innovation is essential for companies to maintain a competitive advantage in their field of production or service [1]. Schumpeter [2] famously argued that industries must incessantly revolutionize their economic structure from within, that is, they must innovate with new processes and products. Innovation is closely aligned with the emergence of entrepreneurs who form new companies based upon new products and services with some combination of improved quality, durability, service, and price. Academia has recognized the growing important and interest in innovation studies with new educational programs and research journals.

In this study, we propose to explore the relationship between Design Science Research (DSR) and Innovation, particularly in the areas of information and communications technologies and systems (ICTS). What are the synergies between the research streams on these two topics and how can we identify and exploit the commonalities and differences? In particular we examine the implementation of an

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actual innovation process in Chevron as a case study and explore how the application of DSR guidelines might enhance innovation practices in that organization. This work is particularly appropriate now because of the current focus on innovation as a source of competitive advantage and the growing momentum in IS research relating to IS-enabled business transformation.

We begin by discussing the Hevner et al. [3,4] guidelines for DSR in Section 2. Section 3 then surveys the innovation literature for matching guidance. The Chevron innovation case study is presented in Section 4. Via the case study, examples of alignment and gaps between the two fields are investigated. Section 5 briefly highlights the findings of the case study. Section 6 concludes the paper with the discussion of our research approach to study the issues raised in our comparisons of the two research streams.

2 Design Science Research Guidelines

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 [5]. The ICTS field since its advent in the late 1940's 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, e.g. innovations.

The DSR paradigm is highly relevant to information systems research because it directly addresses two of the key issues of the discipline: the central role of the IT artefact in IS research [6,7,8] and the perceived lack of relevance of IS research to the business community [9]. The design science paradigm has its roots in engineering and the sciences of the artificial [10]. 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.

The primary goal of the Hevner et al. [3] *MISQ* paper is to provide an understanding of how to conduct, evaluate, and present DSR 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 seven guidelines are proscribed for conducting and evaluating good design science research. A detailed discussion of each of the seven guidelines is presented in the *MISQ* paper. The proposed guidelines as summarized below provide a basis for understanding and evaluating the processes and products of DSR.

2.1 Design as an Artefact

The result of design science research in ICTS is, by definition, a purposeful artefact created to address an important organizational problem. Hevner et al. [3] define the artefact as the constructs, models, methods, and instantiations applied in the development and use of information systems. Artefacts are innovations that provide a degree of novelty into an application context. Some aspect of the artefact must be an original contribution to the existing knowledge base of the application domain. Thus, we posit that artefact originality is a defining characteristic of DSR which makes the new artefact an innovation to the field of application.

2.2 Problem Relevance

Pragmatic design science research begins by identifying and representing opportunities and problems in an actual application environment. The goal of relevance initiates DSR 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 in real-world contexts [4].

2.3 Design Evaluation

The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods. Evaluation is a crucial component of the DSR process. Because design is inherently an iterative and incremental activity, the evaluation phase provides essential feedback to the construction phase as to the quality of the design process and the design product under development. A design artefact is complete and effective when it satisfies the requirements and constraints of the problem it was meant to solve [10]. Evaluation approaches and techniques must be rigorously appropriated from the research knowledge base.

2.4 Research Contributions

Design science research must provide contributions to both the application environment in the form of a problem-solving artefact and an addition to the field's knowledge base. Additions to the knowledge base will include any extensions to the original theories and methods made during the research, the new artefacts (design products and processes), and all experiences gained from performing the iterative design cycles and field testing of the artefact 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.

2.5 Research Rigor

Rigor addresses the way in which research is conducted. DSR requires the application of rigorous methods in both the construction and evaluation of the designed artefact. Rigor is derived from the effective use of the knowledge base – theoretical foundations and research methodologies. Success is predicated on the researcher's skilled selection of appropriate techniques to develop or construct an artefact and the selection of appropriate means to evaluate the artefact.

2.6 Design as a Search Process

Design, as a verb, is essentially a search process to discover an effective solution to a problem. Problem solving can be viewed as utilizing available means to reach desired ends while satisfying laws existing in the environment [10]. Abstraction and representation of appropriate means, ends, and laws are crucial components of DSR. These factors are problem and environment dependent and invariably involve creativity and innovation. Means are the set of actions and resources available to construct a solution. Ends represent goals and constraints on the solution. Laws are uncontrollable forces in the environment. Effective design requires knowledge of both the application domain (e.g. requirements and constraints) and the solution domain (e.g. technical and organizational).

2.7 Communication of Research

The goal of a design researcher is to publish in top journals in the application field. Any discussion of top-quality publication outlets must draw a distinction between journals with technology-focused audiences and management-focused audiences. Good DSR produces results of interest for both audiences. Technology audiences need sufficient detail to enable the described artefact to be constructed (implemented) and used within an appropriate context. It is important for such audiences to understand the processes by which the artefact was constructed and evaluated. This establishes repeatability of the research project and builds the knowledge base for further research extensions by future researchers.

On the other hand, management audiences need sufficient detail to determine if organizational resources should be committed to constructing (or purchasing) and using the artefact within their specific organizational context. The rigor of the artefact design process must be complemented by a thorough presentation of the experimental design of the artefact'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 artefact.

3 Innovation Research

3.1 Innovation Definitions

The voluminous and eclectic innovation literature has been described by Adams et al. [11] as a "fragmented corpus." In an antecedent paper, Wolfe [12] concluded that it had made little contribution to the understanding of innovative behavior in organizations and his evaluation of the results as being "inconclusive, inconsistent and characterized by low levels of explanation" was surely a pointed criticism of the field. Slappendel's subsequent [13] mapping of the literature on innovation in organizations in terms of three theoretical regions; the individualist perspective, the structuralist perspective, and the interactive process perspective; has been applied by the IS community to the analysis of software process improvement (SPI) innovations [14].

More recently, there have been some noteworthy attempts to provide a more holistic appreciation of the innovation landscape such as the compilations by Fagerberg et al. [15] and by Shavinina [16]. However, Fagerberg's [15] conclusion that "our understanding of how knowledge-and-innovation operates at the organizational level remains fragmentary" and "that further conceptual and applied research is needed" indicates a scarcity of progress in the intervening period. Avgerou [17] comes to the striking conclusion that "the term innovation is not actually widely used" in the information systems literature. Swanson [18], who has been notable among the IS research community in addressing the subject, argues that the innovative deployment of information technology is "increasingly crucial to competitive survival and success."

3.2 IS Innovation Process Management Frameworks

Information System (IS) innovation has been described as any new way of developing, implementing, and maintaining information systems in an organizational context [17]. A so-called "resource-based" view of IS innovation has been popular in the literature [19]. This view sees the ability to leverage IS in new ways as being a core competence of an organization and a source of sustainable competitive advantage. Resources that might lead to competitive advantage may include proprietary IS technology and unique IS technical and/or management skills. Peppard et al. [20] examined the problem of value creation from IS investments from an organizational as opposed to an IS functional perspective. Drawing on resource-based theory, the authors argued that the effective deployment and exploitation of information should be viewed as a 'strategic asset.' To leverage value from IS, the authors proposed that organizations must recognize and develop information management competencies and that the elements of these competencies should be distributed throughout the organization and not be solely resident in the IS function. They characterized these competencies as being of three types: information strategy, information exploitation, and IT/IS supply. Furthermore, in Peppard and Ward [21] the authors developed a model linking the IS capability with IS competencies and resources.

Swanson [18] described IS process innovations in his so-called "tri-core" model as covering three aspects of the business – type I innovations confined to the IS task, type II innovations that support the administration of the business, and type III innovations embedded in the core technology of the business.

There have also been several IS Management frameworks developed to assist practitioners to manage the IS resource. Examples include the Capability Maturity Model (CMM), the International IT Library (ITIL), and the Control Objectives for

Information and related Technology (COBIT), as well as the IT Capability Maturity Model (IT-CMF) [22,23].

From the practitioner community, thought leaders have emerged from product design and organizational design consulting firms. In 1991, Tom Kelly published *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm IDEO*, and articulated a 5-step methodology to guide teams through a process of innovation. The steps were:

1. **Understand** the market, the client, the technology and the perceived constraints on the problem
2. **Observe** real people in real-life situations to find out what makes them tick: what confuses them, what they like, what they hate, where they have latent needs no addressed by current products and services.
3. **Visualize** new-to-the-world concepts and customers who will use them
4. **Evaluate** and refine the prototypes in a series of quick iterations
5. **Implement** the new concept for commercialization

This approach has been adopted widely among the innovation practitioner community, including Chevron. The application of these innovation guidelines in Chevron was investigated as an example of how innovation processes are executed in practice and how they might relate to the guidelines of design science research.

4 Case Study: The Application of an Innovation Process in Chevron

The methodology described in Kelly [24] has been refined over time and adapted by innovation practitioners to fit their particular organizational culture. Research conducted by Innovation Value Institute has identified many IT organizations -- including Intel, Northrop-Grumman, Merck, and Chevron -- that have tested this methodology and adapted it for use. In Chevron steps 3 and 4 of the IDEO methodology are changed to focus on Ideation (the creative process of generating, developing, and communicating new ideas and solutions), Refinement (iterating ideas until ready for demonstration), and Prototyping (the creation of early samples or models built to test a concept or process or to act as a thing to be replicated or learned from).

In 2008 Chevron IT, after testing and adpating the methodology to Chevron IT's culture and supporting practices, introduced its variation of the innovation methodology entitling it "The Innovation Cycle" and deploying it through a multi-day workshop entitled "Idea Storms". Chevron IT also applies components of the Innovation Cycle for specific business challenges in workshops entitled "Idea Jams". Over 150 Idea Storms and Idea Jams have been conducted.

This study explores Chevron IT's practical application of it's six-step Innovation Cycle:

1. **Understand** the market, the client, the technology and the perceived constraints on the problem
2. **Observe** real people in real-life situations to find out what makes them tick
3. **Ideate** by generating, developing, and communicating new ideas and solutions
4. **Refine** ideas into themes
5. **Prototype** early samples or models built to test a concept or process or to act as a thing to be replicated or learned from
6. **Approve** select prototyped ideas that will be implemented in production

The case study being analysed in this paper involves a Chevron ”IT Idea Storm” innovation workshop conducted in May 2009 entitled ”RAVE Application Extension” where RAVE refers to Chevron’s Refinery Asset Virtual Environment. The workshop’s goal was to identify innovative practical technical applications in Chevron for RAVE beyond the environment for which it was produced.

Participants from several functional technology oriented disciplines in Chevron were facilitaed through Chevron IT’s Innovation Cycle beginning with ”Understand” to insure clarity of the technology, it’s current application and potential use beyond current use. Artefacts from this portion of the workshop include a document describing RAVE and its value (an excerpt follows). The critical aspects of the RAVE project were:

1. **RAVE definition:** RAVE – Refinery Asset Virtual Environment – was originally developed to simulate Chevron’s Refinery environment. 3-D refinery asset models are incorporated with contextual data from multiple sources. A Web2.0 virtual room allows subject matter experts (SMEs), represented as avatars, to engage in remote collaboration, decision making, and work process scenarios.
2. **RAVE business drivers**: Directly increase Safety, Reliability, and Operational Performance, providing decision makers with the information they need, associated with a manufacturing asset, in a virtual collaborative space: collaboration with Chevron HAZOPs (Hazard and Operability) response team processes; Operator training; New plant model reviews; Knowledge capture; Immersive operations intelligence.
3. **RAVE value**: Work processes executed repetitively in a RAVE environment: Improve organizational capability; Reduce costs for remote participation in decision making; Increase SME (Subject Matter Expert) participation with in-room ad-hoc context information; Improve work processe execution, reducing the risk of incidents and injuries; Lead to fewer and shorter unscheduled shutdowns.

Table 1 lists the DSR guidelines as articulated by Hevner et al [3] and the corresponding activities in the Chevron Innovation Process in the context of the RAVE case study. Summary statements of DSR guidelines are described in the left column and corresponding Innovation Process activities and artefacts, as found in Chevron’s RAVE case study, are listed in the column on the right. The case study indicates that innovative artefacts can take on many forms from documented research and concepts to articulation of decisions made during evaluation activities.

The ability to describe the output of each step in the innovation cycle as artefacts is an important breakthrough. It allows the innovation practitioner to understand and calculate the value of output from each step in the cycle. Understanding the business value of the innovation process is one of the major problems facing organizations today. Table 2 lists the artefacts generated at each stage of the Chevron Innovation Process. The volume of artefacts and representative examples from each step in the innovation cycle employed in the RAVE case study are shown.

5 How Design Science Research Informs Innovation Processes

Our thorough understanding and analysis of the Chevron case study has led to a number of key insights helping us identify how design science research might inform the innovation process. Based on our initial analysis, we find five areas of potential DSR contribution.

5.1 Artefacts

The Innovation literature focuses on the contribution of the artefact to the application environment and the ‘adopting unit.’ On the other hand, DSR requires a contribution to both the application environment and to the field’s knowledge base.

The case study indicates that innovative artefacts can take on many forms of abstract knowledge (e.g. models, architectures, methods), as well as, physical or systems-based instantiations. Current innovation processes, as exemplified by the application of the IDEO innovation approach in Chevron, focus on the outcome of the overall process rather than the artefacts that are created at each stage of the process.

The identification and analysis of artefacts created throughout the entire innovation process may well be a core differentiator between DSR and Innovation and is worth exploring in future research.

5.2 The Central Role of Evaluation

DSR guidelines stress the importance of evaluation of utility, quality, and efficacy. Apart from an effort by Venkatesh and Davis [25] to establish evaluation criteria for disruptive innovations, there is little evidence of extensive use of evaluation methods in the innovation process, although there is a very extensive literature on technology acceptance models [26]. It is not clear how innovators appropriately select evaluation methods to provide convincing evidence of their artefact’s utility and qualities? We posit that the emphasis on evaluation in DSR could have great potential to inform innovation processes.

In the case study, evaluation of the quality of resulting innovation steps is based on the Innovation Challenge artefact with the exception of the initial stages of step 3 (Ideation), and step 5 (Prototyping) when open ideas and concepts are accepted without judgment. Evaluation in each step in the RAVE workshop used the RAVE value descriptors as documented in the Table 1 description of RAVE.

5.3 Rigor

DSR guidelines stress the application of rigor in the development process – as a means of enhancing the quality of the artefact that emerges from the process. A

Table 1. Design Science Guidelines vs. Chevron's Innovation Process

Design Science Process Guidelines [3]	**Innovation Process Artefacts [based on Kelly [24]]**	
Design-science research must produce a viable **artifact** in the form of a construct, a model, a method, or an instantiation.	**Innovation Step**	**Artefact**
	1. Understand	Documented research
	2. Observe	Documented a) experiential research; b) documented reference points
	3. Ideate	Documented : Idea fragments; Themed ideas; Validated ideas; Archived ideas
	4. Refine	Documented concepts
	5. Prototype	Working models; Attribute documentation
	6. Approve	Management summary material; decision documentation
The objective of design-science research is to develop technology-based solutions to important and **relevant** business problems.	Before the innovation cycle is applied an artefact (Documented "Innovation Challenge") is produced to detail the business challenge's a) strategic fit, b) Organization Support; c) business application; d) timing requirements	
The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via **evaluation** methods.	Evaluation of the quality of resulting innovation steps is based on the Innovation Challenge artefact with the exception of the initial stages of step 3 (Ideation), and step 5 (Prototyping).	

Table 1. *(Continued)*

Effective design-science research must provide clear and verifiable **contributions** in the areas of the design artifact, design foundations, and/or design methodologies.	Only contributions that are new and unique to the business group executing the Innovation Challenge are in focus with the innovation process. We define new contribution as follows: a) **Radical:** Introduction of a new solution that changes the way we do buisness b) **Reapplied:** Adaption of a solution developed for another problem c) **Incremental:** Augmenting a previous solution with new elements
Design-science research relies upon the application of **rigorous** methods in both the construction and evaluation of the design artifact.	Rigor is applied before and after application of the Innovation Cycle – (before) as the Innovation Challenge is defined and (after) as approved prototypes are implemented into production. Guidance is provided within the innovation cycle to allow creative thinking and to avoid behavior that would limit generative output -- but in general the innovation cycle is used for fast, creative thinking to generate new ideas. With this rigor, structure, definition, and judgment are purposefully avoided in initial steps of the Ideation and Prototyping steps.
The **search** for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	With innovation Search thinking is tied to thinking about contribution as only contributions that are new and unique to the group executing the Innovation Challenge are in focus.
DSR must be **communicated** both to technology-oriented as well as management-oriented audiences.	Communication is contained within workshop groups until ideas are elevated to prototypes. Ideas collected in the Ideation step are saved for future challenges.

Table 2. Artefacts Generated in The Chevron Innovation Process

Innovation Process Steps	**Artefacts generated by Chevron "RAVE" Case Study**
1. Understand	See detail documented in introduction of RAVE above.
2. Observe	Participants documented over 30 observations of RAVE and its potential application to Chevron, including this example: "When I see the actual flow rate of a pipe via a meter and see how I could virtually view the pipe and the flow direction – it expands my understanding of the environment – and triggers many ideas for monitoring and controls"
3. Ideate	Idea Fragments 69 initial ideas (in the process we call these "idea fragments") were submitted including this incremental innovation example: *"Ability to walk through a virtual environment and "tag" an idea / question in the context"*. And this reapplied innovation example: *"Apply RAVE Chevron Decision Support Centers -- remote decision support centers are nearer to reality than remote control rooms"* Idea Themes/Groups: Workshop participants grouped idea s into: 1) Patent worthy 2) Research required 3) Explore and Test 4) Radical 5) Existing; 6) Discard Validated ideas: Workshop participants agreed to concentrate on 6 ideas for detailed focus, including: *"3D Asset model updates automated via linking to Asset management and Work Order management subsystems."* Actionable ideas: Workshop participants agreed 12 ideas were relatively simple to implement and immediately actionable – and a workshop participant agreed to take the ideas to production after workshop completion. An example: *"General facility introduction / training overview for visitors and community leaders to be added"* Archived Ideas: The remaining 5 idea groups -- 63 idea fragments) were archived in our idea management tool for future reference.
4. Refine	Workshop participants took the 6 patent-worthy ideas and produced descriptions of concepts using Chevron's IP process and forms

Table 2. *(Continued)*

5. Prototype	Through modelling exercises workshop participants produced descriptions of each patent-worthy concept, including conceptual, functional and practical attribute description.
6. Approve	Participants presented conceptual prototypes to Chevron's Patent Attorney assigned to the workshop. Through an iterative process documented prototypes were refined to the point where Patent Attorneys could go through the formal IP and then Patent "production" process.

corresponding emphasis on rigor in construction and evaluation is not to be found in the Innovation literature although Cooper's [27] Stage Gate Model does offer a systematic approach containing reviews of decisions at critical phases of the development process. We would argue that rigor in innovation processes is just as essential as in DSR. Attention to the most appropriate and effective techniques for building and evaluating the innovation is critical to an innovation's acceptance and success in the market place.

The Chevron Innovation Manager noted that *"in companies that don't have a rigorous innovation practice, people with new ideas don't know what to do with them and don't know whether their ideas are harvested or not. In the absence of evaluation criteria, or where the criteria is poorly defined and ad hoc, idea selection can appear to be arbitrary or as a result of bias. Innovation processes that are not executed well can result in demotivating employees and killing their creative contributions. Evaluation is probably the heart of an effective innovation practice because it articulates the criteria by which ideas are selected... and promotes the innovative behaviour that enables contributors to be recognized and rewarded".*

In the Innovation Process implemented in Chevron, rigor is applied before and after application of the Innovation Cycle – (before) as the Innovation Challenge is defined and (after) as approved prototypes are implemented into production.

Guidance is provided within the innovation cycle to facilitate creative thinking and to avoid behavior that would limit generative output -- but in general the innovation cycle is used for fast, creative thinking to generate new ideas. With this rigor, structure, definition, and judgment are purposefully avoided in initial steps of the Ideation and Prototyping steps. Evaluation in each step in the RAVE workshop used the RAVE value descriptors documented in the introduction of RAVE above.

5.4 Search

In the case study, only contributions that are new and unique to the group executing the Innovation Challenge are in focus, so there is an onus on members of the innovation community to perform relevant searches. The RAVE workshop leveraged the business knowledge of participants to identify ideas as unique or redundant.

The focus for communication is within workshop groups until ideas are elevated to prototypes. Ideas collected in the Ideation step are saved for future reference, to add to the body of organization knowledge with the hope of application to future business challenges. Concepts presented to the Patent Attorneys were held privately during the IP and Patent Search formal processes. All other ideas and concepts were stored in Chevron's IT Management tool and made available for future use.

While we found a number of similarities between the search processes for design artefacts in DSR and the Chevron innovation process, we believe that further study is needed to understanding the relationships between the methods for searching complex solution spaces for innovations and design solutions.

5.5 Contributions and Value

DSR guidelines stress that clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies are required. In parallel the innovation cycle stresses the drive for solutions that are new, value-added contributions to the organization applying them.

The study looked at the value of artifacts throughout the innovation cycle which lead to important findings that are useful to business, as understanding the business value of the innovation process is one of the major problems facing organizations today. Only contributions that are new and unique to the business group executing the Innovation Challenge are in focus with the innovation process. Chevron defines new contribution in three categories:

1. Radical: Introduction of a new solution that changes the way we do business
2. Reapplied: Adaption of a solution developed for another problem
3. Incremental: Augmenting a previous solution with new elements. The RAVE workshop leveraged the business knowledge of participants to identify ideas as unique or redundant.

We note the similarity of these three categories with the Knowledge Contribution Framework proposed by Gregor and Hevner [28]) as shown in Figure 1. The radical contribution aligns with invention. The reapplied contribution aligns with exaptation. The incremental contribution aligns with improvement. Thus, we claim that the production of value in the IDEO process can be expanded to include the DSR guidelines of contributions to both the research knowledgebase and the practical application environment. Future research will explore this claim.

6 Research Approach

This research is being undertaken in conjunction with the Innovation Value Institute (www.ivi.ie). Applying the principles of engaged scholarship [29, 30], ICTS Innovation is being investigated using a design process with defined review stages

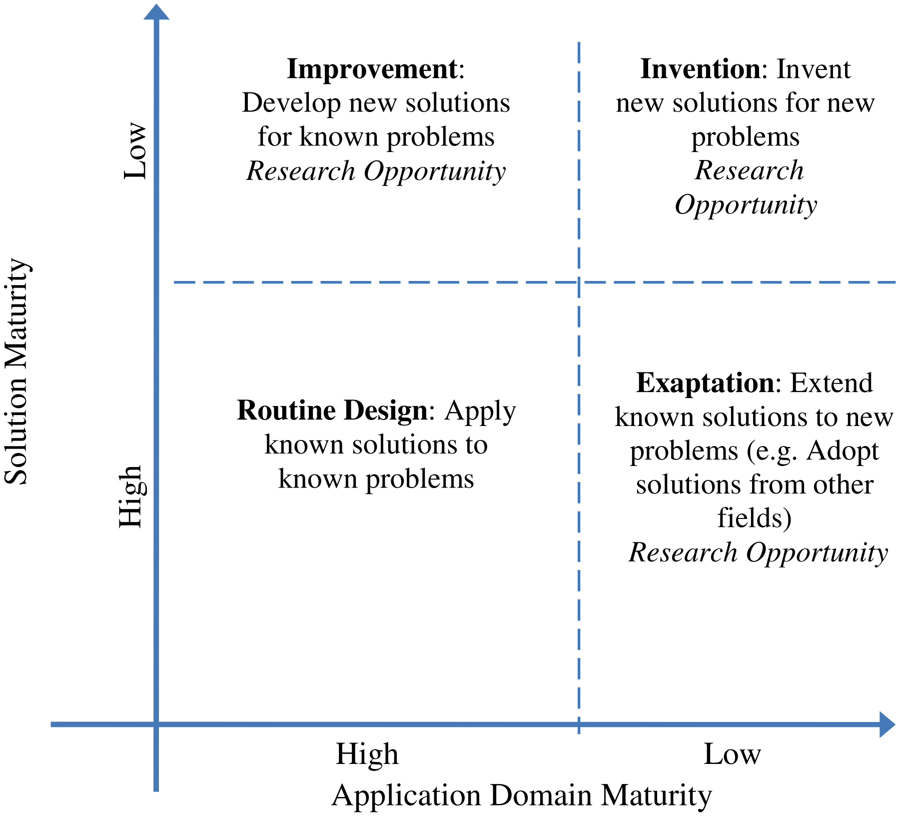

Fig. 1. Knowledge Contribution Framework [28]

and development activities based on the DSR guidelines advocated by Hevner et al. [3]. During the design process, researchers participate together with practitioners within research teams to capture the views of key domain experts. Using a case study approach supported by semi-structured interviews, researchers investigate the practice of innovation in some of its consortium members. A focus of the research is the design decisions and rationale underpinning innovation processes so that the relationship between DSR and Innovation might be better understood.

Among its 60+ members the IVI has many leading exemplars of IT Innovation practice including Intel, Chevron, Microsoft, SAP, etc. This collaborative community of like-minded peers are committed to investigating and advancing tools and best practices associated with IT-enabled Innovation. The consortium provides an ideal opportunity to conduct a series of in-depth case studies, across a range of innovative organizations, leading to insights into the relationship between DSR and Innovarion. Our next step in our research approach will be to formulate a set of research questions based on the results of the Chevron case study analysis discussed above. We will then refine these questions with the help of industry advisors to determine areas of greatest impact to advance innovation in our targeted case study companies.

7 Summary and Conclusions

The research fields of DSR and Innovation are firmly established as important aspects of IS research. They continue to evolve rapidly, with research agendas driven by researchers with deep expertise in either of the two fields. However, little attention has been given to identifying how the concepts of DSR and Innovation impinge on each other. An investigation based on a case study of the innovation process implemented in Chevron suggests that there are key insights that can be drawn from the DSR guidelines that can potentially impact and improve organizational innovation processes. Our research addresses the opportunity to explore how the concepts in DSR might inform Innovation. A future objective is to also explore the impacts going the other direction – How can successful innovation processes inform and improve our DSR activities. Further future research will be conducted under the aegis of the Innovation Value Institute – a consortium of leading companies engaged in various forms of ICTS innovation.

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Applying Design Science Approach in ICT4D Research

Mobile Phone Based Agriculture Market Information Service (AMIS) in Bangladesh

M. Sirajul Islam and Åke Grönlund

Örebro University, Swedish Business School
Fakultetsgatan 1, Örebro 70182, Sweden
{sirajul.islam,ake.gronlund}@oru.se

Abstract. This paper describes the characteristics and scope of Information and Communication Technologies for Development (ICT4D) and Design Science Research (DSR), and subsequently presents findings from a case study regarding how the call for future research, practical and methodological, on IS in general and ICT4D in particular can be well addressed with DSR. The paper contributes to the domain of design research knowledge as it critically discusses as well as exemplifies the use of DSR in an interpretive research perspective that aims at solving some socio-economic problems, which is significantly lacking in contemporary research. The major argument here is that DSR can be fruitfully used in ICT4D research as long as the goal of ICT4D research is to innovate or design something new. Furthermore, due to the stage-gate model nature of DSR, its comprehensive use in ICT4D needs an integrated research approach with well-coordinated activities throughout the development process.

Keywords: ICT4D research, design science research (DSR), Information Systems (IS), IT artifact, Mobile phones, Agriculture Market Information Service (AMIS), Farmers, Bangladesh.

1 Introduction

Information and Communication Technologies for Development (ICT4D or ICTD) can be defined as use of ICTs in the development agenda, especially for the improvement of quality of life (living, literacy, health, life expectancy etc.) by way of enhancing decision-making capability at the individual, group or community (micro), sectoral (meso), national (macro) and global (meta) levels. A research report from UNDP asserts that "ICTs can enhance capabilities for human development when applied with foresight, clear objectives, a firm understanding of the obstacles that exist in each context and proper policies that establish an institutional framework that promote the use and benefits of ICTs for the poor " [1, p. 4].

ICT4D is an interdisciplinary research field. Emerging during the past decade, it is new compared to the Information Systems (IS) field in general. According to a literature search, use of design science in ICT4D research is significantly lacking, although design science research (DSR) is an old research paradigm especially in engineering

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discipline. Acknowledging the lack of a universal definition of DSR, Iivari and Venable [2] define DSR as a "research activity that invents or builds new, innovative artifacts for solving problems or achieving improvements, i.e. DSR creates new means for achieving some general (unsituated) goals, as its major research contributions" (p.4). They further assert, "Such new and innovative artifacts create new reality, rather than explaining existing reality of helping to make sense of it" (p. 4). This is a socio-technologically-enabled-contextually-situated [3] research approach that can also serve for socially-constructed development aspects of ICT4D research. DSR, therefore can be a powerful research tool especially in a situation where a researcher needs to address many key questions [4, 5] related to development, users, and IS/ICTs within a limited time frame (in contrast to action research) and within a coherent research framework. However, so far little has been done to understand the artifact itself, although there are by now a good number of studies in IS in general and in ICT4D in particular. Referring to an argument of Orlikowski and Iacono [6], Sein et al. [7] suggest that IS requires a research method that explicitly recognizes IT artifacts which are shaped by the interests, values, and assumptions of developers, investors and users. Furthermore, although current ICT4D research investigates social and development aspects directly associated with contemporary technological innovations there is a lack of a clear theoretical and methodical stance of ICT4D research. With the exception of Walsham's [8, 9] and Klein and Myers' [10] guidelines for IS interpretive field study, there is a significant lack of notable methodological directions for conducting ICT4D research. According to a recent study by Dörflinger and Gross [11], "[ICTD] research lacks appropriate research methods along the entire development lifecycle spanning design, development, deployment, evaluation and monitoring." (p. 517). They therefore suggest that ICTD research needs "a shared methodology and rigorously applies appropriate research methods" (p. 517). As so far DSR mainly applies or assumes a positivist perspective and ICT4D has a slant towards interpretive approaches, there are reasons to try to understand if and how the two could be joined. To that end, this paper presents some theoretical arguments in combination with an illustrative case study regarding how we can adopt DSR in an ICT4D research based on an interpretive perspective in the process of constructing an ICT artifact that aims to address problems related to socio-economic development.

The subsequent discussion proceeds by defining characteristics and scope of DSR and ICT4D, followed by a comparative argument and concluding remarks.

2 Design Science Research: Characteristics and Scope

McKay and Marshall [12] define design as an iterative process of initiating something new. They explain, in accordance with Archer [13], that design involves "an activity [that] gets conceptualized as an oscillating conceptual and practical activity, with thinking and activity swinging between clarifying requirements (reducing obscurity) and articulating provisions that match the requirements to varying degrees, until a solution that satisfies the problem owner emerges" (p. 608).

However, in order to materialize conceptualized activities and proposed designs, one needs to have thorough understanding about the context and its various interrelated elements. Design science, therefore is a suitable approach that deals with the study of design contexts and their components. Cross [14] explains it as a "body of work which attempts to improve our understanding of design through 'scientific' (i.e. systematic, reliable) methods of investigation [...] the study of the principles, practices, and procedures of design [...] includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems" (p. 53).

DSR fundamentally stands on a 'problem solving' paradigm [15, 16]. It takes the approach that understanding problems is not enough, attempts have also to be made to solve them. In fact, trying to solve (socio-technical) problems is the preferred way to understanding them, because there is no single solution that can be calculated in a desktop research manner; solutions are situated, and the artifacts themselves can be seen as actors in the context in which they are implemented. McKay and Marshall [12, p.8] therefore characterize DSR as a "multi-paradigmatic area of scholarship" that "employs a diverse set of methods including those from the paradigms of positivism, interpretivism and critical theory". For example, "Boland (1989) takes an interpretive perspective on design science research, whereas Hevner et al. (2004) take an implicit positivist stance" [12, p. 8]. According to Hevner et al. [15, p. 75] "the design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts. [......] foundational to the IS discipline, positioned as it is at the confluence of people, organizations, and technology". Innovation, in this context, defines ideas, practices, technical capabilities and products that help to effectively and efficiently accomplish the task of analysis, design, implementation, management, and use of information systems [15]. Innovation emerges from the archival and through the process of new knowledge creation. McKay and Marshall [12] in this regard contend that "because of the fact that design, and in particular design in IS, has diverse human and organizational aspects, it was argued that this [a broad and encompassing] body of knowledge must be built through a design science research approach" (p. 9). Here the 'design' is both a process – a set of activities – of which one is the construction of an artifact (or product) that seeks to address some aspect(s) of a certain problem domain [15]. The following remarks adapted from the comprehensive study of Hevner et al. [15] provide a very constructive view on the design science research: "The fundamental questions for design-science research are, 'What utility does the new artifact provide?' and 'What demonstrates that utility?' Evidence must be presented to address these two questions. That is the essence of design science. Contribution arises from utility. If existing artifacts are adequate, then design-science research that creates a new artifact is unnecessary (it is irrelevant). If the new artifact does not map adequately to the real world (rigor), it cannot provide utility. If the artifact does not solve the problem (search, implementability), it has no utility. If utility is not demonstrated (evaluation), then there is no basis upon which to accept the claims that it provides any contribution (contribution)" (p. 91).

The most commonly cited artifacts in DSR are (i) constructs (vocabulary and symbols), (ii) models (abstractions and representations), (iii) methods (algorithms and practices), (iv) instantiations (implemented or prototype systems) [15, 17, 35], and (v) (new and) better theories. Vaishnavi and Kuechler [3] discuss these five artifact types as the outputs of design science research. However, artifacts may also include social innovations, new properties of technical, social or informational resources [18]. Hevner et al. [15] argue that designing an artifact is a complex matter due to the need for creative advances and the emergence of insufficiency of existing theories. Therefore, DSR can be used as a theory building method [19]. On this point, the design theory itself is not prescriptive, rather its artifact specification is prescriptive which helps to justify why certain classes of artifacts will solve certain classes of problems [20].

The issue in this paper is to understand how well the interpretive research paradigm and the DSR model go together and how they can be best mixed for operationalizing a particular research question. DSR researchers, taken together, apply many different ontological views, i.e. contextually situated alternative world-states which are socio-technologically enabled [21]. As a research approach, the Niehaves [22] study shows how DSR shares the compatible elements of the two fundamental research perspectives – positivism and interpretivism, and the guidelines of DSR vary according to an assumed epistemology.

3 Deploying Mobile Phone Based AMIS in Rural Bangladesh

In order to present an idea about how a DSR approach can be used in an ICT4D initiative, this section provides a brief description of design, implementation and evaluation of a mobile phone based agriculture market information service (AMIS – an artifact), which was initiated for farmers in Bangladesh for improving their socio-economic opportunities by providing better bargaining power in their dealings with middlemen as well as a real choice regarding where and when to sell their agricultural produce. The AMIS, locally known as *PalliNet* (RuralNet), was a mobile phone based ICT4D research project [23] which operating for six months in 2009 on a test basis at some remote villages in a northern district of Bangladesh. The service supported small farmers (n =100) by connecting them to three neighboring wholesale and retail markets through daily provisions of information about the price of crops for no charge. Price data were gathered by local price collectors who sent maximum wholesale and retail price information every morning from the respective markets during the early trading hours via SMS in a prescribed format. The data were stored on a server maintained in the capital city (Dhaka), and disseminated via SMS to the registered farmers according to individual preferences. Before going to markets, the farmers had current and timely information on prices of the produce they were to sell.

One of the authors of this paper was involved as a close observant [8, 9] as well as one of the designers of this system. The main research question was 'how can mobile phone-based AMIS be designed and deployed in order to improve socio-economic opportunities for farmers in Bangladesh?' The notion of development in this research project was based on Sen's [24] capability approach where development is treated as expansion of freedom. Sen's 'development as freedom' is concerned with expanding the freedoms of individuals to make real choices in everything that is important to them, as well as reducing the unfreedoms (of not being able to make those choices).

The main question in this research project was operationalized by means of four research objectives, which were investigated in four studies with corresponding research questions (Fig. 1). These objectives were: (i) to understand the scope and challenges relating to market information services for farmers of poor regions; (ii) to diagnose the situational realities of Bangladeshi farmers in regard to access to information services; (iii) to understand the process of adopting mobile phones and to investigate practices and preferences regarding access to market information in a rural

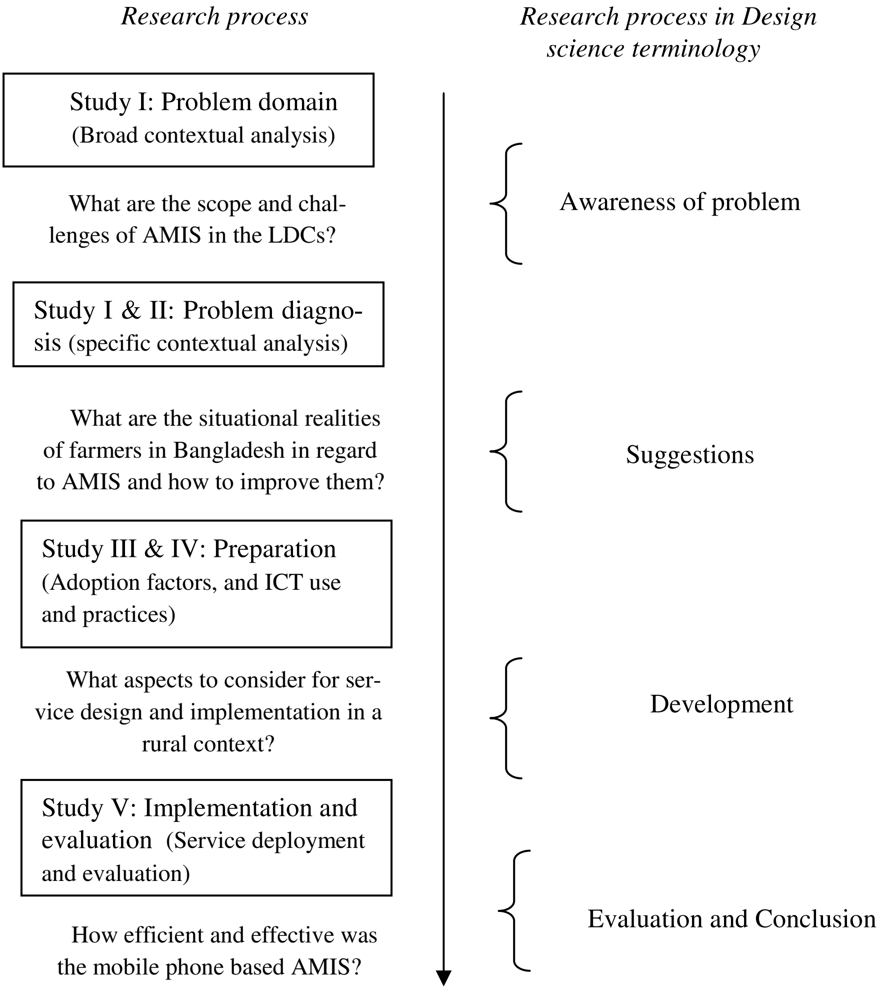

Fig. 1. Research process based on the framework of DSR [21]

context in order to prepare and design a mobile phone based AMIS; and (iv) to implement and evaluate the efficiency and effectiveness of a mobile phone based AMIS deployed for the farmers of Bangladesh, including reflection from a development perspective.

Out of many descriptions of design research processes – such as Hevner, et al. [15], March and Smith [35], Purao [25], Gregg, et al. [26], and Nunamaker, et al. [27] – Vaishnavi and Kuechler [21] propose a general methodological framework for design science research. In this paper AMIS, as an ICT4D research intervention, has been explained within this framework, shown in Fig. 1. According to Vaishnavi and Kuechler [21], this framework, which originated through analysis of many design efforts, emphasizes the knowledge generation processes inherent in any design effort.

The process of this methodology and the respective phases of studies were the following:

Awareness of Problem: Awareness about the problem for this research project emerged initially (by curiosity) from the social reality of the farmers' community and later formally (as a researcher) from a problem related to the effectiveness of a web based AMIS initiated by the Ministry of Agriculture of Bangladesh. Bangladesh is one of the least developed countries (LDCs) with almost half of its population living on under US$ 1.25 per person a day. Farmers of Bangladesh are not only the backbone of economic development, but the main working force for safeguarding food security for about 160 million people. Yet, they are one of the weakest communities in terms of every aspects of development, especially on economic grounds. One of the main reasons behind their economic insolvency is uneven access to market price information, in comparison to the intermediaries in the market chain. In most cases, farmers are being compelled to sell their agro-produce to the wholesalers at a very lower price, sometime even below to their production cost. One of the tools for improving their bargaining power and provide reliable information from the major and neighboring markets is to give them access to usable and affordable AMIS. In an effort to provide citizen centric e-government services, the Government of Bangladesh initiated a web-based AMIS which turned out ineffective for farmers as most of them do not have access to the Internet and as the overall education level of the farmers is not conducive for using a web-based service. On the other hand, a majority of rural households have mobile phones, which suggest deploying a mobile phone based AMIS might be more useful. Of course, designing an effective ICT artifact in a context of a poor rural region is not so easy as we need to consider not only the technological aspects, but also the socio-economic elements of the context in which the artifact will operate. Understanding the various constraints and possibilities, internal and external to the artifact, and deploying it accordingly in a certain context is a prerequisite for effective use. In order to do so, two studies were carried out. The first one (Study I of Fig. 1) focused on the nature, scope, problems, and challenges of existing AMIS in all (n=49) the LDCs in terms of users, management, funding, infrastructure, and data. The other one (Study II) focused on the effectiveness of the existing web-based AMIS of the government in regard to socio-economic realities of the demand side stakeholders. These two studies helped to define the problem domain and subsequently to narrow down the focus in order to diagnosis the problem in the specific context. In both cases, artifacts (AMIS, whether traditional, web, or mobile) were a central focus, while the problems in regard to design, use, access, and effectiveness were determined from a human development perspective. Study I was a qualitative research based on two literature surveys, conducted online, investigating multiple AMIS case studies. The collected data was categorized and analyzed based on an evaluation framework designed for the purpose, called 'IS project evaluation matrix' (IS-PEM) [28]. Although Study II concerned with the effectiveness of the existing web-based AMIS, the focus was on usability and accessibility in relation to the socio-economic and technological realties of farmers in Bangladesh. Data were collected by means of interviews with the concerned officials of the Ministry of Agriculture who were involved in designing and running the web-based service. In addition, a survey based on a structured questionnaire was carried out among 1050 farmers, wholesalers, and retailers (350 from each group) covering 13 out of 64 districts of Bangladesh. Studies I and II both suggested a mobile phone based AMIS would be a good idea as phones are more easily and widely available among the farmers than any other communication technology

Suggestion: This is a creative step that deals with tentative design based on a novel configuration of e new initiative (or artifact), either existing or new. The studies that were carried out for 'awareness of problem' led to 'suggestion' for a tentative design of an AMIS based on the lessons learned from the existing initiatives and expectations from the users. As artifacts are "bundles of materials and cultural properties packaged in some socially-recognizable form" [6, p. 121], the suggestion phase dealt with investigating two embedded aspects of mobile phone based AMIS - the mobile phone itself in terms of use and individual characteristics, and the information to be provided via this technology. This phase (Study III) investigated the use and practices of mobile ICT and expectations in order to suggest a novel configuration (Study IV; [34]) and a feasible design of an AMIS in a rural context. One output from Study III was a conceptual framework called the Rural Technology Acceptance Model (RuTAM) [33]. These two studies (III and IV), in combination with Studies I and II, provided a comprehensive understanding of the various constraints and prospects associated with AMIS and a direction towards how a feasible AMIS should be designed in the context of rural Bangladesh.

Development: This phase is a technical one, which focuses on the development of ICT part of the project. Therefore, Study V [23] was particularly related to development and implementation of a suggested design of AMIS. There were two parts of this study – the construction of the artifact and the subsequent evaluation of its use. The construction of the artifact was based not only on the lessons learned during the previous studies (I to IV) but also on the feedback received during informal and formal implementations. The informal one involved discussions among the members of design team. The formal one was an actual implementation among 100 registered farmers. A mid-term review during the formal implementation also helped to improve the service (i.e. the final output). The major activities involved in this phase were, designing an interactive SMS based prototype, testing with server, modems/routers, and mobile handsets, data processing, validation, error handlings, security in access, and testing of dissemination. The implementation activities involved campaigning, making the local farmers aware of the service and registered in the system, recruiting and training price collectors, simulating the system and feeding the data into the system by them on a regular basis.

Evaluation: This phase is concerned with evaluation of the constructed and implemented artifact in accordance with certain criteria. This phase also contains an analytical part that deals with making hypotheses about the behavior of the artifact. The rest of case study V focused on evaluation of the implemented service, which was carried out in two phases, midterm and after the test period. The main purposes of these evaluations were to improve the ongoing service and to get feedback whether the utilities of the service were in accordance with the expectations. The evaluation criteria were based on two perspectives – development (effectiveness) and technological (efficiency). The development perspective focused on the expansion of social and economic capabilities and actual improvement of incomes, while the technological perspective concerned efficiency, availability, and appropriateness of the chosen technology and service. An interpretive case study [9] approach was the basic method of this phase, where both the qualitative and quantitative techniques were adopted. As an 'involved researcher', close-observation helped to gain insights about the human-technology interaction in a certain social environment by a professional community.

Conclusion: This is the final phase of DSR, which requires presentation of the findings to relevant audiences in a clear manner. However, although it seems like the grand final part of DSR, there are some conclusions that may emerge from each of previous activities, which are also subject of communication to other researchers as well as practitioners. In this case study, the findings were communicated as scientific papers and presented at international conferences, workshops, and classroom lectures as well as published [23, 28, 32, 33, 34] as research papers in journals and proceedings relevant to ICT4D. Overall, the practical contributions of this study are, (1) to get a conceptual views on how to develop and implement mobile phone based service (an artifact) for the farmers of poor regions, (2) comprehensive views of the challenges and scope of AMIS in the LDCs through an Information Systems Evaluation Matrix (IS-PEM), (3) increased understanding of the farmers' attitudes and preferences towards the use of technology in general and mobile phones in particular, (4) ways of holistically evaluate the key aspects of an e-service, and (5) broadening the understanding of ICT for human development in the context of a poor rural region. As for the theoretical contribution, the study proposes RuTAM that explains the factors influencing the adoption of mobile phones among the farmers of a poor region.

4 Use of Design Science Approach in ICT4D Research

Developing something new as a constructive intervention through a design process and evaluating utility, quality and efficacy of the designed artifact in relation to the predefined developmental goals are the major concerns for DSR in ICT4D research. According to Dearden et al. [31, p. 2], "If we aim to design ICT that is 4D, the approaches that we adopt must be sensitized to how they empower people locally to progress their own visions of the kind of social development and therefore the form and function of ICT that they want". The case of a mobile phone based AMIS

Table 1. A general comparative characteristics of DSR and ICT4D research

General criterion	*DSR*	*ICT4D/ICTD Research*
Research Perspectives	Introduces demonstrable artefacts or innovations dealing with systems and solving a class of problems [7]	Technocentric human development
Normative dimension	Problem solving paradigm; offers prescriptions on creating artifacts [29]	Problem solving and problem investigations
Nature of problems	Business problems [15]	Socio-economic and human development problems
Views on realities	Multiple, contextually situated and socio-technologically enabled [3]	Multiple, contextually situated and socio-technologically enabled
Research objectives	To create effective artefacts or innovations [22]	To investigate how development is influenced by or associated with IT artifacts
Dominant approach and Method	Developmental measure artifactual impacts on the composite systems; Positivist epistemological assumptions, but also open to alternative epistemologies [22]	Interpretive approach, qualitative case study; No particular epistemological assumptions
Dominant views	Design process and evaluation of tools or artifacts	Tools and ensembles for development
Relation to knowledge	Knowledge-using/ prescriptive [22]; Knowing through making [3]; Objective knowledge [22]	Knowledge producing and using; Subjective as well as objective knowledge
Results/ Outputs	Heuristic [29], Design knowledge; Knowledge of tasks or situation in order to create effective artefacts or innovations [22]	Knowledge of task or situation in order to understand deployment, access, use, efficiency and effectiveness of ICTs for meeting a particular developmental agenda
Research direction and guidelines	Well defined [8, 15, 22]	Not so well defined [30]

demonstrates that all phases of DSR can be dealt with addressing certain socio-economic and technical issues with a particular interest in human development for the farmers' community of poor rural regions. DSR, in this case shows its methodological openness which provides for operational flexibility. Contemporary DSR methods are based on stage-gate processes that follow a separated sequence from scoping and building to evaluation, instead of an integrated sequence, which is a necessary condition for generating knowledge [7]. However, the AMIS case shows that in the process of constructing an artifact, the designing process goes with presenting multiple findings and contributions based on multiple research approaches. This suggests that use of DSR in ICT4D requires an integrated approach.

Based on the overall discussions in this paper and the AMIS case in particular, Table 1 summarizes general characteristics of DSR and ICT4D research. The table would help us to understand as to what extent and how DSR approach can be fitted into the ICT4D research. The use of DSR in ICT4D research is compatible only when the goals are particularly pertinent towards designing or innovating something new. The AMIS case shows that DSR can not only be used for solving business or organizational problems [15], but can also be applied for addressing socio-economic problems. The largely dominating interpretive perspective of ICT4D research goes well along with the multiple, contextually-situated and socio-technically enabled [3] design science ontology. DSR has epistemological openness, although it is often dominated by an implicit positivist epistemology [36]. Such openness is also conducive for ICT4D research, especially for evaluation and effectiveness purposes. Defining and measuring or evaluating the 'D' of ICT4D is still a debatable issue. Nobel laureate economist Sen sees development as expansion of human capability – the substantive freedoms, which are distinguished from "the informational focus of more traditional normative approaches, which focus on other variables, such as utility, or procedural liberty, or real income" [24, p. 18]. Such a view of development, in contrast to prevailing quantitative view (e.g. GDP growth, number of computers etc.), requires interpretive research perspectives. Finally, ICT4D research rests within a broader domain of Information System based on a development perspective, while DSR is a research approach that aims at operationalization of particular research questions and objectives related to design problems. More specifically, ICT4D research focuses on any of five strategic issues – how, why, when, what and whom, while DSR as a whole concerns the 'how' although the rest are used for knowing the context of the artifact which is a comparatively more complex process than the design itself.

5 Conclusion

This paper describes the characteristics and scope of ICT4D research and DSR, and subsequently presents an example case study demonstrating how the call for future research on bridging the gap of lacking appropriate research approaches in ICT4D can be well addressed with DSR. The paper contributes to the domain of design knowledge by critically discussing and exemplifying the use of DSR in an interpretive research perspective that aims at solving certain socio-economic problems, something that is significantly lacking in contemporary research. The above discussion shows that DSR can fit well into ICT4D research as long as the goal is to innovate or design some artifact. ICT for development comprises of three main strategic questions: what sort of technology or artifact (instrument), for what sort of development (goals) and how these two can be fitted together in order to achieve these goals (effectiveness). The components of DSR address all these three questions. DSR not only guides us to systematically design an artifact, but also helps us to associate design aspects in relation to the various considerations of development. Although it has historically emerged from the engineering discipline, DSR can be a good choice for mixed or open method research in social science in general and ICT4D in particular.

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A Design Science Approach to Development of Educational IS

Justin L. Bond* and Chetan S. Sankar

Auburn University, Auburn, AL, USA
`{justin.bond,sankacs}@auburn.edu`

Abstract. In many technical disciplines, employers have suggested that insufficient focus has been given to the professional skills of students. In recent years, accrediting agencies and members of industry have emphasized the importance of these skills for technical graduates, suggesting that curricula must change. Following calls for industry and academic collaboration, we have worked with an immersive experiential learning provider to develop and test the use of a design science approach for converting case studies into an educational IS called "serious games." We designed two iterations of a serious game focusing on communications. Testing of the serious game in classes is leading to improvement of the methodology and we plan to develop other serious games in the future. The results of this research show the value of a design science approach to developing educational IS. We explain our iterative design process and provide suggestions for educational IS creation.

Keywords: Design Science Research, Design, Serious Games, Professional Skills, Engineering Education.

1 Introduction

In a relatively short time, academia has been transformed by the many successes of the information systems (IS) field. Just as corporations adopt IS to achieve business goals, academia adopts new IS to achieve its own goals. A primary goal of academia, the education of students, has seen profound benefits from growth in IS. Recent innovations have led educators to adopt a variety of online educational tools (e.g., learning management systems, simulations, and serious games) to achieve this goal.

While discussing the history of IS, Kuechler and Vaishnavi [1] explain the importance of design and the lack thereof in many historical implementations of systems designed by and for industry. Many have also overlooked a rigorous design process in their rush to apply technology to academia's problems. The extant literature on learning styles has provided evidence that students have varying strengths and preferences in the ways they take in and process information [2], and this evidence must be considered during the design of educational IS. When considering learning

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* Corresponding author.

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styles, it becomes evident that the development of IS for education requires careful design and testing to achieve the aforementioned goal of academia.

A common instructional methodology in the business and engineering disciplines is the use of case studies. As a form of problem-based learning, case studies attempt to present students with complex real-world problems. Although positive benefits are associated with case studies, theoretical disparities remain between the learning preferences of students and the instructional techniques of case studies. We posit that real-world problems presented by existing case studies can be enhanced using gaming approaches to develop new instructional materials called "serious games."

The primary goal of this paper is to apply the design science principles emphasized by Hevner, March, Park and Ram [3] and Peffers, Tuunanen, Rothenberger and Chatterjee [4] to the development of serious games for use in education. We attempt to answer the following research question: Will there be a difference in learning outcomes between students who experience class lectures, case studies, and serious games? To answer this question, the remainder of this paper begins by describing the current state of serious games. We then discuss the capability of serious games to improve professional skills. We focus primarily on developing a serious game artifact. We conclude with suggestions for future research and the benefits of applying a design science approach to developing educational instructional materials.

2 Literature Review

2.1 Serious Games

For most of the world, IS has become an ever increasing part of our lives. The current generation of students, also referred to as "digital natives" [5], has been trained from childhood to handle large amounts of information quickly, use alternative methods for gathering information, and use innovative methods to communicate [6]. We see a recognition of this in academia and industry, with higher projected investments for online learning initiatives [7]. With a wide selection of technology tools at their disposal, the challenge for educators is how to choose an effective tool that best fits the goal of a particular discipline and a specific course. In technical fields, a growing concern for educators is the improvement of professional skills, such as communications. Fortunately, extant literature provides a starting point for the design of an information technology (IT) artifact aimed at improving professional skills.

One such technology that is gaining prominence in education is called serious games. Michael and Chen [8] define serious games as "game[s] in which education (in its various forms) is the primary goal, rather than entertainment." Prensky's [5] description of digital gaming's benefits includes learning by doing (i.e., active learning), learning from mistakes, goal-oriented learning, and role play and constructivist learning. Past discussions of games in education concerned the merit of games for the purpose of learning, however, Moreno-Ger et al. [9] suggest that the discussion has advanced from whether there is educational potential to how games should be developed. Therefore, we collaborated with a company specializing in developing immersive scenarios. We used the design science approach to provide guidance and direction for game development.

2.2 Design Science Research

The benefits of design science research (DSR) have been touted by academics for many years [10, 11], suggesting that it is "a problem solving paradigm" [3]. DSR focuses on the identification of a problem that can be addressed by an IT artifact. A more recent conversation by Gregor and Hevner [12] suggests that a more expansive view of the IT artifact includes any designed solution that solves a problem in context.

Prior to Hevner et al. [3] there was ambiguity regarding the process of conducting design science research. However, Hevner et al. provided seven guidelines for design science research to produce effective artifacts: 1) to design "a purposeful IT artifact created to address an important organizational problem"; 2) problems must be relevant to "unsolved and important business problems"; 3) "the utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods"; 4) there must be "clear contributions in the areas of the design artifact, design construction knowledge (i.e., foundations), and/or design evaluation knowledge (i.e., methodologies)"; 5) there must be rigor in the research and design of the artifact; 6) a search must be conducted for the best design; and 7) research must be communicated to both technical audiences and management.

After a detailed examination of the methodology above, Peffers et al. [4] developed a design science research methodology (DSRM) to guide future research. Their intention was to develop a DSRM for the production and presentation of DSR in IS which could limit the growing disparity in the field. Their resulting methodology contained six process elements: problem identification and motivation, definition of the objectives for a solution, design and development of the IT artifact, demonstration of the artifact's use, evaluation of the artifact, and communication of the process to researchers and other relevant professionals.

Although an abundance of DSR methodologies exist, researchers must choose among the available alternatives to define their own activities to meet the requirements of their research project [12]. Thus, we chose to apply the DSRM developed by Peffers et al. [4] in the following section for the development of a serious game.

3 Methodology

Prensky [5], among others, asserted that a game should have a clear overall vision. In an attempt to adhere to this line of thought, our serious game design began by applying the setting and problem from a well known case study, i.e., failure to communicate effectively prior to NASA's launch decision involving the Challenger space shuttle in 1986. As individuals around the world observed this event, they witnessed an explosion, resulting from a catastrophic failure that could have been averted. The events prior to the launch decision provided the problem-based learning scenario for our serious game.

We developed the first iteration of our serious game in the Fall of 2010 in an attempt to answer the research question above. We documented the design process of the first iteration in a step-by-step manner using the DSRM.

3.1 DSRM Iteration One: Fall 2010

Although existing DSR methodologies differ on the number of activities involved, there appears to be consensus on certain integral components. Gregor and Hevner [12] explain that all DSR projects should address problem identification (i.e., the research question), building the artifact, evaluating the artifact, and demonstrating research contributions. Each of these is addressed below.

Activity 1: Problem Identification and Motivation. Iivari [13] suggested four major sources of ideas for DSR to make the origin more transparent: practical problems and opportunities; existing artifacts; analogies and metaphors; and theories. In the current study, our focus is on practical problems and opportunities. Specifically, we focus on developing serious games from existing case studies, with the intention of creating a more appropriate match between the instructional materials and the learning styles of students, while improving communication skills.

Activity 2: Define the Objectives for the Solution. Peffers et al. [4] suggest that the objectives for a solution can be qualitative or quantitative. Therefore, our design aimed to address both qualitative and quantitative problems associated with the improvement of communications skills of technical students, and matching the serious game to the learning preferences of students. We sought to develop a game that entertained students (i.e., captured their attention), while improving learning outcomes associated with communication skills.

Activity 3: Design and Development. Drawing from the communications literature and extensive research related to the learning styles of engineering students [2], we began designing the initial iteration. By applying the Index of Learning Styles [2], we found that our students displayed the following learning styles: active (learning by trying things out), sensing (concrete thinking, practical), visual (prefer visual presentations), and sequential (linear thinking processes, learn in small steps). These results suggest a preference for many of the components of serious games, while also providing guidance for game design.

Working with our corporate partner, we developed characters and a story line to present the details of the Challenger case study without revealing the factual outcome of the case. Students entered the game as a newly hired engineer at a fictitious company, Lunar Aerospace. An interactive environment was developed to allow students to view and control on screen conversations with other employees at Lunar Aerospace. Throughout the game, students were presented with actual slides created for NASA managers, and asked to respond to questions from co-workers and supervisors within the game. Students received feedback via a scoreboard. This provided a gauge of their performance in relation to their peers.

Activity 4: Demonstration. Peffers et al. [4] suggest that demonstration can involve the use of the artifact "in experimentation, simulation, case study, proof, or other appropriate activity." To demonstrate the IT artifact, it was introduced in an introduction to engineering course at two universities in the southeastern US. Students completed the serious game in a computer lab, for which they received a score, receiving a score at the conclusion of the game.

Activity 5: Evaluation. According to Peffers et al. [4], the evaluation stage involves the comparison of the objectives to the observed results after the artifact is implemented. The evaluation used in this study produced both quantitative and qualitative results. The internal scoring mechanism of the game provided an empirical representation of each student's performance while traversing the game (i.e., a scoreboard). In response to our first objective, improvement in the communication skills of technical students, quantitative results suggest that serious games can produce positive impacts. The qualitative evaluation, collected through questions in the post-survey instrument, produced mixed results, yet it provided important information for revisions in the subsequent iteration. When asked about using this serious game to learn communication concepts, 17 percent said it was fun, and 19 percent said it was realistic. Additional comments revealed a desire for increased interaction with the game, the addition of audio and video, improved graphics, and changes to reduce the feeling of tediousness while progressing through the game. However, 70% of students expressed interest in working with serious games in the future. With regard to our second objective, a more appropriate match for the learning styles of today's technical students, our evaluation reveals the need for improvement.

After completing the evaluation portion of a DSR project, Peffers et al. [4] suggest that researchers must iterate back to activity three or continue to the dissemination of results. At this stage, we proceeded to activity three to improve the serious game.

3.2 DSRM Iteration Two: Spring 2012

At the conclusion of iteration one, our collaborative team was able to acquire funding from the National Science Foundation for continued work. The additional funding allowed recruitment of evaluators and additional employees for our industry partner. We summarize the early stages of our efforts below.

Using the case study from iteration one, we apply improvements in response to feedback gathered during our evaluation efforts. In response to student concerns about the tediousness of the game, and in an attempt to improve learning, we examined the literature discussing cognitive load theory (CLT). A primary component of CLT is an individual's working memory, in which all cognitive processing occurs, and total load cannot exceed working memory resources if learning is to occur [14]. Cognitive overload has been found to occur in multimedia environments, therefore, we applied a segmenting technique to divide the game into acts and scenes, allowing the students to focus on learning objectives individually, while still following the story. To address student concerns about interaction, additional story paths are being added, allowing more control over user outcomes. Graphics will significantly improve in the second iteration with almost exclusive use of audio for conversations, rather than text. Videos will address the visual learning styles of our students. Avatars will be replaced by actors to improve realism within the game. Finally, a progression matrix will be used to allow students to progress through the organization, creating a more game-like atmosphere.

4 Contribution of Research to IS Discipline

The primary contribution of this research is the application of Peffers et al.'s [4] DSRM to the creation of an IT artifact, whereby a well known and commonly used instructional methodology was repurposed as a serious game.

As a result of the efforts presented here, additional propositions for future research were developed. While our efforts did not test these propositions, they can be viewed as an extension of our work and applicable to others seeking to evaluate repurposed instructional materials during DSR: 1) application of DSR for the repurposing of existing instructional methodologies can lead to improvements in students performance; and 2) application of DSR for the repurposing of existing instructional methodologies can lead to increased acceptance of course content by students. Future research should attempt to provide empirical evidence of improvements from educational IS developed using DSR in relation to tradition instructional methodologies.

5 Conclusions

While the topic of DSR is not new to the field of IS, recent publications have advanced the field with significant models for guiding the design process [3, 4]. Such profound advances provide a promising landscape for researchers seeking to apply DSR to new areas in innovative ways. As such, we are delighted to have the guidance of the DSRM for use in education. Future researchers can expand our efforts to convert existing instructional methodologies, while matching the learning styles of today's learners and improving learning outcomes. Using a design science approach, in collaboration with business, we were able to convert a proven instructional methodology, case studies, into a serious game that improved the professional skills of technical students, while matching the learning styles of students. Therefore, the dissemination of this DSR is sure to benefit students, educators, and businesses seeking to design educational learning tools.

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Applying Design Science Research in Enterprise Architecture Business Value Assessments

Martin Meyer[1] and Jim Kenneally[2]

[1] Dublin City University, Dublin Ireland
`mmeyer@computing.dcu.ie`
[2] Intel Labs, Leixlip Ireland
`jim.kenneally@intel.com`

Abstract. In the effort to measure the business value and impact of Enterprise Architecture (EA), we need to adapt an adequate form of information systems research in order to cope with encountered challenges. For this purpose, we employed Design Science Research (DSR), a problem-driven approach to provide a solution represented as artifacts offering the projected utility to our stakeholders. The main contribution is the detailed focus on how artifacts are actually built in an organizational context. The DSR we conduct happens within a well-known information systems research framework and follows widely accepted principles and guidelines. We explain the business need that arose from the current business practices in the course of a case study and describe the methodology we pursue and how we intend to solve the problems we identified. Thereby, we outline the evolutionary state of the artifacts during our adapted research process.

Keywords: Design Science, Enterprise Architecture, Business Value Assessment.

1 Introduction

Conducting research in the field of information systems involves many challenges, especially when considering the context of business and industry demands. We constantly encounter problems which need to be solved or emerging business needs that have to be satisfied. For this purpose, we must follow a rigorous procedure to deliver the adequate solution. As a means of achieving this, we have Design Science Research (DSR) at our disposal which creates novel things that serve human purposes as contrasted by natural science that tries to understand reality [1]. Hence, Design Science is the research of the artificial which produces different kinds of results such as constructs, models, methods and instantiations which are referred to as artifacts [1] [2]. In our case, we want to apply this kind of research to the field of Enterprise Architecture (EA) and more specifically to the way we measure and assess the business value and impact of it as perceived by different stakeholders. In collaboration with an industry partner, we identified the business need to facilitate a more sophisticated way of assessing EA in an organizational context which calls for

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an appropriate methodology of research and hence, the satisfaction of this business need shall be given by designing various artifacts. Consequently, this work is focused on artifacts in terms of development as well as the context in which they are intended to be applied and we therefore provide our research methodology centered on the artifacts and discuss the state of these throughout the research process.

2 Design Science Application

The choice of DSR suits our work well since it demands a rigorously identification of the problems we face which is of utmost importance since the design of the artifacts are dependent on the outcome of this analysis. Additionally, the research process is well documented and enriched with guidelines and principles which are inevitable for quality research output. And last but not least, our artifacts are designed to solve problems in an organizational context where we have to clearly understand the environment and need to utilize all means available from the knowledge base consisting of company knowledge, academic research, and other forms of publications and best practices. For our work, we employed the IS research framework proposed by [2]. Our environment consists of stakeholders, the strategy, processes and the current EA function within the company. Arising from this environment we can identify problems or business needs respectively which should bear a certain amount of relevance. The IS Research itself is dominated by the employed research methodology for both artifacts and theories, i.e. design science and behavioral science are complementing approaches.

Research, as many other disciplines, needs principles and guidelines. They ensure that the result of the contribution achieves a certain level of quality. Hence, as suggested in [3], we adopt the DSR principles when designing our artifacts and in addition, we follow the seven guidelines proposed in [2].

We employ the basic research methodology outlined in [3]. Although other methodologies can be found in literature, such as [4] and [5], we focus on four basic phases for our design science application although we consider these methodologies as sub-steps of our process. The main phases or activities respectively are *Analysis*, *Design*, *Evaluation*, and *Diffusion*. Each main phase consists of several sub-steps in which particular deliverables is produced.

3 Case Study

3.1 Context: The Business Value of Enterprise Architecture

Enterprise Architecture is meanwhile a comprehensive discipline within the IT domain which is underlined by the number of contributions from both industry and academia. Additionally, the support for EA in form of frameworks seems to have taken a sheer unmanageable amount of approaches as the title of [6] suggests. Nevertheless, in pursuit of keeping the organizational chaos at bay companies, especially large ones, make use of these frameworks and aim for the execution of an enterprise-wide EA function.

While we appreciate the value proposed by EA it is not always clear how to exactly measure and assess it in terms of business value and maturity [7].

Measurement of EA benefits and specifically the EA business value (EABV) is not a trivial task. There is always a gap between real and perceived value and it differs for the particular stakeholder groups [8]. Even on an enterprise-wide level, we are still struggling with getting the right numbers. Consequently, metrics for EA are still to be sought after for there is currently little guidance on how EA value can be captured [7].

The measurement of EA benefits has been discussed several times in literature, i.e. in [9] where an IT management assessment framework is presented. In [10], EA outcomes and success factors are evaluated by employing a conceptual framework and conducting a quantitative analysis at firm-level. Deriving the value from a model-driven analysis as in [11] is another contribution.

3.2 Applied Research Process

Analysis

In our first phase of our research process, we rigorously analyze the current state of the EA function and the problems entailed with it. A part of our analysis is extracting problems from the environment by conducting surveys and expert interviews with our stakeholders in an exploratory manner. The summary of our problem analysis is shown in Table 1.

Table 1. Problem analysis summary

Problem Class	Questions
Perception/Definition Problem	What is EABV?
	How is EABV viewed?
Visibility/Transparency Problem	Where can we find EABV?
	How can we measure EABV?
Improvement/Optimization Problem	How can we improve/optimize EA adoption, collaboration, Governance, decision making, practices, maturity and BITA[1]?

Design

The main process phase of DSR is devoted to the design of artifacts because this is what DSR is all about, providing an artificially crafted solution to a problem in the form of an construct, model, method, or instantiation. The *EABV Framework* (EABVF) is the main artifact. It provides guidelines and deliverables, e.g. performance reports, and is directly based on the *EABV Model* (EABVM) which serves as underlying value definition and is incorporated in all other artifacts to allow the same base of value understanding. The *EABV Measurement Process* (EABVMP) is an approach to perform an EA benefits and impact evaluation integrated into current practices. As a tool to assist decision makers we design an *EA Balanced*

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[1] Business-IT-Alignment.

Scorecard (EABSC) based on [12], [13] which relies on different perspectives where objectives and appropriate measures indicate the performance of a chosen set of characteristics. Naturally, the objectives of our artifacts are to solve the problems and business needs that were identified earlier. These objectives are directly addressing the problem statements of the previous section which described our problem analysis.

Moreover, we need to be aware of the requirements that are attached to them. We differ between business, architectural, functional and non-functional requirements for each of our artifacts. For more information about requirements, see [14].

Evaluation

In the Evaluation phase, the time has come to evaluate the artifacts. Therefore, we need to undertake a small-scale demonstration of the artifact whether it is applicable for that kind of problem and we obtain some preliminary results. The more comprehensive large-scale test and evaluation over a certain period of time to validate the artifact comes next and generates an evaluation report. The evaluation of the artifacts will take place in an organizational context.

Diffusion

Diffusion marks the step of emitting the outcomes of the research process to different kinds of audiences through various channels by means of various media, usually in form of a publication. The usual types of audiences are either management-oriented or technology-oriented which consequently calls for a different form of representation, i.e. the focus of the DSR contribution must be adapted to the intended audiences [2].

4 Research Analysis

We already described the basic layout of the research process which generally is assumed to be iterative. After our process analysis, we suppose this process is more of

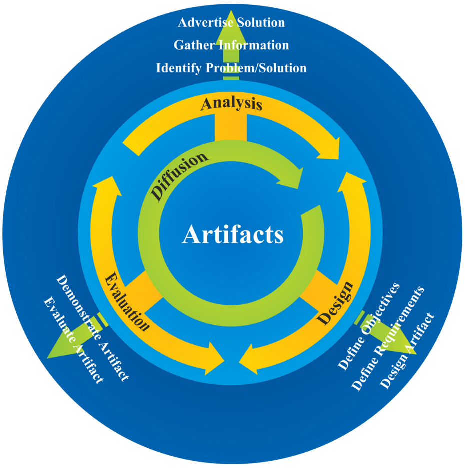

Fig. 1. DSR Artifact Build Cycle Process

an artifact build cycle where it is possible and often even necessary to step back from one phase to another in order to accommodate for requirements or changes which were not considered yet. This artifact build process cycle is depicted in Fig. 1 and provides another perspective on our research process. It also clarifies the role of the diffusion phase which can actually be done throughout a research project.

As we further analyzed our research, we deem it very useful to provide an artifact build cycle based on the build process. Thereby, we are interested in the actual state of the artifacts during the whole research process. These states are outlined in Table 2.

Table 2. Artifact state during research process

Phase	Artifact State
Analysis	
Identify Problem/Business Need	First ideas and concepts how to solve encountered problems or business needs.
Gather Information	Further develop initial ideas and concepts.
Advertise Solution	Present initial solution proposal where the intention on how to solve the given issues is elaborated in order to get the support for the development.
Design	
Define Objectives	Based upon the solution proposal, the objectives of the artifact are clearly specified.
Define Requirements	An important step is to specify the requirements for the artifact, which can be business, architectural, functional and non-functional requirements.
Design Artifact	The actual design and development of the artifact is a big sub-process itself and can be achieved in numerous of ways depending on the nature of the artifact. Here, the artifact takes the desired representation in its projected end state.
Evaluation	
Demonstrate Artifact	Demonstrating the viability of the artifact in a certain form helps to justify the research effort and that the solution delivers the intended results. This is the initial test of the finished artifact in its native environment.
Evaluate Artifact	Evaluation is the rigorous assessment of the artifact and builds upon the findings from the demonstration. It shall be shown that the artifact provides the sought-after utility for the target stakeholders. Results from the evaluation can trigger another analysis or redesign of the problem or the artifact respectively.
Diffusion	
Communicate Solution	The now finally finished artifact is ready to be diffused through various inter- and intra-organizational channels although premature diffusion is possible.

5 Conclusion and Further Research

In our paper, we presented a practical DSR application in the domain of EA business value assessment and therefore went through an adapted research methodology. The identified problems are solved by four artifacts: the main artifact is the EABV Framework which incorporates an EABV Model and comprises of an EABV Measurement Process and an EA Balanced Scorecard. All of these artifacts are designed und evaluated with an industry partner who provides the business environment as well as parts of the knowledge base in terms of our chosen research framework. In doing so, we greatly benefit from the structured procedure which alleviates the surrounding project management for all participants and additionally sheds light on the actual creation of the artifacts. Thereby, we contributed to the research rigor by enriching the state of artifacts in the course of various process phases. Based upon our achievements so far, we further step along the projected process path to evaluate our artifacts in an organizational environment. As a concurrent process phase, we continue to diffuse our findings in order to encourage the discussion of our solution as well as our methodology to achieve it.

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Reconceptualising Dynamic Capabilities: A Design Science Study on the Role of Agency

Abdelghani Es-Sajjade and Krsto Pandza

Leeds University Business School, Maurice Keyworth Building, Leeds LS2 9 JT,
The United Kingdom
`{A.Es-Sajjade,K.Pandza,A.Es-Sajjade}@leeds.ac.uk`

Abstract. This paper addresses gaps in research on dynamic capabilities, specifically regarding the role given to individual managers within this context. I argue that there is a relationship between patterns through which dynamic capabilities develop and the role of managerial agency. I offer three contributions by means of this study. First, a management design is chosen that is positioned somewhere in between the path-dependent and path-creation design which allows an active conception of managerial agency accommodating elements of social and behaviour strategies, purpose, and creativity within the context of dynamic capabilities as an evolutionary phenomenon. Second, I follow a longitudinal, inductive study approach using a single case study strategy to elucidate the micro-level process elements inherent to the evolutionary nature of dynamic capabilities. Third, I adhere to a design science research approach to produce a model of dynamic capability that is relevant and prescriptive of nature to management practice.

Keywords: dynamic capabilities, agency, design science, absorptive capacity.

1 Introduction

During the past four decades different paradigms in strategy literature have looked at respectively exogenous (e.g. industry and environmental settings) and endogenous (e.g. resources, routines, capabilities) factors related to inter- and intra-firm heterogeneity. The dynamic capabilities view (DCV) is an example of a view revolving around endogenous attributes of organizations [1]. Complementary to the resource based view, the DCV has proven particularly useful for examining firms operating in Schumpetarian environments where innovation-based competition is paramount to survival and success [2].

While a variety of definitions of dynamic capabilities has been suggested, in this paper I will use the definition proposed by Helfat et al. (2007: 3): [the capacity of an organization to purposefully create, extend or modify its resource base.] This definition is chosen because it considers the role of managers in the origin and development of dynamic capabilities; a central theme in this study. Despite its valuable contributions to the understanding of competitive advantage in turbulent environments, the DCV is still in need of more empirical work and longitudinal

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studies to empirically back theoretical developments and increase relevance and prescriptions for management practice [3]. It is a challenge for firms to utilise dynamic capabilities because there is little prescriptive guidance on how to identify them and how they should be managed [4]. A design science research approach could help produce Mode 2 knowledge in this field [5]. Another point of critique is that many studies draw on evolutionary economics [6]; a stream of literature which hardly reserves any ‘space on the stage’ for individual intentionality or managerial agency because of oversimplified behavioral assumptions [7]. Albeit there have been previous studies referring to the multilayered nature of capabilities they still have been treated as collective, repetitive entities, embedded in organizations at either micro- or macro-levels of analysis [8].

Many types of dynamic capabilities haven been identified: e.g. product development, alliance management, and strategic decision making. To impose a clear empirical scope, in this study I examine the absorptive capacity (AC) process of an organization as a dynamic capability [9]. AC refers to the degree to which a firm is able to identify, assimilate, apply and exploit knowledge from its environment [10]. The role of individuals is a key component in the original logic of the AC construct but insufficient attention given to the process characteristics of absorptive capacity has led researchers to disregard this role [11].

In countering this critique, it is argued here that there is a relationship between patterns through which capabilities develop and the role of managerial agency. More specifically, I do not focus on micro-foundations in the sense of constitutional relationships between capabilities and managers; instead I aim to explore interdependencies between managerial action and the evolution of capabilities. To investigate this relationship, a design science approach is adopted which lends itself well to a practical analysis of interaction between agents and social artifacts [12]. In executing this research an inductive case study is conducted following a single case strategy with embedded units of analysis. In addition, by evaluating the role of managers in a design science context it is expected that this study will generate implications and prescriptions for practice.

The remainder of this paper is organized as follows: the next chapter provides the theoretical framework of this study through a brief review of the literature on design science in management studies and dynamic capabilities. Subsequently, in the third chapter research design and methodology are described. Finally, results are discussed with initial findings and implications for practice and academia.

2 Theory

2.1 Design Science in Management Studies

In this study I aim to investigate the interaction between managerial agency (i.e. the role of managers) and dynamic capabilities by adopting a design science approach. An important driver for this is that the management field is behind in its relevance to practitioners and hence the urgent pull from practice is a long way from being fulfilled [13]. In respect of responding to an increasing need for relevant and prescriptive knowledge a design science perspective on the management theory of dynamic capabilities is taken in this research project. To provide some theoretical background, a review of literature on design science in management is given in this section.

The debate about the applied characteristics of the management field and its seemingly unsatisfactory relevance for practice has generated different reactions from scholars. For example, Weick [14] disregards the notion of a practice oriented field in rigorous and inventive theorizing about phenomena in organizations. An alternative view is held by a group management scholars arguing for a balance between practical relevance and scientific rigour [15]. Yet a third perspective makes the case for a central role for practical relevance by creating a new (sub-) discipline different from the management field's social science heritage [16]. This school of thought perceives management research as primarily a design science. Many of the thought found in this stream demonstrate clear links with Simon's landmark work on sciences of the artificial (social science) versus sciences of the natural.

From an analysis of Simon's work and its differentiation between social and technological artefacts, Pandza and Thorpe [17] raise an interesting question, viz.: if there are different ways through which artefacts emerge; is it then possible to distinguish between different types of design which reflect these differences? They propose three different management designs: the deterministic; path-dependent; and path-creation design.

First, the deterministic design centralises the role of a designer deterministically influences the behaviour of artefacts. Here, the deliberate design process is characterised by a duality of creativity and analysis. An example of a deterministic design in management is the 'strategy as design' stream of thought. This perspective views strategy making as a top-down, prescriptive process with a designer role for the board and the CEO. Furthermore, this view asserts that the environment can be analysed and that a firm's opportunities and threats can be derived from it. However, in the complexity of the social and organisational world it is unlikely that designer will be in control of the sequences of the design process and the behaviour of artefacts. Therefore, Pandza and Thorpe argue that design in social science is quasi-deterministic at best.

Second, the path-dependent design argues differently that the behaviour of artefacts is not determined by a designer; rather artefacts evolve and react to a selective force according to premises of Darwinian selection and Lamarkian progression. Processes of evolution pertain to stability, semi-automatic repetition, learning, adaptation, path-dependency, and stability. This view is exemplified in theory of population ecology which conceptualises organisations as adhering to macro-level selection mechanisms that drive their evolution into survival or failure. The path-dependent perspective assigns a passive role to human agency as is adapts to selective forces and is highly sceptical regarding the possibility of a prescriptive science dictating guidelines for evolution.

Third, an alternative view emerges from the idea that theories emphasizing passive adaptation or foresight based, deterministic rule-following fail to provide insight into the creation of new knowledge paths [18]. The path-creation design defines design as a search for novelty that cannot be predicted as opposed to foresight based design of the first perspective. In addition, despite the recognition of the evolution of social phenomena; this view suggests agents can actively shape the occurrence of artefacts in ways dissimilar and novel to the establishment Moreover, instead of a central designer, agency is distributed throughout the social system under study. Pandza and Thorpe argue that the path-creation design is a promising avenue for design science in management since it connects agency, evolution, and design.

It remains questionable however whether design science provides a valid substitute for existing paradigms in management research and whether it differs from explanation based, theoretical development centred management science. Although pro and contra arguments are plausible, these questions pertain to a sufficiently important and complicated matter that they merit separate treatment. For the purpose of this study a design is chosen that is positioned somewhere in between the path-dependent and path-creation design since I argue for an agency based view on dynamic capabilities. I propose an alternative to dichotomist perspectives that prefer either micro or macro aspects of social reality. I conceptualize agency as 'the intentional and purposive, creative action of individuals related to their capacity to act and make a difference, which is enacted through social interaction between individuals and groups' [19]. The next paragraph reviews the dynamic capabilities literature and discusses the application of a design that synthesizes between path-dependence and path-creation.

2.2 Dynamic Capabilities

The Dynamic Capabilities Framework. The dynamic capabilities framework explains why firms are able to respond in a timely manner to changes in their environment through innovation and the effective combination and deployment of internal resources and competencies. To survive and competitively succeed in contexts of rapid technological change, firms should possess dynamic capabilities that prevent them from developing core rigidities.

Acknowledging the valuable contributions previous studies have made, these expositions however remain unsatisfactory because of the following weaknesses which I will summarise briefly. Most research on dynamic capabilities has focused on content or "what" questions with a lack of attention given to the "how" or process elements which is central to a behavioural view on organisations [20]. Furthermore, there is a general lack of empirical studies in the field [21]. A fundamental criticism relates to the role of individual agency in dynamic capabilities which is neglected, reduced to an oversimplified model, or conceptualised as a capability constituent [22].

This study responds to these weaknesses on several levels: first, by adopting a longitudinal research design to shed light on the process elements inherent to the evolutionary nature of dynamic capabilities by empirical means of inquiry. Second, by integrating the path-creation management design into dynamic capabilities theory I still acknowledge the evolutionary nature of dynamic capabilities but I argue that managerial agency distributed throughout a firm plays a role as well in the patterned development of dynamic capabilities. This implies a design that combines features from the path-dependent and path-creation perspective. Third, the focus on managerial agency and a design science approach to dynamic capabilities is expected to produce knowledge relevant to managerial practice.

Absorbing Technological Knowledge. In its original conceptualization [23] absorptive capacity (AC) refers to the extent to which a firm is able to identify, assimilate, apply and exploit knowledge from its environment. As a contributor to organizational performance, absorptive capacity has been defined as a dynamic capability centred on knowledge creation and utilization to enhance a firm's ability to obtain and sustain competitive advantage[24]. Defining AC as a dynamic capability provides the opportunity to study the managerial processes that constitute AC because these have remained a black box [25].

Despite a vast amount of literature dedicated to AC, studies to date have remained predominantly at a conceptual level, lacking empirical studies which are needed to further develop its conceptualization and work towards a unified understanding of this construct [26] and increase its relevance and prescriptive value. Another important gap in light of this study is the underestimation of managerial agency which inhibits our understanding of the role of individuals who search the environment, integrate knowledge and exploit it in a design science model; which is key to understanding how a firm develops and utilizes its absorptive capacity [27].

In an attempt to address these points of critique, this study adopts a design science perspective on AC in an attempt to unravel the nature and evolution of the AC process and its underlying patterns; and how these interact with managers to develop a model that is explanatory, relevant, and prescriptive for practitioners. Based on a more detailed review of the above literature and the results of this case study a model is developed which is depicted in *figure 1.* Since this is an inductive study (see next chapter), it is expected that additional and richer concepts will emerge as more data is collected and hence this framework is expected to undergo change as a result of an iterative process going back and forth from (re)conceptualisation to data analysis.

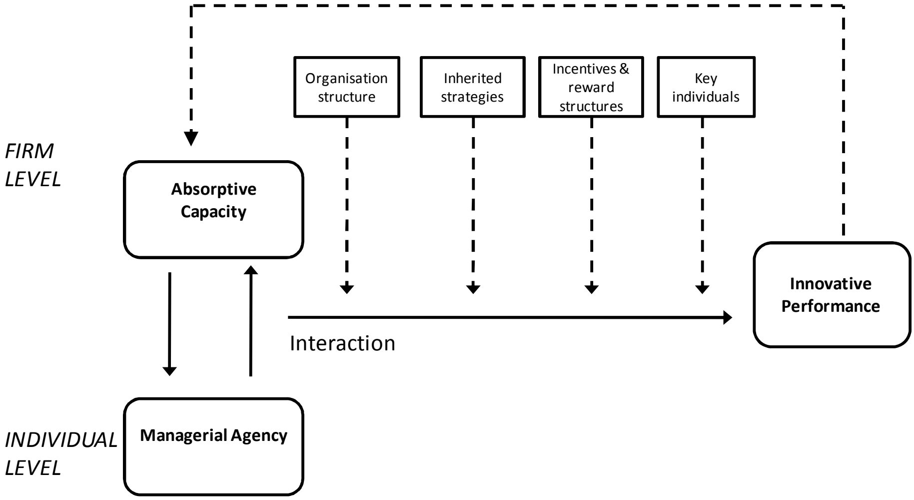

Fig. 1. An Agency Based Model of Absorptive Capacity (adapted from Lewin et al., 2011)

3 Methodology

Due to the qualitative nature of the problem definition I adopt an inductive theory-building approach [28], following a single case study strategy [29]. Since this topic is still recent and many conceptual issues are not yet transparent in existing theory make case study research a reliable method for gaining insights into the dynamic capabilities using a design science approach. Moreover, the case is examined with two embedded units of analysis: dynamic capabilities as a firm level phenomenon and managerial agency on individual level.

Semi-structured interviews are the main source of data. In a later stage a survey will be distributed in each case to produce quantitative data which is used to detect empirical regularities on a more general level [30]. The aim is to derive models and generate both description-oriented organisation theory as well as prescription-oriented management theory from discovered patterns in this study's results. This line of reasoning is based on the assumption of the existence of a social reality independent of its identification by social analysts and actors [31]. As a design science research exercise, this study's methodology contains elements which facilitate Mode 2 knowledge production: a) a placement in the case firm, and b) workshops to reflect on

Table 1. Methods of data collection

CATEGORY	DESCRIPTION
Interviews	• Semi-structured interviews (recorded, transcribed and coded using computer-assisted qualitative data analysis software Nvivo8) that last approx. 1-2 hours • Different individuals interviewed, involved in the strategy and/or innovation process for internal validity of research • Approx. 30-50 interviews per case (depending on saturation and capacity)
Archival documents	• Study of archival data (annual reports, news clippings, internet sources, strategic plans, project plans, roadmaps, PowerPoint presentations and possible other sources)
Observation& Placement	• Period during which the researcher participates in activities during several weeks • Observation of relevant events
Embedded survey	• A survey with a structured questionnaire distributed during interviews to be completed later on; or conducted per telephone/e-mail with individuals who are not interviewed • Includes different informants involved in current and former projects
Design research workshops	• Workshops in which representatives participate in reflecting on research findings (at the mid and end of the research project) • Deliverables of workshops: suggestions for intervention, contribution to design of innovation processes; i.e. translation of scientific findings into practical relevance

findings together with the case subject and suggest areas for intervention. An array of methods (see table one below) of data collection is used for field research.

4 Results

4.1 Research Setting

Field research was carried out in a global telecommunications company which I will refer to as “Telco Ltd.” Telco Ltd. was established in 2002 by specialists in radio telecommunications technology. Its defining service or core business is high-speed, wireless network solutions for the transportation sector. More specifically, this firm offers products in four categories: media service; technological infrastructure; on-board equipment; and data management. Its clients are commercial and government owned transportation providers. Telco Ltd. operates in the wireless telecommunications sector where technological innovation is key to survival and success (Porter, 2001). Furthermore, the firm is market leader in wireless technology and data networks in the transportation sector and is active in the Americas, Europe, Asia, Middle-East, and Australia with approximately 200 employees. Telco Ltd. is experiencing fast growth in a turbulent industry with frequent technology leaps and increasing complexity in customer demands.

4.2 Data Collection

Data collection started in May 2011 with a workshop held at the University of Leeds and a subsequent visit of a week to Telco Ltd.’s headquarters where eight initial interviews were held. The CEO and owner of the firm was present at this initial workshop which was held to define research objectives and develop a proposal that fits both solution-oriented and descriptive-oriented research to enable a problem-driven Mode 2 of knowledge production for this project (Starkey and Madan, 2001). As a result the CEO shared an expectation of a contribution in the form of a model from this study to his firm which is on the brink of entering the next stage in its organisational life cycle as it is currently confronted with the challenge of maintaining the dissipative ‘edge of chaos’ between efficiency and flexibility which is illustrated by this quote from an interview with the CEO: [We need to be more structured, more focussed, less flexible.]

Consequently, this research project is expected to deliver a model that prescribes and explains the integration of innovation and strategy processes. Having interviewed staff at different hierarchical positions during the visit to headquarters, it became clear innovation based growth seems to be both a strategic objective as well as a day-to-day concern in a market with a strong number two and demanding clients and hence the absorption of technological knowledge held externally and the consequent integration in Telco Ltd.’s strategy is a pivotal process. Eight interviews were held so far of which the analysis is summarised in the remainder of this chapter.

4.3 Data Analysis

Telco Ltd. is a company that struggles with its innovation process in that it recognises it needs a more structured approach but does not want to let go of the low-barrier, spontaneous, informal way of doing technological innovation. The CTO explained:

[There will be a formal process for it but right now everybody has the autonomy to be able to do this. But it's going to be short lived. It's been this way for a number of years. It's coming to the point where we have to be organised in a more traditional business sense.]

The firm's has got six patents in Europe at the moment and more in the pipeline in both Europe and the United States. I.P. is a strategic resource and developing new technology from various sources is crucial to preserve its competitive edge and hence this capability is at the core of Telco Ltd.'s strategy and operations. The first steps in the innovation process; i.e. from identification of an idea or knowledge to an actual resource commitment into implementation are highly informal and dependent on social interaction between individuals, groups and even between external customers and competitors. Telco Ltd.'s sources of technological knowledge are:

- The CEO, senior management team, software developers, engineers and sales staff in the organisation and their communities.
- Customers: train operators who specify their problems and objectives and ask Telco Ltd. to solve and meet these. Telco Ltd. organises workshops in which it invites its customers to generate ideas for new services and technologies. Here, Telco Ltd. tests its early innovative ideas for feedback from customers. Knowledge emerging from this group gets absolute priority in the resource allocation component of the innovation process as was explained by the CEO and Technical Director.
- Mobile telecom providers; one German provider's venture capital company has its representative on the board of Telco Ltd. and provides access to technologies.
- RFI's and RFP's: 'a leaky process' according to the CEO and confirmed by the Technical Director in which technology and product specifications from competitors are revealed by additional requests from the concerned project's client.
- Online sources: specialist forums and communities that discuss the latest technology in software development.

In the first wave of interviews, sessions were held with staff from different parts of the organisation occupying different hierarchical positions. The job positions involved were; CEO/owner (2 interviews), Chief Technological Officer, Technical Director (2 interviews), Application Developer, Software Engineer, Teamlead System Administration. One of the main questions revolved around interviewees' role in the innovation process as regards to the identification and integration of new technology and how this knowledge is integrated into Telco Ltd.'s organisation. Furthermore, they were asked how the process of sourcing and utilising technological innovation has developed and how their role as managers/specialists has influenced this path. These two central questions correspond to the patterned development of absorptive capacity as a dynamic capability and the role of agency with respect thereof. An analysis of feedback on these questions follows.

The CEO and owner of Telco Ltd. is a mechanical engineer with a PhD in friction and wear and an MBA. He has been starting businesses since the early nineties and has a strong entrepreneurial drive. The CEO developed the core technology in the year 2000 as a WiFi based network switching technology which has now developed in an end-to-end systems integration solution. The initial service proposition was tailored for the train transportation sector and revolutionary changed the way railway services were offered in terms of on board connectivity for passengers and train operating staff. He described his role as an entrepreneur and manager since his background does not match the technical context of Telco Ltd.

[We see massive gaps with what we have and what we need to have in knowledge.] (CEO)

The CEO mentioned different directions for addressing these gaps: hiring new staff with specific expertise; the acquisition of firms possessing knowledge required for an R&D project; search efforts by sales staff; and the CEO's network. He further explains that Telco Ltd. is an open company where anyone can approach him with innovative ideas:

[There's very little formal stuff. It's who shouts loudest, who can make the case best. And then in the end you're right, the ideas don't come from me but in the end it's up to me to say: "Yes" to this one or "no" to that one.]

Regarding his receptiveness toward innovative ideas:

[I say yes more than no. They keep asking the same question. They got their pet projects and they'll keep pushing them.]

All interviewees refer to the innovation process as very informal but recently moving to a more structured process. From the CEO it became clear that there are different processes for innovation related to new technologies close to the core technology and for fundamentally new technologies; i.e. ideas emerging from local vis-a-vis non-local search. Technologies relatively close to the core business follow a more structured path and go through the Project Office's stage gate process. Development of distant technologies and idea generation is less structured (see *figure 2*). The latter one tends to get lost as the organisation matures according to the CEO who regards it as his duty to preserve it.

The above depicted innovation process is subject to social complexity in the idea stage when staff interact and discuss its potential. Furthermore, there is additional social interaction involved when the idea is presented to the CEO or other senior management staff (decision diamond) for resources. Subsequently, after the

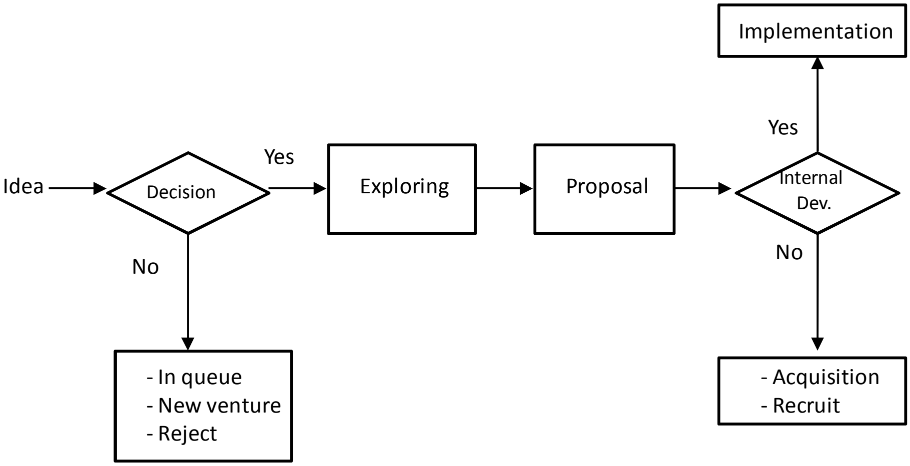

Fig. 2. Telco Ltd's innovation process

exploration or Proof of Concept (POC) stage which the CEO described as "playing", a proposal to the rest of the organisation is constructed and presented; another instance of social dynamics. In this stage depending on the feedback and enthusiasm the idea is either internally developed or additional staff is recruited or even an acquisition of a firm takes place to address the knowledge gap for this R&D project.

Incremental innovation which expands on the core technology of Telco Ltd. is handled differently and does hardly involve senior management. This type of technological knowledge creation is characterised by autonomous processes as the CTO explained:

[There will be a formal process for it but right now everybody has the autonomy to be able to do this. But it's going to be short lived. It's been this way for a number of years. It's coming to the point where we have to be organised in a more traditional business sense.]

This type of innovation follows a defined project management protocol and release schedule management by the Project Office. Autonomous action occurs in different ways across units. The Teamlead System Adminstratopm explained that the Apps Developers are known for a collective approach to innovation as a team. The Apps Developer confirmed this by revealing a social interaction process within the Apps Team before an innovative idea would be shared with the rest of the organisation. It seems after the team decides favourably, the idea is communicated as originating from the team instead of an individual. This indicates the presence of strong team cohesion and possibly a collective cognitive frame. The Apps Developer said to experience innovation as spontaneous, often starting with a white board session and if enthusiasm increased a teleconference would be organised with team members in other countries.

[Open atmosphere, you're allowed to talk to people. Formal meetings don't yield much.] (Apps Developer)

The Technical Director who is responsible for the developers and engineers is a key individual in the process of integrating new technologies into Telco Ltd.'s innovation process because he is well connected in both the commercial and technical parts of the organisation:

[One of my strengths is I got a foot in the technical camp and one in the business world. The guys are a bit isolated from the activities in the rest of the business. Guess I'm bit of a sounding board and a bit of a filter for the business as well.]

Regarding the acceptance of new technologies he prioritises both in a formal and informal way. A new technology solving customer problems gets absolute priority. The same goes for ideas that reduce costs. However, he also stated that sometimes new technologies embed uncertainty and based on potential value, risks are taken by accepting such projects.

[In some areas we need to take a leap of faith: like scheduling information systems. Very expensive.]

Such uncertainty in new knowledge integration usually indicates social dynamics pertaining to e.g. legitimization, socialization mechanisms, and power relationships (Todorova and Durisin, 2007; Pandza, 2010) and these elements emerged slightly when he discussed some radical ideas being promoted for a while now in the organisation but still not having enough momentum to be accepted and implemented. He also gave two examples of two fundamentally new technologies that were pushed for two and three years and are now being implemented. These projects are related to RFID and a considerable overhead cost reducing technology shifting hardware to software.

Another interesting notion came from an interview with an operational employee whose role is not described here because of the potential risk of this statement. First this interviewee complained about hardly any time to keep up with technological developments in the environment due to a too high day-to-day workload. This interviewee further held the opinion that the identification of new technologies and its consequent communication within the firm seems to be the exclusive right for some individuals higher up in hierarchy, an idea which he strongly opposed. The question is whether this is an individual opinion or whether it is something experienced by an identifiable group, perhaps the team to which the interview belongs?

5 Conclusion

From initial interviews it became clear that autonomous action is crucial to the innovation process of Telco Ltd.; specifically for the integration and development of new technologies close to the core business whereas more radical technologies pass through a more informal process but simultaneously require more approval and commitment from individuals higher in the hierarchy. New technologies that went through these processes have led to the development of Telco Ltd.'s capabilities transforming it from a WiFi technology provider to a network and systems integrator competing with the likes of Nokia-Siemens and Alcatel-Lucent. Finally, the social complexity associated with adopting new technologies suggests a pivotal role for agency and social interaction in this process of absorbing new technologies. Some of the elements that became apparent within this context during the interviews are: pitching, issue selling, individual and collective cognitive frames, collective action, team dynamics, and autonomous action. As this research project progresses more (detailed) facets of agency and social and behavioural strategies are expected to emerge.

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Design Science Approach to Measure Productivity in Agile Software Development

Richard Vidgen[1], Brian Donnellan[2], Sabine Matook[3], and Kieran Conboy[1]

[1] University of New South Wales, Australian School of Business,
Sydney NSW 2052, Australia
`r.vidgen,k.conboy@unsw.edu.au`
[2] Innovation Value Institute, National University of Ireland, Maynooth, Ireland
`brian.donnellan@nuim.ie`
[3] The University of Queensland, UQ Business School, 4072 Brisbane, QLD, Australia
`s.matook@business.uq.edu.au`

Abstract. While adoption of agile software methods is high, little hard, rigorous evidence exists as to the success of these approaches. This paper describes the design science process that will be used to create a measure for productivity in agile development environments. We consider design science to be suitable because measuring performance in software development is laden with issues around measurability, ambiguity and imperfection. As a result, we need the rigor that design science brings while still maintaining relevance.

Keywords: design science, agile development, productivity.

1 Introduction

Agile software development approaches have been widely regarded as being highly effective. Many case studies report success stories from agile development projects, citing faster delivery, more satisfied and happier customers, and less bugs [e.g., 1].

Despite the substantial amount of books, journal papers, and industry reports reporting the effectiveness of agile methods, there is a lack of hard evidence to support this view [2]. The absence of measures in agile may be attributed to the people focus of the approach: agile software development assumes a collaborative and interactive environment in which developers and customers are highly motivated to work together to co-create valuable, working software [3].

To address this lack of rigor, the authors plan to identify and evaluate a set of measures for agile development. Given the focus on rigor, the development of a core set of artifacts - and the need for comprehensive evaluation and communication - the authors decided to adopt a design science (DS) approach to the research.

We begin by discussing the relevant literature on DS in Section 2, concluding with a description of the DS research (DSR) process that will be used as the basis for this study. Section 3 then describes the structure of the research for this study, based on the process model in Section 2. In section 4 we draw on the application of DS in this paper to reflect more broadly on the DS process.

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2 Design Science

Design activities are central to most applied disciplines, and DSR has a long history in many fields including architecture, engineering, education, psychology and the fine arts [4]. While there is no widely accepted definition of DSR, when distinguishing between DSR and Action Research, Ilvari and Venable [5] defined DSR as *a research activity that invents or builds new, innovative artifacts for solving problems or achieving improvements*. Such new and innovative artifacts create new reality, rather than explaining existing reality or helping to make sense of it [6].

The DSR paradigm is highly relevant to IS research because it directly addresses two of the key issues of the discipline: the central role of the IT artifact in IS research ([7, 8]) and the perceived lack of relevance of IS research to the business [8]. DS seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, and use of IS can be effectively and efficiently accomplished.

The result of DSR in IS is, by definition, a purposeful artifact created to address an important organizational problem. An IT artifact represents “any designed solution that solves a problem in context.” [9], p. 4-5. Artifacts can be innovations that provide a degree of novelty into an application context.

March and Smith [10] identify two design processes and four design artifacts produced by DSR in IS. The two processes are *build* and *evaluate,* and the four artifacts are constructs, models, methods, and instantiations. The role of artifacts is to address heretofore unsolved problems; the artifacts are evaluated with respect to the utility provided in solving those problems. The design of the artifact is a non-linear process in which uncertainty, uniqueness and conflict can emerge.

A central concern of DSR has been the development of a systematic and process-oriented approach to design and the practical application of such approaches [36]. Pfeffers et *al.* [11] designed and demonstrated a process for carrying out design science (DS) research in information systems and demonstrated use of the process to conduct research in four case studies. The purpose was to develop a DSR process (DSRP) model that would meet three objectives: it would be consistent with prior literature; be a nominal process model for doing DS research, and provide a mental model for presenting and appreciating DS research in IS.

3 Illustration: Productivity Measurement in Agile Software Development

In this section, we use Pfeffer’s et *al.* [11] DSR process to present the design of a measurement system for agile software development projects. Figure 1 summarizes the artifact creation. Our entry point in the creation process is at the objective phase and thus, specific for and focused on a tangible outcome.

3.1 Problem Identification and Motivation

First, the problem is defined and motivated [11]. Our problem space is agile development where a measure gap impairs project success. We suggest to address the agile metrics gap by applying "lean thinking" [2]. This is a "management approach that emphasizes creating value for end customers and eliminating activities that are not value-adding (waste)" [3, 12]. Lean thinking is rooted in the manufacturing industry and can be traced back to Toyota's 1950s Production System [13].

3.2 Objectives of a Solution

In the second stage, the objectives of the solution are specified [11]. In our case, the objective is the creation of a system for agile software development projects to measure the productivity of these projects. Hence, we aim to achieve the following three objectives with the novel artifact: (1) Measurement of agile productivity at any stage of the development process; (2) Identification of areas in the process that can be improved to achieve higher productivity; (3) Control and comparison of the agile development process across teams within a firm and across firms.

3.3 Design and Development

In this third stage, the artifact will be created [11]. First, we do a literaure review on lean management metrics. Second, we translate the measures to the agile software development context. This translation process needs to be sensitive to the similarities and differences between lean management and agile software development. For example, lean does not appreciate people centred practices and rather promotes automated work flow tools, progress measures and simulations [12].

3.4 Demonstration

In this stage, the problem solving capability of the artifact is demonstrated [11]. To demonstrate the use of the measurement system to solve the existing gap in productivity, we plan to conduct field interventions in firms.

3.5 Evaluation

The evaluation focuses on empirical evidence for the effectiveness of the artifact but also on the degree of goal/objective achievement [11]. During the field interventions, participatory observations and interviews will be conducted with development teams and also particular individuals (e.g., managers, developers).

3.6 Communication

Communiction of the novel artifact but also of the entire design process will be undertaken [11]. For our research, we target scholary and practitioner outlets.

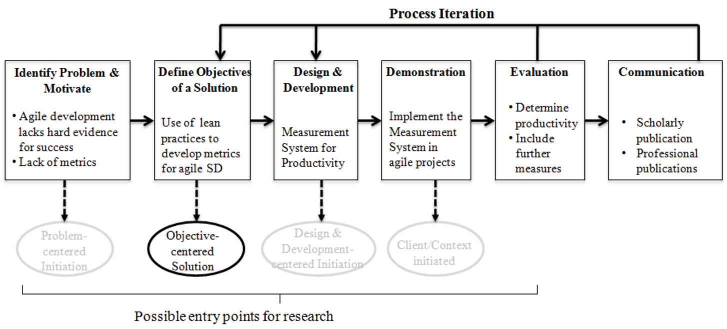

Fig. 1. The design science process applied in this study

4 Reflections on the Design Science Process

In applying the Peffers et *al.* [11] DSRM we encounter a number of issues – both practical and theoretical. A burning question for the design scientist is what constitutes an ‘artifact’. Hevner et *al.* [6] posit how we might design artifacts that help organizations overcome the acceptance problems predicted by theory: *“We argue that a combination of technology-based artifacts (e.g., system conceptualizations and representations, practices, technical capabilities, interfaces, etc.), organization based artifacts (e.g., structures, compensation, reporting relationships, social systems, etc.), and people-based artifacts (e.g., training, consensus building, etc.) are [sic] necessary to address such issues.” (p. 84).*

The term ‘artifact’ is being made to do some heavy lifting indeed, ranging from tangible bits of technology, such as software artifacts, through to intensely social artifacts, such as “consensus building”. For any given design research project, the artifacts to be built need to be identified and boundaries drawn. If the boundaries are drawn in an inappropriate manner, for example productivity measures (a technology-based artifact) are introduced but the artifacts related to training, organizational support, and consensus building are not addressed then the DS project will likely fail to be accepted. Is this failure attributable solely to the technology-based artifact? To the organization-based and people –based artifacts?

There is a strong sense that problems are pre-existing in the world and that the role of design science is to identify these problems and to then propose solutions. This seems like a reasonable approach for technology-based artifacts, for which a set of requirements can be specified and a solution designed. It is not so apparent that the problem solving approach can be taken once the context of application for the artifact is taken into account and organizational/people based artifacts are included in the mix.

Linstone [14] has highlighted some shortcomings of the traditional perspective grounded in science and engineering. In this traditional worldview problems are defined with the assumption that they can be solved; Linstone (ibid.) argues that solving a problem creates new problems - we shift problems rather than solve them. Linstone also argues against reductionism (a reliance on data and models as the only legitimate means of enquiry), the analyst (design scientist) as objective observer; individuals as types (but not as unique persons); and a linear, universal model of time.

Linstone labels the traditional perspective as the *technical (T)* perspective. Mitroff and Linstone [15] augment the technical view with organizational and personal views of a problem situation. The *organizational (O)* perspective is concerned with social entities, processes, justice and fairness, the problem of the moment, and reasonableness. The *personal (P)* perspective is concerned with individuation, power and influence, values and morality, challenges, and a need for beliefs [15].

These different perspectives are concerned with how we consider a problem situation. Linstone [16] justifies the use of multiple perspectives firstly on the grounds that *"each perspective yields insights not obtainable with the others"*, and secondly "*the O and P perspectives are essential in bridging the gap between analysis and action*" (p. 314). Linstone [16] argues that the T perspective focuses on analysis, but must be supported by O and P analyses when moving to implementation. DS is dominated by technology-based artifacts within a T perspective, while successful implementation and evaluation will require attention to be given to organization-based artifacts (O perspective) and people-based artifacts (P perspective). In situations where the role of technology-based artifact is downplayed and the organization/ people-based artifacts take greater prominence, then DSR becomes largely indistinguishable from action research. Peffers et *al.* [11] *"[i]n DS research, design and the proof of its usefulness is the central component, whereas in action research, the focus of interest is the organizational context and the active search for problem solutions therein*" (p. 72).

Peffers et *al.* [11] then say that the resolution of this point is outside the scope of their paper. We suggest that a study of information systems will always, by definition (and based on the assumption that we are not computer scientists), include some aspect of the organizational context. Hevner et *al.* [6] go further and claim that this context should include a consideration of profit. Thus, while DSR is concerned with providing solutions to organizations the *O* and *P* perspectives will always have relevance. Sometimes, this relevance will be slight and a focus on technology-based artifacts is appropriate and the *O* and *P* dimensions have only weak effects. At the other end of the spectrum the *O* and *P* perspectives will be paramount and such a design science project would indeed be indistinguishable from action research (Fig.2).

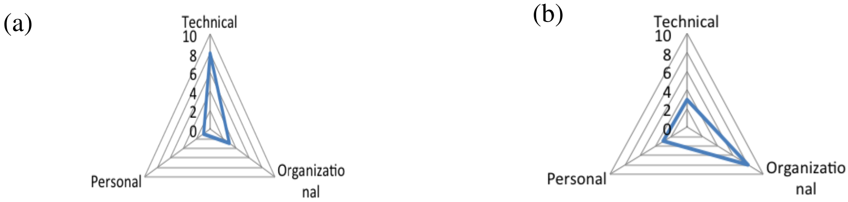

Fig. 2. Profiling design science and action research

Our proposed DSR project has a substantial technology-based artifact content. In the first phase, we develop an agile measurement system based on lean principles. Evaluation of this artifact will involve agile team members and IS managers with an emphasis on technical rationality and the technology-based artifact rather than the *O* and *P* dimensions (Fig. 2a). A further evaluation will be needed to assess how well the agile measurement system works in an organizational context, at which time the technology-based artifact will need to be supplemented with organizational and people-based artifacts (Fig. 2b). The evaluation resembles an action research project.

5 Conclusions and Future Research

Despite the substantial amount of prior agile research, there is lack of hard evidence to support the effectiveness of agile methods [2, 17]. To address this issue, the authors plan to identify and evaluate a set of measures for agile software development.

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