A Meta-Level Design Science Process for Integrating Stakeholder Needs

Demonstrated for Smart City Services

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Abstract: Currently there is an issue in the design process of smart city services, where citizens as the main stakeholders are not involved enough in requirements engineering. In this paper, we present a meta-level design science process, based on an extended version of design science research methodology, that can be used to create requirements engineering frameworks to inform smart city service requirements engineering processes. The introduced meta-level process is beneficial as it can be used to ensure that design guideline research processes are rigorous, just as design science process ensures scientific rigor in design research. Additionally, we present a previous case study and frame it using the new meta-level design science process.

1 INTRODUCTION

Smart cities are innovative cities, which use ICT to improve quality of life for citizens (Anthopoulos et al., 2016; Booch, 2010; Kondepudi and others, 2014). According to Ferguson (2004) services are the enablers in the digital cities and therefore, responsible to improve the citizens' quality of life. In the other word, the services in the smart cities need to respond to the needs of the citizens. In this regard, Pourzolfaghar and Helfert (2017) have defined the term 'smart service' for the services which meet the smart cities quality factors and respond to the smart cities stakeholders' concerns.

Prior to introduction of agile method in early 2000, software developers were using traditional approaches to develop software. In traditional development methods, such as the waterfall, requirements are divided into two different categories of user and system requirements, or functional and non-functional requirements. Functional requirements are statements of software features and depend on some factors, e.g. the expected users (Sommerville, 2011). The functional user requirements define specific facilities to be provided by the software. According to Sommerville (2011), imprecision in the requirements specifications is the cause of many software engineering problems. Smart cities should ensure quality factors as perceived by the end users, which are often the citizens, and ensure that they are included as stakeholders already in the requirements engineering phase of projects.

A review of the recent literature suggests that requirements engineering processes, as it exists in smart city service design today, need guidance. A requirements framework would enable service developers to define the user requirements in line with the citizens' needs in smart cities. However, how to ensure that the requirements framework responds to the needs of the application domain, is valid and is scientifically rigorous?

To address the issue, we

1. extend Ostrowski's design science process for creating meta-level artefacts (2011, 2012), and
2. present how this new design science process can be applied to create requirements engineering frameworks.

Ostrowski et al. (2013) presented a method for creating abstract design knowledge with business process modelling, which is suitable for situations where it is possible to capture explicit organizational knowledge. In this paper, we present an alternative, grounded theory -based approach, which is more suitable for complex problems with human factors that are difficult to address with formal modelling

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(Urquhart et al., 2010). The new approach presented in this approach is more suited for social systems where the knowledge is tacit instead of formal, which is often the case in human societies.

To summarize the research problem, we want to investigate *how stakeholder needs can be better included in the smart city service design process.* To address this issue, *we present a design science research process for meta-level knowledge artefacts that can be used to design requirements engineering frameworks*.

The rest of the paper is structured as follows. In section two we review recent literature on smart city service design and requirements engineering. In section three we review design science and meta-level knowledge artefact creation. In section four we present a new framework for creating abstract design knowledge and an initial evaluation of the framework in the context of requirements engineering research. The paper ends with section five, conclusion.

2 OVERVIEW OF SMART CITY SERVICE DEVELOPMENT AND REQUIREMENTS FRAMEWORKS

2.1 Smart City Service Development

The general method to develop the services in smart cities is agile development method. This is due to the priceless capabilities of agile methods in terms of quick delivery, simplicity, flexibility, easy risk management, and less process time compared to traditional models (Shah, 2016). However, recently many researchers disclosed some challenges facing agile methods in terms of defining appropriate goals and considering stakeholders concerns. For instance, Kakarontzas et al. (2014) reported some challenges related to planning the projects, setting achievable and realistic goals and objectives, and taking into account the stakeholders' concerns. Likewise, Dingsoyr and Moe (2013) presented some challenges at the time of project planning, the role of architecture, collaboration between developers and stakeholders, and constraints in contracts. Shah (2016) outlined the challenges facing agile methods as follows: 1) lack of high quality interactions with stakeholders; 2) overrunning time and cost problems due to evolving requirements; 3) lack of quality requirements in initial stages that is essential for success; 4) unrealistic expectations; and 5) no formal modelling for the requirements.

2.2 Requirements Engineering

Requirements engineering is one of the crucial stages in software design and development, as it addresses the critical problem of designing the right software for the right user (Aurum and Wohlin, 2005). It is concerned with identification of goals for a proposed system, the operation and conversion of these goals into services and constraints, and the assignments of responsibilities for development. There are different levels of requirements, such as functional requirements that specify what the system will do or non-functional requirements which guide solution design.

Stakeholders play an essential part in requirements engineering, as they represent all the involved parties and will in one way or another define the requirements (Aurum and Wohlin, 2005). Typical stakeholders are product managers, various types of users and the products' software developers. However, requirement gathering is rarely trivial and requirements elicitation involves seeking, uncovering and elaborating requirements in a complex process, which can involve conflicts between stakeholders (Zowghi and Coulin, 2005). Conflicts between different stakeholder parties leads to a requirements priorization process, where importance, risk cost and other factors are used in deciding what features to include in requirements (Berander and Andrews, 2005).

3 DESIGN SCIENCE RESEARCH APPROACH

The overall research approach for this paper is design science (Hevner et al., 2004), which is commonly used in the information system sciences to create artefacts in the form of instantiated systems or new design knowledge (Ostrowski et al., 2011). Hevner and Chatterjee (2010, p. 5) define Design Science Research (DSR) as follows:

"Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem."

From the above, Hevner and Chatterjee (2010, p. 5) derive the first principle of DSR: "The fundamental principle of design science research is that knowledge and understanding of a design problem and its solution are required in the building and application of an artefact." What essentially separates the design science research process from routine design practise is the creation of new knowledge (Hevner and Chatterjee, 2010). If the design process is rigorous, it is based on existing theories and produces new scientific knowledge, then the process can be considered design science research.

The concept of an artefact is at the core of the research science process. In a synthesis of the Sciences of the Artificial (Simon, 1996) and Developing a Discipline of the Design/Science/Research (Cross, 2001) by Hevner et al. (2010), they broadly define artefacts, which are the end-goal of any design science research project, as follows: Construct (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), instantiations (implemented and prototype systems), and better design theories.

The situations where DSR is well applicable are situations where humans and software systems intersect (Hevner and Chatterjee, 2010), like information systems or software engineering research. What makes information systems research unique is that it investigates the phenomenon where technological and social systems intersect (Lee, 2001), which requires a research methodology that takes both into account.

The original paper on design science by Hevner et al. (2004) does not present a model or process for performing design science research. However, a later paper (Hevner, 2007) refines the concept further and identifies the existence of three design science cycles that are present in all design research projects. These cycles are the Relevance Cycle, which connects the contextual environment to the research science project, the Rigor Cycle, which connects the design activities to the knowledge base of scientific foundations, and the Design Cycle which iteratively connects the core activities of building a design artefact and research.

Hevner's three cycle view clarified the elements of design science research, but it still doesn't still provide a clear linear view of design science research process. To provide a process model Peffers et al. (2007) synthesized the design science research methodology based on the evolving body of knowledge on design science. The process contains six activities, which are summarized as follows: Problem identification and motivation, defining the objects for a solution, design and development, demonstration, evaluation and communication.

3.1 Creating Meta-Level Knowledge Artefacts

In this section we describe the design knowledge framework for design science by Ostrowski et al. (2012), which underlines the division of design science research into an empirical part (a design practice) and a theoretical part (meta-design). These two parts exchange knowledge. The design knowledge framework presents a process for creating meta-knowledge artefacts, which consist of abstract design knowledge. These meta-artefacts in turn can be used in the creation of situational design knowledge, such as instantiations or IT systems.

Meta-design artefacts can be used as 1) a preparatory activity before situational design is started, 2) a continual activity partially integrated with the design practice, or 3) a concluding theoretical activity summarizing, evaluating and abstracting results directed for target groups outside the studied design and use practices (Goldkuhl and Lind, 2010; Ostrowski et al., 2012). Meta-design artefacts are based on data types as opposed to specific instances of data (Ostrowski and Helfert, 2012). These types of artefacts are general, or "unreal" according to Sun et al. (2006). However, meta-design produces solid and generic background for design science activities to construct solutions for a real environments, systems and people (Ostrowski and Helfert, 2012; Sun and Kantor, 2006).

In Figure 1 we extend Hevner's three cycle view (2007) to include the split between abstract and situational knowledge. The original three cycle view included only the top half and considered only situational knowledge. The top level contains the environment and situational design, where design science could be applied to create requirements for one specific smart city service. The lower level contains the creation of abstract design knowledge, which informs and guides the design of situational artefacts. Ostrowski et al. (2011, 2012) have earlier created a similar extension for the process model by Peffers et al. (2007), following the ideas by Goldkuhl and Lind (2010).

In our case, the meta-design context is fitting for the creation of requirements framework, because we create meta-level design knowledge (framework) that guides the creation of the situational design (set of requirements). Both levels of design, situational and abstract, produce a method as the artefact. However, the situational design produces a set of requirements and the abstract design part produces a requirements framework to guide the requirements process.

Ostrowski et al. (2011, 2012) further divide the meta-artefact design process into three steps that interact with each other: Modelling, literature review and engagement scholarship. We relate them to the cycle model as the (theoretically grounding) rigor cycle and the meta-relevance cycle, as seen in Figure 1.

In the abstract design knowledge phase two levels of knowledge, literature and design experts, contribute to create reference models for design (Ostrowski and Helfert, 2012). Literature review allows developing an initial scope and reviewing existing knowledge, and collaboration with practitioners allows ensuring problem relevancy and gaining current knowledge. These two information sources are combined to a reference model, which allows modelling and evaluation of solutions. This model is then compared to existing body of knowledge in theoretical grounding in a rigor cycle, and to designers for the design practice phrase in a meta-relevance cycle.

The knowledge exchanges presented in Figure 1 are also form the three-part grounding process: Theoretical, empirical and internal grounding (Goldkuhl and Lind, 2010). Theoretical and empirical grounding between the meta-artefact and the artefact design cycle, and internal grounding in both artefact design cycles.

3.2 Evaluating and Grounding Meta-Level Knowledge

As with all design science research, the validity of the artefact is judged by its utility (Hevner et al., 2004). Therefore, the model resulting from meta-artefact design should be evaluated to establish its validity before applying it to the artefact design cycle.

There are two levels of evaluation in design science research: artificial and naturalistic (Venable, 2006). Artificial evaluation is contrived or non-real in some manner and may consist of simulations, field experiments or lab experiments. Naturalistic

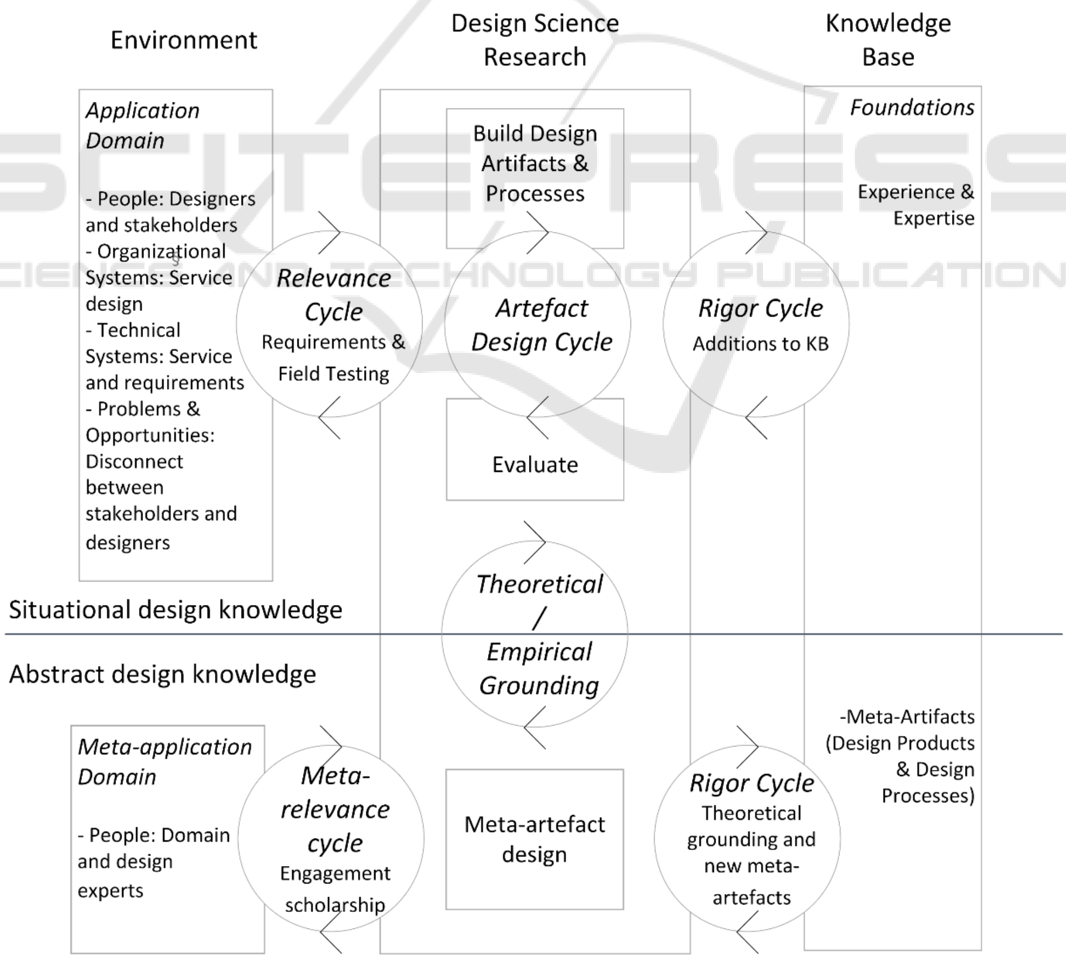


Figure 1: Extended Cyclic View of Design Science Research Process.

evaluation is full evaluation of the situational artefact in its intended environment, the application domain. Naturalistic evaluation may consist of methods such as case studies, survey studies or action research.

Ostrowski et al. (2012) present that for abstract design knowledge artificial evaluation is more suitable and for situational design knowledge naturalistic evaluation is most suitable. They also present a process model where situational design knowledge is validated with naturalistic evaluation and abstract design knowledge is further validated by that after an empirical grounding process.

4 META-LEVEL DESIGN PROCESS FOR DESIGN SCIENCE RESEARCH

In this section, we present a new meta-level design process that is builds on Ostrowski's work (2011) and earlier work on fitting the grounded theory research methodology in design science research process (Gregory, 2011). Ostrowski's framework is business process modelling -based and suitable for design science cases where large organizations are central and the knowledge is explicit. We present an alternative that is aimed for situations with complex human factors and individuals as actors, such as citizens as stakeholders in service design processes, and the knowledge is tacit.

4.1 A Framework for Creating Meta-abstract Design Knowledge Artefacts

Ostrowski's framework for creating meta-abstract design knowledge for information systems recommends three steps for creating models for information systems: 1) Literature review, 2) collaboration with practitioners, and 3) then creating an ontological model using one of the business modelling languages (Ostrowski and Helfert, 2012). It is aimed for process-oriented environments, such as large organizations or situations where business process modelling is appropriate (Ostrowski and Helfert, 2012, 2013).

In this section, we present an alternative process that uses grounded theory (Glaser and Strauss, 1967) as defined by Urquhart et al. (2012; 2010) for information systems research to generate a design theory. In the process design we follow the line of research that discusses and evaluates using grounded theory in design theories (Adams and Courtney, 2004; Goldkuhl, 2004; Gregory, 2011; Holmström et al., 2009). This alternative approach is valuable for creating meta-level design knowledge for situations that involve complex human factors that are a challenge for formal models, or for situations where is not initially clear who are the actors, their relationships and the exact nature of the issue is not clearly defined.

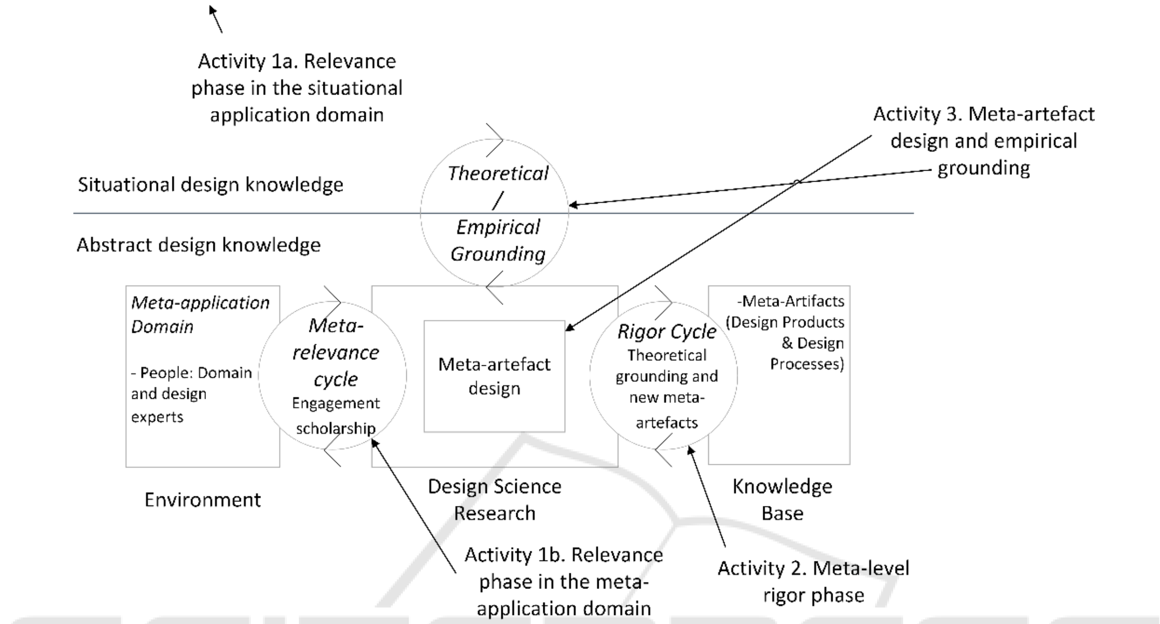
The objective of grounded theory is the discovery of a theoretically comprehensive explanation about phenomena, using techniques and analytical procedures that enable investigators to develop a theory that is significant, generalizable, reproducible and rigorous (Adams and Courtney, 2004). The aim of grounded theory is not only to describe a phenomenon, but also to provide an explanation of relevant conditions, how actors respond to the conditions and consequences of the actors' actions (Kinnunen and Simon, 2010; Urquhart et al., 2010). For data analysis, it has a systematic set of procedures that support the development of theory that is inductively derived and continuously tested against empirical data through constant comparison (Strauss and Corbin, 1990).

Grounded theory has three levels of theory: 1) narrow concepts, 2) substantive theories, and 3) formal theories (Urquhart et al., 2010). Substantive theories have been generated within a specific areas of inquiry, The highest level of abstraction is a "formal theory", which focuses on conceptual entities, such as organizational knowledge (Strauss, 1987). Our alternative process uses design science to first 1) first generate a situational grounded theory based on relevance cycle interactions, 2) use theoretical integration (Urquhart, 2007) in the rigor cycle to compare and extend the grounded theory to create a substantive theory, and 3) uses the theory to create a model to assist in situational design phase.

In Table 1 we present the three process details as synthesized from guidelines by Urquhart et al. (2010; 2012) for information systems research and Gregory (2011) for design science research methodology, and how they can be applied to requirements framework generation. The Table 1 also includes a subset of Figure 1, and relates the three process steps to the extended three cycle view of design science.

To summarize the process, in phase 1a the situation is investigated, and phenomena and actors around the current situations are identified. This involves gathering source material from the actors, often interviews, and using the grounded theory methodology to code the results. In phase 1b the meta-application domain is engaged, with the researcher interacting with domain and design experts. This results in a situational theory of the issue and initial ideas for a solution. This situational theory is then scaled up in phase 2 by engaging current academic knowledge and using theoretical integration to scale up the situational theory. Finally, in phase 3 the researcher should create a meta-level

Table 1: Meta-level artefact design, as guided by grounded theory, connected to the extended three cycle model.



Design science activity	1a. Relevance phase	1b. Meta-relevance phase	2. (Meta-level) rigor phase	3. Meta-artefact design phase; empirical grounding
Grounded theory activity	Open and selective coding; initial theoretical coding	Advanced theoretical coding; theoretical grounding.	Theoretical grounding and scaling up. Relating the emergent theory to literature.	Constant comparison. Grounding the theory back to original data.
Outcomes	Identifying core phenomena, relationships and initial explanation. Concepts defined.	Grounding the emergent theory in existing expert views. Initially grounded situational theory.	Rigorous situational theory.	A prescriptive meta-level artefact that can guide artefact design. Design informed by the descriptive situational grounded theory.
As applied in requirements framework design	Discovering key concepts and issues in smart city service design and how the stakeholders in the application domain perceive it.	Grounding the initial solution concept in requirements engineering expert opinions. Having a concept for solution that is supported by practitioners.	An initial concept of a requirements framework. Supported by existing literature.	Requirements engineering framework that has been created to address the issues in requirements design as explained in the situational theory. Supported by the (empirically and theoretically) grounded theory.

artefact based on the scaled-up theory that can be used to inform situational design processes. In the example presented in Table 1 this meta-artefact would be a requirements engineering framework that addresses issues discovered in phases 1 and 2.

4.2 Evaluating the Meta-abstract Design Knowledge Framework with a Sample Case

In this section, we evaluate the utility of our meta-abstract design knowledge framework by presenting how it can guide and inform an ongoing design science meta-artefact design process. This is an initial form of artificial evaluation (Venable, 2006), which should establish a preliminary utility of the framework (Ostrowski et al., 2012; Pries-Heje et al., 2008), and thus its validity (Hevner et al., 2004).

The evaluation consists of framing an existing series of case studies by Pourzofarghar et al., where abstract design knowledge is created by using the meta-abstract design knowledge framework. In this series of case studies Pourzofarghar et al. have discovered that currently citizens are not involved enough as stakeholders in current smart city design processes (Pourzolfaghar et al., 2016; Pourzolfaghar and Helfert, 2017), even though they are most often the end users. This is a clear issue in software system design, because requirements elicitation from all stakeholders is a critical part of requirements engineering (Zowghi and Coulin, 2005).

This far the research group has identified the issue and established a problem definition (Pourzolfaghar et al., 2016), and have created a taxonomy based on a literature review to inform smart city service developers (Pourzolfaghar and Helfert, 2017). The next step is to create a requirements engineering framework that would enable smart city requirements engineering processes to better consider citizens as stakeholders.

When one frames the entire process in the context of a design science process as presented in Figure 1 and Table 1, there are two levels. On the situational level, the application environment is 1) smart city service developers using a requirements design framework to create services, and 2) the service users as stakeholders. The knowledge base is the scientific body of knowledge on the topic. The meta level on the other hand consists of Pourzolfaghar's research group, who are creating a requirement engineering framework to inform individual service requirements engineering processes. What we are presenting in this paper is a framework to describe and formalize meta-level design.

The research group is creating several meta-artefacts, of which the smart city service taxonomy was the first one (Pourzolfaghar and Helfert, 2017). The taxonomy is a meta-artefact, because it is not the result of smart city service design processes, but instead has been created to *inform the design process*.

In Table 2 we frame the research group's design process as a meta-artefact design process with the new meta-abstract design knowledge framework and present a proposed plan how they would proceed. The benefits of the framework in this case is ensuring that their framework is strongly grounded in actual citizen needs while enabling scaling up the theory to a more general level. Having a framework to support the meta-level design science research process also ensures that the relevance, rigour and design grounding are all considered in the process.

After creation of the research plan (as summarized in Table 2) the members of the research group were interviewed first individually and then as a group. The research group agreed that the plan is beneficial and could inform their meta-artefact design process. While not full proof of the framework's validity, it can be considered a promising initial evaluation and suggests that the framework evaluation should proceed with further, empirical testing. The interview-based evaluation found the following benefits from the proposed approach.

- The main goal for the process is designing effective services that can improve citizen's quality of life, and so grounding the design theory back to stakeholders is beneficial.
- The design process involves complex, human problems, as service design is a complex, human-centered issue. In this case the new, proposed framework would be suitable.
- The research topic exists at intersection of human computer interaction studies with users and smart city services, business process modelling and software development processes. Flexible model creation process allows addressing all of these issues.

5 CONCLUSIONS

In this paper, we presented an issue in smart city service design stakeholder involvement and a new method that can be used to inform the design of meta-artefacts, such as requirements frameworks. This has the potential to improve the quality of services and design processes, not by directly addressing the issue, but by presenting a method for creating abstract design knowledge for design science research.

Table 2: Framing an existing case with the design science-based meta-artefact framework.

Design science activity	1a. Relevance phase	1b. Meta-relevance phase	2. (Meta-level) rigor phase	3. Meta-artefact design phase; empirical grounding
Grounded theory activity	Open and selective coding; initial theoretical coding	Advanced theoretical coding; theoretical grounding.	Theoretical grounding and scaling up. Relating the emergent theory to literature.	Constant comparison. Grounding the theory back to original data.
Case activities and outcomes	- Discovering what needs exist in regard to smart city services in the local context with interviews and the grounded theory coding-based analysis process. Interviewing both smart city service designers and stakeholders. - Creating a simple, situational grounded theory model to describe what needs exist, how requirements engineering processes respond to current needs and what is missing.	- Grounding the local, situational model of smart city service requirements design in smart city service designer opinions. Creating a model of requirements engineering processes as part of theoretical coding. - Having a model of user needs in the environment that allows weighing the taxonomy.	- Scaling up the taxonomy and model of user needs by rigorously comparing it to existing scientific literature. - Seeing if the local situational theory matches existing scientific knowledge and identifying the novel contribution. - Scaling up the requirements engineering model	- A formal taxonomy that has been generated from local observations and then scaled up by literature review. - A situational model of user needs in smart city services that can be used to weigh the smart city service taxonomy and to inform smart city service design processes. - Validation: Grounding the scaled-up model by applying it in the original context.

We also extend the current state of the art in meta-artefact creation processes (Iivari, 2015; Ostrowski et al., 2011; Ostrowski and Helfert, 2013) with a grounded theory -based approach and present a novel process description for meta-abstract artefact creation. In this approach, the grounded theory research method can be used in conjunction with a design science meta-artefact creation process to create abstract design knowledge and situational design theories, providing an example of how to apply the combination of grounded theory and design science, as originally proposed by Gregory (2011).

The framework presented in this paper warrants future investigation and evaluation in order to establish its utility and thus the validity. As future work, the researchers will proceed by creating a requirements framework, informed by the meta-artefact creation process presented in this paper.

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