Proceedings of the Federated Conference on
Computer Science and Information Systems pp. 317–320

ISBN 978-83-60810-22-4

Commonality in Various Design Science Methodologies

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Based on reviewing foremost literature, the paper discusses various design science research methodologies along with their case studies. It concentrates on activities (tools, methods, actions) that are used while constructing an artefact. We have identified common activities occurring across 'design' steps, which were not indicated in their methodologies. Combining them and drawing on that finding, we propose a concept of reference model, which gives more insights and additionally dissipates design science high level of abstraction.

I. 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*,*5*,*6*].

Research, as a process, is "the application of scientific method to the complex task of discovering answers (solutions) to questions (problems)" [*7*]. We can differentiate between the study of natural systems, such as physics, biology, economics and sociology [*8*], and the creation of artificial ones, such as medicine and engineering [*8*,*9*].The core mission of the former is to develop valid knowledge to understand the natural or social world, or to describe, explain and possibly predict. The centre of the latter is to develop knowledge that can be used by professionals in the field in question to design solutions to their field problems. Understanding the nature and causes of problems can be a great help in designing solutions, and is the focus of design science [*10*]. However, design science does not limit itself to the understanding, but also aims to develop knowledge on the advantages and disadvantages of alternative solutions [*10*]. Though literature reflects healthy discussion around the balance of rigor and relevance [*11*] in DS research, agreement on the DS fundamentals aspects such as definition, methods, outputs has yet to be achieved [*12*]. The area is still being shaped [*2*,*13*].

Views and recommendations on the methodology of DS research vary among papers, e.g. [*14*,*15*,*16*,*7*,*17*,*18*,*19*,*20*,*21*,*22*]. One set of guidelines by Hevner [*11*] has been widely cited, there being concern with their high-level and lack of specificity [*23*]; however, some papers reveal few instances of their actual applications [*24*].

Thus, though generally highly regarded and widely cited, DS methodological guidance from the precursors Hevner [*11*] and Walls [*25*] is seldom 'applied', suggesting that existing guidelines and methods are insufficiently clear, or inadequately operationalised - still too high a level of abstraction [*18*]. Alturki [*23*], inspired by Winter [*12*] stating that there was a "lack of a commonly accepted reference process model for DS research", structured DS Roadmap to guide researchers across the DS lifecycle. In our opinion, this is the most comprehensive collection of design science paradigms to date. However, we argue that some proposed DS methodologies concentrate on developing artefacts for specific aspects of IS [*26*,*14*,*5*] and therefore we still take others into account.

In this paper we discuss common activities that occur across various DS methodologies in a step in which an actual artefact is being created/produced/developed. Some authors refer to the step as build [*17*], design & development [*18*], design solution [*27*] , or develop (construction) [*23*] For the purpose of this paper we refer to it as the construction step.. The paper is organized as follows. First, following Offerman's [16] claim that not much guidelines is provided in IS literature on construction step, we will present the lack of details by discussing selected DS methodologies. Next, we identify activities of that step in case studies that were conducted in order to evaluate those methodologies. By activities, we 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 those methodologies, but Offerman's [*27*]. Then, we distinguish these activities that are common across DS methodologies and propose a concept of a reference model for the construction step. It could be seen as a guideline for this step regardless of selected methodology. Finally, we will discuss further research on the reference model and its application to DS.

II. Various Design Science Methodologies

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'' [*28*]

A number of researchers, both in and outside of the Information Systems (IS) discipline, have sought to provide some guidance to define design science research [*11*]. Their work in engineering [*29*,*30*,*31*,*32*], computer science [*33*,*34*], and IS [*35*,*36*,*33*,*17*,*20*,*25*,*22*] have aimed to collect and distribute the appropriate reference literature [*19*]; characterize its purposes, differentiate it from theory building and testing research and from other research paradigms.

They enhanced its essential elements; and claim its legitimacy. Some researchers in IS and other disciplines have contributed ideas for process elements [*29*,*34*,*30*,*25*,*20*,*33*] . These papers include some component in the initial stages of research to define a research problem. Figure 1 illustrates the most influential papers helping shape design science tenet over two decades, in our opinion. Nunamaker et al. [*7*] and Walls et al. [*25*] emphasized theoretical bases, whereas engineering researchers [*29*,*30*] focused more on applied problems. Takeda et al. [*34*]

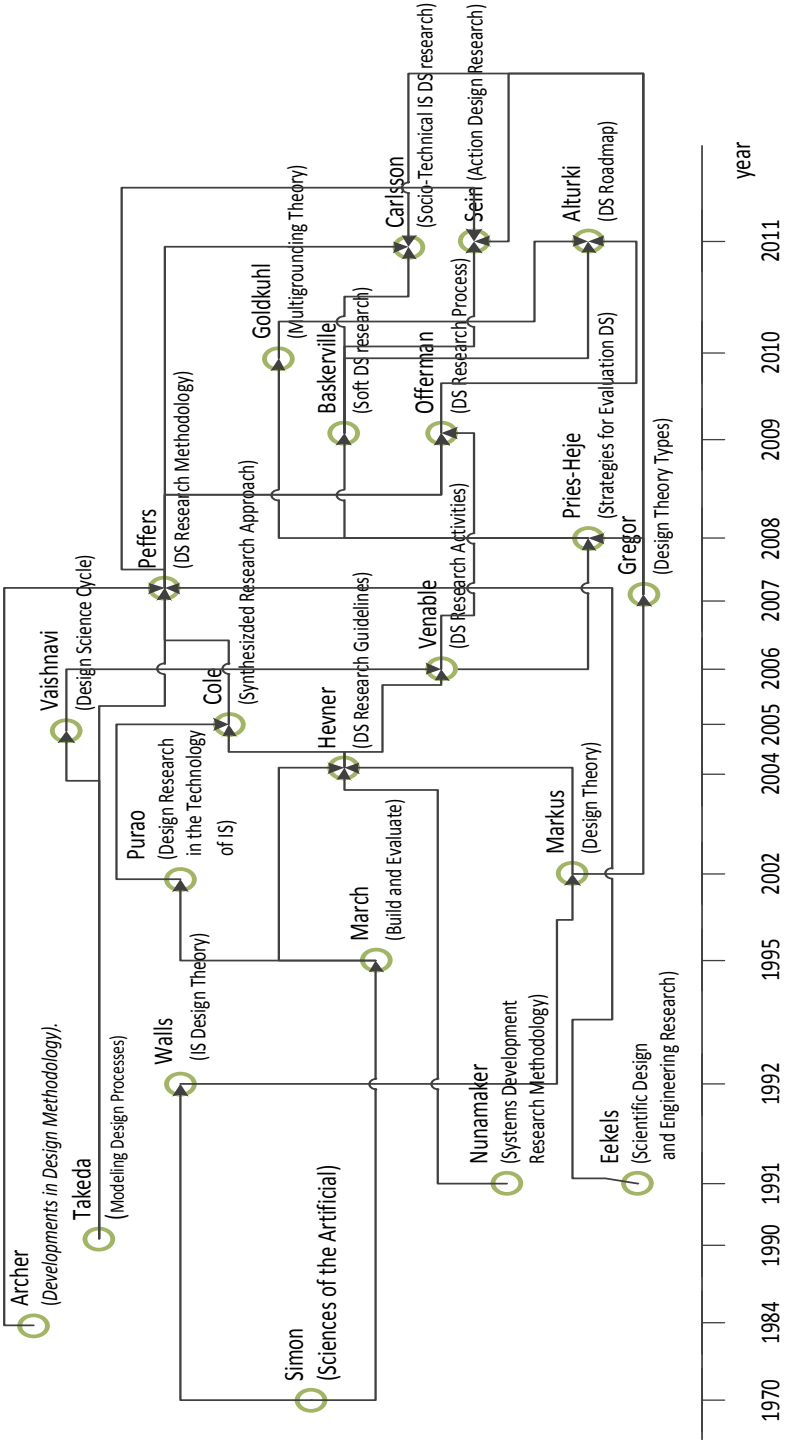

Figure 1Design Science paradigms over years

suggested the need for problem enumeration. Hevner et al. [*11*] asserted that design science research should address important and relevant problems. Based on those representative papers which stated or suggested process elements, the components of the design science research methodology (DSRM) were synthesized by Peffers [*18*].

Even though there were different methodologies, we observed a common agreement on their outcomes. Researchers define the DS outcome as an artefact, in form of a construct, model, method, and an instantiation [*17*,*11*]. Some researchers understand artefacts as "things", i.e. entities that have some separate existence [*31*]. Constructs are defined as "concepts" and "conceptualizations" [*17*] and "vocabulary and symbols" [*11*]. These 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" [*17*]. 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…" [*11*] "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." [*11*]. A method is defined as "a set of steps (an algorithm or guideline) to perform a task" [*17*]. An instantiation is a prototype or a specific working system or some kind of tool [*31*]. Most researchers agree on those form of artefacts (e.g. [*19*,*3*,*23*]); however, the methodology to achieve them varies [*18*,*26*,*14*].

III. Commonality in Artefact Construction

Having thoroughly read articles from Figure 1 we observed that researchers (e.g. [*26*,*19*,*21*]) clearly pointed out to the *construction* step as the one where the artefact is formed; however, without giving much details on how to approach it. To gain additional details, we decided to connect those steps with case studies of their methodologies. We excluded papers that did not present design science methodologies or put forward case studies that did not provide enough insight to withdraw seeking activities. Then, we created a table that provided only names of the construction steps in proposed design science methodologies and descriptions of undertaken activities in relevant case studies. Commonalities in different steps were out of scope in our search. Upon constructing the table, we analysed those activities in regards to the source from which information about artefact is gathered. We observed that two main streams could be distinguished. Researchers either reached to relevant literature or collaboration with relevant practitioners in order to construct artefacts.

Upon constructing the table we observed that the main activities in construction steps concerned literature review and collaboration with practitioners. By literature review we 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 building foundation on which the artifact 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. [*37*]. The level of engagement may depend on the nature of seeking artefact. Nonetheless the conducted activities, such as focus group discussions, semi-structured interviews, and workshops will still be concerned as the main facilitators in the act of design. Our search indicated, that in 78% of all case studies, the researchers gathered relevant information, for constructing artefacts, from literature and contacting practitioners from the field. The rest 22% focuses mainly on relevant literature. Those facts and the commonality that we discovered from various design science methodologies led us to suggest a concept of the reference model that could facilitate the construction step in DS research.

Figure 2 illustrates a place of our concept model in DS. The reference model will provide description of activities and the proper order that should be undertaken in construction step regardless of used DS research methodology. It will play role of facilitator guideline rather than a solution adviser.

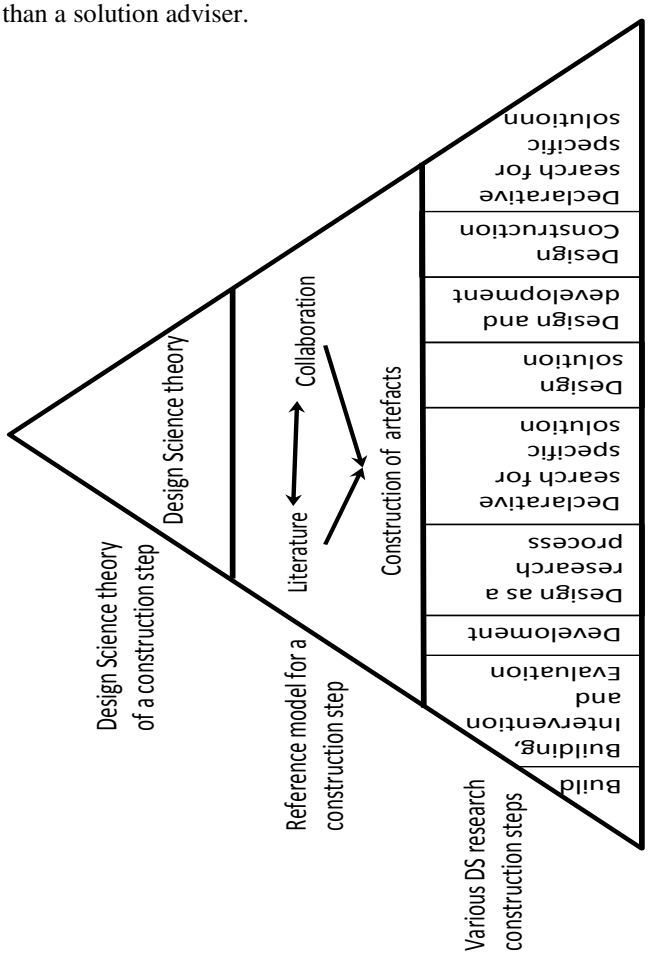

Figure 2 Place of Reference Model in DS

IV. CONCLUSION

In summary, we observed that literature and collaboration with practitioners play an important role in constructing/producing/developing an artefact. However, since our concept was made on case studies from various design science research methodologies, additional research on these activities is advised. The reference model can be further constructed upon investigating how these activities impact on DS research methodologies and particular artefact. In other words, to get reference model we need filter out all factors which occurrences are caused by specific solutions rather than constitute a solid path.

In this paper we discussed commonality that occurs in various design science methodologies in respect to a construction step. This is the step when information on and construction of solution is produced. We stated that DS methodology should not only indicate directions of research, but provides detailed steps on how to conduct this research. We identified common activities of construction step in case studies, which were conducted and presented throughout variety of DS papers. We proposed that these activities could be used as a reference model that would facilitate construction step regardless of selected DS research methodology. Before designing such a model, we suggested additional research, which would focus on the potential impact of those activities on particular methodologies. This is required in order to state a proper order and detail those activities further. Next the reference model will be validated via case studies in our future work.

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