How can our community become more scientific and cohesive? Towards a taxonomy of systems architecting benchmarking problems for evidence-based research

Romain Pinquié[1]

[1]Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, France

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1 Introduction

As reported by several members of the design research community, "*There is this concern that design research does not live up to the standards of science: it is creating in a sense too many theories and models, which jeopardises the coherence of the discipline and which indicates that design research does not yet have the means to test and refute design theories and models*" (Vermaas, 2014). Despite the warnings sent by whistle-blowers for a decade now, research design quality remains far from the scientific empirical standards of related disciplines, such as human-computer interaction, operational research, ergonomics, or psychology. Design research often recommends loose sets of recommendations rather than reproducible and replicable procedures. Many reasons are invoked to justify the lack of design research quality, including the interdisciplinarity of the discipline with a mix of research methods and cultures, the influence of industry on the definition of broad and complex research objectives hampering the internal validity of results, or the lack of cumulative research due to the rapid disclosure of research results in papers of marginal quality that do not contribute much to the human body of knowledge.

The case of systems architecting will serve to illustrate the problem as it is often considered that it is more art than science, founded on common sense and intelligence, guided by heuristics derived from inspiration tempered by hard experience. A long-term objective is to convince young systems engineering researchers to adopt theory-driven (Briggs, 2006; Cash, 2018) and evidence-based (Robinson et al., 2021) research practices because cause-and-effect theory can lead to systems architecting processes that far surpass those produced by a sound mind and a gut feeling. Moreover, too often, new modelling methods or software are proposed. Still, the outcome researchers seek to improve with new systems architecting software or methods is the phenomenon of interest: the effect a theory purports to explain. The modelling software or method is only a means to effect changes in the phenomenon of interest. As academic researchers, we should concentrate on what outcomes we seek to improve with the processes, methods, modelling methods and software we propose. For systems architecting researchers, many possibilities exist, such as productivity, creativity, decision-aiding, traceability, etc. A potential phenomenon of interest could be "What causes systems architects to define a correct architecture?". Labelling the phenomenon of interest is not sufficient. It must be explicitly defined. For example, the word "correct" has many connotations in English.

I will attempt to answer the question: **How can theory-driven and evidence-based research practices help our systems engineering community become more scientific and cohesive?**

2 Methods

To answer the research question, a literature review of systems architecting research papers was conducted to 1) identify how various communities define systems architecting, 2) collect fundamental systems architecting research problems, and 3) make an inventory of causal theories that can drive the

design of a system architecture. Systems architecting objectives or problems depend on each other since, for instance, a space allocation problem requires the prior definition of subsystems by having previously solved an architecture generation problem. Therefore, a matrix of causal dependencies is proposed to identify the interdependencies and logically order the systems architecting problems. Finally, open systems architecting research benchmarks (Pinquié et al., 2024, 2022) will be introduced to support evidence-based research by 1) improving validation quality in a fair, transparent, and systematic way, 2) facilitating reproducibility, if not replicability, 3) fostering cumulative research in engineering design, and 4) rapidly learning the essence of background knowledge with interest in finding its leading edge.

3 Results

Preliminary results of this methodological work will be presented to get feedback. First, the literature review shows that the definition of systems architecting is deeply routed to the design research communities. Although there is no official relationship between geographical area and membership, there is a clear separation between the EMEA and the US, as represented by the members of the Design Society and INCOSE. Browsing research papers published in conferences and journals affiliated with each community shows that the former focuses on product architecture, whereas the latter concentrates on system architecture. The case studies chosen to illustrate research proposals in conferences and journals affiliated with each community also indicate the difference between product and system architecture. Product case studies are mechanical or electromechanical small-scale, short-life and relatively greenfield systems. Conversely, in the systems engineering community, systems are large with relatively high structural complexity, long life and brownfield involving significant modifications, extensions, or replacement of an existing, precedented "as-is" system in an existing environment to an updated "to-be" system. Second, the literature review derives an initial version of a cause-and-effect influence diagram of theoretical systems architecting research propositions. Third, analysing existing works enabled me to create a collection of systems architecting objectives standardised in a taxonomy of fundamental systems architecting problems, as operational research has its taxonomy of research problems. Fundamental systems architecting research problems include concept finding, modularity, architecture topology layout design, space allocation, embodiment design, interface routing, configuration selection, […], and sizing. Finally, an open science scientific benchmark (Pinquié et al., 2024) is proposed to show how benchmarking can enable us to operationalise evidence-based research.

4 Discussion

Future work will aim to strengthen the existing proposal with peer reviews, including reviews by professional systems architects. Hopefully, it will attract the attention of our community, whose members will participate in the transformation towards more scientific systems architecting research.

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