Faculty of Design

2021

Field Notes: Tensions between systemic design and systems engineering

Barba, Evan

Field Notes: Tensions Between Systemic Design and Systems Engineering

Evan Barba

As an emerging interdiscipline, systemic design remains in tension with existing disciplines that share its theories and methods. Articulating these tensions is an important step in differentiating systemic design from what has come before. Systems engineering is one such established discipline; one whose unit of analysis (the system) and purpose (designing) are similar to those of systemic design. Yet, these disciplines differ considerably in their work practices, goals, and domains. By analyzing both differences and similarities, this work aims to generate a better relational understanding between the two. Initially, I discuss some epistemological points of distinction that demonstrate how the two disciplines emphasize different aspects of systems and design to define very different types of problems and solutions. Then I will contrast how differing methods employed by these disciplines arise out of their different philosophical positions. Finally, I suggest some ways that methods from systems engineering might be adapted for use in systemic design with specific benefits for stakeholder engagement and modeling that can help advance the adoption of systemic design approaches in areas that are traditionally the purview of systems engineering and vice versa.

Keywords: Systems Engineering; methods; methodology; epistemology

Introduction

The introduction to ***Systemic Design: Theory Methods and Practice*** (Jones & Kijima, 2018) lays out the tensions between Systemic Design (SD) and Systems Engineering (SE) in the most basic terms:

> This book presents emerging work in the co-evolving fields of design-led systemics, referred to as systemic design to distinguish it from the engineering and hard science epistemologies of system design or systems engineering… Systemic design is distinguished by its scale, social complexity and integration – it is concerned with higher-order systems that that entail multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centred design to complex, multi-stakeholder service systems. (p.2)

Indeed, there is a clear distinction in terms of core philosophy and practices between the two fields, and this quote implies that systemic design is in many ways defined by its opposition to systems engineering and other hard science approaches. However, this break with the hard sciences, while clear and definite, need not be all-encompassing. As SD evolves, is it not possible for the field to actually draw on its tensions with SE as a source of productive advancement? If this is possible, we need to start by exploring the tension in more detail and articulating where the two fields share common ground, where there will never be agreement, and, most importantly, where some negotiation and better dialogue may help both fields advance and evolve in new ways. This work is intended to be a step toward these goals.

"We've Had Our Differences"

Different Kinds of Problems

As a branch of engineering, systems engineering is concerned primarily with the optimization of systems over their life-cycles to create reliable, predictable, and cost-effective outcomes (Hirshorn, et al., 2017). Core to this mission are basic methods such as requirements gathering, project management, and measurement of variables and results. SE emphasizes decomposition of systems into their constituent parts as an analytical starting point and integration of those parts to create sub-systems and a working whole (Haskins, et al., 2006). While SE employs a variety of quantitative and qualitative methods at various stages of the design process, quantitative metrics are heavily favoured. However, qualitative interviews frequently appear at various stages and qualitative judgments are often made when choosing various options. Nonetheless, SE relies heavily on assigning numerical values to options and outcomes and employing computational tools to manipulate these values.

Systemic design (SD) has a much shorter history than SE, and, while embracing many of the same systems and design theories, nonetheless presents many epistemological and practical differences. While SE approaches do appear in areas like urban planning, disaster response, and organizational management, SE was born out of, and is most suited to, the design of systems for the production of products where tight constraints, clearly specified emergent goals, and well-controlled processes are assumed. By contrast, SD uses design-led approaches that embrace the murkiness of systems without clear endpoints or boundaries, are typically larger and more interconnected than single-product systems, and are dominated by social relations rather than technical ones (although both SE and SD can be understood to operate on sociotechnical systems).

SE's roots as an engineering discipline direct its focus toward clearly defined problems. When the messy world prevents clear scope and boundaries, SE aims to clarify or draw them as its first activity. SE's tendency to be adopted in large scale engineering endeavours in aerospace, automotive, and other product manufacturing domains means the problems it choices are particularly suited to the outcomes it provides; essentially, engineered solutions to engineering problems. Complexity is embraced in SE only in its most linear form. True, the boggling number of components, sub-systems, and interfaces required to produce a modern airliner defines it as a complex system; however, the goal is simply to remove uncertainty from the process and replace it with efficiency. Non-linear interactions, which are responsible for emergent behaviours of complex natural and social systems, and make them both diverse and difficult to manage, are anathema to SE concerns. Any non-linear behaviour is a danger to the SE enterprise and its goal is to remove these entirely, or to at least minimize their impacts on the overall system by isolating them. For example, the lithium battery fires that delayed the release of the Boeing 787 Dreamliner (Ash, 2020) were an unpredicted and unwanted emergent result of its design. The solution was to control and contain the fires by retrofitting a steel battery box and venting the hot gases to the exterior of the plane. By contrast, SD tends to embrace non-linear behaviours in the systems it studies, accepting that they are necessary to the overall health and purpose of the system, and trying to leverage these dynamics in ways that allow the system to evolve through its own mechanisms rather than removing them from the system to allow for better control.

Different Roles for Humans

A second point of tension between SE and SD involves the relationship between humans and the system. SD has grown out of a human-centred design philosophy that was itself a response to the over-engineering of human interaction with products, digital technologies most notably. Here too, the same attitudes toward emergence are a dividing line. Engineering based approaches to human-machine interaction, such as human factors, engineering psychology, and usability, all treat human beings as components of the system — operators with required task outcomes to be optimized for efficiency. The human-centred design approaches that underpin SD, break from this tradition to provide for unplanned and unpredictable human-machine interactions on the one hand, and to allow end-user needs and desires to drive the design of the system rather than technical concerns. SD attempts to extend this paradigm shift to the systems level by prioritizing human needs and desired outcomes over system efficiencies and to offer humans more agency in the dynamics of the system itself. However, like SD, SE also places a premium on **stakeholder engagement**, and it is likely that its narrow perspective on the role of humans is a result of the problem domain rather than any philosophical stance on the value of human participation. Therefore, assumptions and practices around stakeholder engagement are likely to be the first place where we should try to reconcile the differences between the two fields.

Both SE and SD are interdisciplinary, they rely on and integrate knowledge and practices from many different perspectives and traditions. This is necessitated by their shared history in systems theory. Both (inter)disciplines have shared understandings of part/whole relations, multi-scale emergence and subsystems, and other fundamental assumptions from systems theory. Many clear differences exist in terms of the way both disciplines adopt design methods that are typical of engineering-led vs. design-led approaches. However, both disciplines also make heavy use of **models and modelling** in their practices, and therefore must share some core methodological beliefs about the value of models in practice. This is likely a second area where the two fields can learn from each other. In some sense, models serve the same purpose in both fields as they do more generally, they create simplified representations of some noteworthy aspects of a system in question. Models also provide an important touchstone in terms of stakeholder engagement, creating shared representations of systems that stakeholders can use in co-design, communication, and documentation. This also suggests that the two disciplines share some core beliefs about the role and value of the cognitive processes that underpin modelling methods and it may be important to unearth these in the quest for common ground.

While SE's close proximity to hard science favours different kinds of models and modelling practice than those that appear in SD, even here there is considerable overlap. For one, the models employed by SE rely quite readily on the same basic human capacities of visualization that models used in SD, like system-mapping (gigamaps, synthesis maps, etc.), do. SE does tend to attach clear numerical values to these models, but these are often far more subjective and qualitative than they appear at first blush. Examples of this can be seen in Design Structure Matrices (Browning & Eppinger, 2012) and Tradespace Exploration (Ross & Hastings, 2005), where numerical weightings can be vastly different based on their sensitivity to upstream qualitative judgments of participants. On the other side, SD has begun to employ more quantitative and computational models (Murphy & Jones, 2020), further closing the gap between these two seemingly different approaches. Modelling techniques that bridge these divides hold great promise for expanding the repertoires of both fields.

Resolving Our Differences

In this short paper I've tried to briefly outline the core philosophical similarities and differences between systemic design and systems engineering in an effort to explore the tension between these two interdisciplinary fields. I've identified systems theory as common ground between the two and located clear differences in the way the two fields approach design. I have also argued that both fields place a high value on stakeholder engagement and the use of models to create representations of the system being designed, and suggested that this intersection is rife for further exploration that may allow the two fields to overlap more usefully in practice. Borrowing some of the tools used in SE to better expand the toolbox of SD approaches may help that field find more application and support in domains commonly associated with SE, while integrating more human-centred approaches from SD in SE frameworks may better humanize that field and let it expand beyond the narrowly focused engineering problems it most often considers.

References

Jones, Peter & Kijima, Kyoichi (eds.) (2018). *Systemic Design: Theory, Methods, and Practice*. Springer Japan.

Hirshorn, S. R., Voss, L. D., & Bromley, L. K. (2017). NASA Systems Engineering Handbook.

Haskins, C., Forsberg, K., Krueger, M., Walden, D., & Hamelin, D. (2006, June). Systems engineering handbook. In *INCOSE* (Vol. 9, pp. 13-16).

Ash, L. (2020). *A Look Back: How Boeing Overcame The 787's Battery Problems*. *Simple Flying*. https://simpleflying.com/boeing-787-battery-problems-overcome/ (accessed May 24, 2021).

Browning, T. R., Eppinger, S. D. (2012). Design Structure Matrix Methods and Applications. United Kingdom: MIT Press.

Ross, A. M., & Hastings, D. E. (2005, July). *11.4. 3 The Tradespace Exploration Paradigm.* In *INCOSE international Symposium* (Vol. 15, No. 1, pp. 1706-1718).

Murphy, R. J., & Jones, P. (2020). Leverage analysis: A method for locating points of influence in systemic design decisions. *FormAkademisk-forskningstidsskrift for design og designdidaktikk*, *13*(2), 1-25.