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Perspective: organisations as complex systems

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Introduction to the special issue

Back in 1983, in the inaugural issue of *Civil Engineering and Environmental Systems*, editors-in-chief Colin B. Brown and John Munro opened their editorial by stating that 'The complexity of civil engineering practices has greatly increased over the last 30 years', concluding that 'this places on the engineer the onus of communicating efficiently with other professionals'. This observation has become increasingly prominent, with the built environment now being composed of a wide range of systems, interacting together across different scales and at almost real-time.

With this Special Issue, we sought to take this observation towards one possible direction by addressing two interrelated questions: (1) should civil engineers play a role in understanding how organisations operate, and (2) is complex systems perspective a viable way for doing so, compared to other more established perspectives.

Contributors to this Special Issue and I argue that the answer to both (1) and (2) is a reassuring yes.

Focusing on (1), resolving the major challenges of the built environment requires coordinated collective action between formal organisations. Civil engineers play a central role to this collective action due to their position at the interface between multiple organisational functions. This provides a unique vantage point, as well as capabilities for solving the most pressing problems in terms of organisation. Porse (2019) and McDonald et al. (2019) provide good examples of how this vantage point can support this collective action at a policy level, in the context of water supply and earthquake resilience respectively (this issue).

Focusing on (2), a complex systems perspective provides a unifying framework for understanding the collective action between organisations, and eventually deriving actionable insights. The perspective has found its home within the natural sciences, where it is typical to abstract the context in search for unifying frameworks (e.g. evidence shows that the underlying connectivity of a wide range of systems shares common features [Watts and Strogatz 1998]). This perspective has arguably improved our understanding of how these complex systems operate (Vespignani 2012). However, when it comes to deriving actionable insights, progress has been relatively slow. This has been partly due to the (justifiable) scepticism by which the engineering community has viewed the complex systems perspective: how can context be abstracted away when it serves as the background for the system's function? (Willinger et al. 2002) Guo et al. use the context of construction safety to argue for a middle ground, where the complex systems perspective can

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be used to generate a sufficiently general model and preserve the operational relevance of the model's output (this issue). At the same time, Carmichael (2019) reflects on some important issues that need to be addressed when deploying quantitative models to better understand the operation of organisations (this issue).

More generally, I hope this Special Issue stimulates a healthy discussion within the wider engineering community on the wider impact that engineers can have, and on the value that the complex systems perspective can bring.

Organisations as complex, socio-technical systems

Despite the fairly inclusive nature of the term 'Complex Socio-Technical Systems' careful unpacking is needed to appreciate the properties it conveys. The basic building block of the term – 'system' – is a derivative of the Greek world *sustēma*, which refers to the interacting nature of a set of components. This definition approximates the one provided by the Oxford English dictionary: 'a set of connected things or devices that operates together'. While intuitive, this definition is too generic to be of any particular use. I prefer the definition of a 'system' as: *an open set of complementary, interrelated parts that interact in non-trivial ways to give rise to the behaviour and properties of a unified, purposeful whole*. This definition emphasises a number of important properties, some of which are overlapping:

- **Open** – the system interacts with, and is affected by, its environment;
- **Interrelated Parts** – the composing parts interact with each other, which is (partly) responsible for the overall behaviour of the whole;
- Interact in **non-trivial** ways **–** interactions may materialise in a wide range of forms; this restriction signals that interactions must be non-trivial to reflect real-world systems (Barabási 2007);
- **Unified, purposeful whole** – the interrelated parts form into a coherent whole that has a given purpose.

The second term – 'socio-technical' – focuses on the multi-faceted nature of modern organisations, where both social and technical facets seemingly interact. In other words, 'socio-technical' systems are composed of technical ('hard') engineering systems embedded within ('soft') management systems (Vespignani 2012). The implication of this coupling is the emergence of multiple scales (e.g. organisations, business-units, teams etc.) and time-frames (e.g. tactical objectives, strategic objectives etc.), making these systems intractable to traditional analysis tools and techniques.

The first term – 'complex' – originates from the Latin word *complexus,* which conveys the relatedness across a group of elements. Dictionary definitions of *complex* include 'consisting of interconnected or interwoven parts' and 'not easy to understand or analyse' – one can appreciate how the former leads to the latter, as one needs to describe the parts *and* how each part relates with the rest to fully describe the state of a complex system (Anderson 1972).

Seizing the opportunity for real-world impact

The perspective of organisations as complex socio-technical systems is not new, and has had vocal proponents from both industry and academia. In an industrial context, Dee

Hock, the founder of VISA, shared his view on what an organisation is: a 'self-organising, adaptive, non-linear [and] complex community' that 'harmoniously blends characteristics of both order and chaos' (Hock 1995). Around the same time, the prestigious academic journal *Organization Science* published a Special Issue aptly titled 'Applications of Complexity Theory to Organization Science' (Anderson et al. 1999). Despite the assumed similarity in views, there was a deep disconnect between the industry and academia: while practitioners were arguing for the need of a complex systems perspective based on their observations (i.e. empirical data), academics responded with theory-intensive models that rarely had data at their core. As an example, of the seven papers published in the aforementioned Special Issue, none of them use real-world data to support the modelling decision and/or validate the findings. That is not to say that the value of that work is limited – if anything, such theoretical work plays a key role in raising awareness on the value of interdisciplinary and sharpening our research questions work (e.g. of those seven papers, three use models from theoretical ecology). Rather, this disconnect highlights a pathology of that time, where limited access to real-world, empirical data amplified the disconnect between industry and academia. As a result, research on complexity remained abstract and had limited impact on the real world.

Fast-forward 20 years and I am glad to report that this disconnect is being reduced. Unprecedented availability of empirical data now allows researchers to penetrate previously elusive organisational aspects. Such aspects range from supply chains, project-based operations (see Figure 1) and teams to entire infrastructures upon which organisations rely. As a result, the power of complex systems analysis is slowly being unleashed, with the potential of real-world impact becoming apparent (Barabási 2011). In doing so, we now know that supply chains are susceptible to dynamical instabilities (Demirel et al. 2019); that seemingly insignificant task failures are sufficient to severy affect project performance (Ellinas 2019); that 'bursty' communications between team members can improve performance (Riedl and Woolley 2017) and that increased interdependence between large-scale systems gives rise to sudden, abrupt failures which could not have been observed in isolation (Buldyrev et al. 2010).

The collection of papers in this Special Issue reflects this trend.

Large organisations are receptive to this shift, responding with initiatives that have a complex systems perspective at their core. The Institute of Risk Management (IRM) published a 2014 report stating that

> Businesses are increasingly complex, and the risks that they face continue to evolve not simply in proportion to the complexity of the organisations themselves, but at a rate that is compounded by the complexity of the environment in which they operate. (IRM 2014)

This report was followed by the recent launch of a Complexity Special Interest Group[1], tasked to push this direction further. Similarly, the International Centre for Complex Project Management and the Australian Government are working closely to release practitioner standards related to tackling the complexity of organisations in project-based operations.[2] A similar initiative was also launched by the Government of Canada.[3] Just these two initiatives are supported by over 15 global organisations – some of which are active exclusively in the built environment – reflecting the appetite and appreciation of the relevance of the complex systems perspective in supporting modern organisations

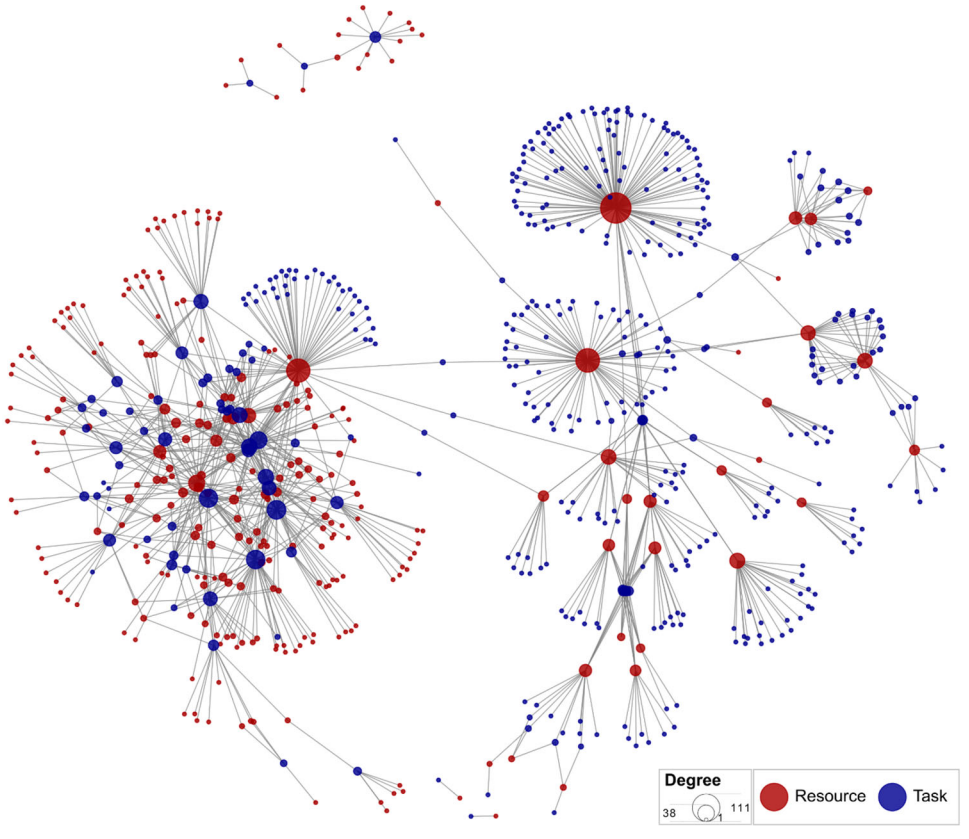

Figure 1. This bipartite network maps the operation of a global organisation, delivering a large-scale engineering project. The network captures the activity of 271 unique individuals, called 'resources' (red nodes) who are responsible for the completion of 721 'tasks' (blue nodes) spread across a period of 745 days. From Ellinas (2018).

in optimising a range of aspects. This trend is an opportunity for the civil engineering community to proactively engage with such initiatives and shape the implications that will result from them, if it wants to remain relevant and impactful.

McKelvey (1999) eloquently asked the broader academic community whether adopting a complex systems perspective to understand organisations was an exciting promise or an academic fad. We think that the receptiveness of the industry strengthens the case for the former, and hope that this community seizes the opportunity to reinforce the premise of this Special Issue: that understanding complexity holds the key in improving modern organisations, and civil engineers are well-equipped to deliver those insights.

Notes

1. https://www.theirm.org/events/special-interest-groups/risk-and-complexity.aspx
2. https://iccpm.com/cpm-competency-standards/
3. https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=21261

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