Proceedings of the IS4CE2020 Conference of the
International Society for the Circular Economy
6 – 7 July 2020, University of Exeter, Exeter
https://www.is4ce.org

Lessons from aspects of systems thinking for an effective, cross-scale circular economy

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Abstract

Companies and policy makers are increasingly inspired to take on ideas related to a circular economy (European Commission, 2019). Discussion of a circular economy often alludes to the need for "systems thinking" (Webster, 2017) or that within the context of a business, a circular economy invokes a "whole value chain" approach (Cambridge Institute for Sustainability Leadership, n.d.). Generally, there are two main strands of systems thinking which may be at play here: (1) a systems engineering approach and (2) a complex adaptive systems approach (West, 2017). This paper describes these two approaches in systems thinking applied to a circular economy and argues that a mature circular economy would draw on structural and cross-scale features inherent in all complex and adaptive systems.

Keywords: system thinking, circular economy

Introduction: Systems described

In 2000, Stephen Hawking was asked to reflect on the 21st century. He responded: "I think the next century will be the century of complexity". His statement was about the profound shift that humanity is facing from seeing real world systems not as *complicated* systems, but as *complex* ones. The main way to understand a *complicated* system is through a structural decomposition (Polie, 2013): to investigate the different parts and relationships and then further subparts and their relationships. The primary way to understand *complex* systems is through functional analysis. That is, through the activities exerted by the system (Polie, 2013).

Because of this, in using the term *systems,* we are reminded of the need to be cognisant of the two ideas hidden in the word "system": the idea of a system as a whole and the idea of a generating system (Ing, 2016). In his work around systems thinking, David Ing (2016) makes the following observations:

1) A system as a whole is not an object but a way of looking at an object. It focuses on some holistic property which can only be understood as a product of interaction among parts.

2) A generating system is not a view of a single thing. It is a kit of parts, with rules about the way these parts may be combined.
3) Almost every "system as a whole" is generated by a "generating system". If we wish to make things which function as "wholes" we shall have to invent generating systems to create them (Alexander, 1968).

   In a properly functioning building, the building and the people in it together form a whole: a social, human whole. The building systems which have so far been created do not in this sense generate wholes at all (Alexander, 1968).

Another foundational characteristic of understanding systems and, especially, complex adaptive systems is that the generating system is operating through iterations around a number of often simple rules around relationships between the different actors. Geoffrey West explores this regularity in his book *Scale* (West, 2017). Sometimes described as 'the rules of the game', this is the deep level at which enduring change is propagated.

Biological systems are dependent on diversity as a source of creativity as well as resilience. The very evolution of a system or systems depends on this characteristic since shocks to systems are inevitable. Diversity is a function of noise in the iteration of a system. (Whitesides & Ismagilov, 1999).

Efficiency and resilience

In their book "Metaphors We Live By", George Lakoff and Mark Johnson explain that metaphors are a fundamental part of the conceptual system of the brain (Lakoff & Johnson, 1980). Metaphors are, therefore, central to the way we perceive ourselves, others and, the world around us (Lakoff & Johnson, 1999). Both approaches to systems thinking that are discussed in this paper, are able to be traced back to two different corresponding metaphors. The *system engineering* approach looks at stocks and flows through the metaphor of a pipework where one is notionally in control of the full cycle of, for example, a material or a product. It is a reductionist approach which tries to isolate the parts and manage the connections and interdependencies, a kind of system dynamics often used in engineering. It addresses a system within described boundaries. The input to such systems is often standardized, open to large scale production and primarily designed to be efficient. Alternatively, the *complex adaptive systems* approach uses nature as a metaphor for stocks, flows and feedback. These systems are often identified as non-linear with indeterminate starting conditions, contain 'noise' as well as signal, and with hard-to-define boundaries. The emphasis on feedback and non-linear interdependence within these systems lead most circular economy pioneers to allude to one category of complex system as a comparator: they are "taking insights from living systems" (Ellen MacArthur Foundation, 2013).

It might appear that the ideas underpinning a feedback rich, interdependent or embedded economy are drawing upon aspects of contemporary systems science. However, there are different emphases located in the choice of system boundaries and the degree of control being attempted. The current economic system rewards economies of scale and labour efficiency (Samuelson, 1966) (Webster, 2017) as it can lower market price, but the loss of spare capacity, diversity or flexibility may negatively affect the resilience of these systems, undermining long-term sustainability (Korhonen & Seager, 2008). Healthy and resilient ecosystems require both efficiency and diversity/interconnectivity. Too much efficiency results in brittleness of the system and too much diversity and interconnectivity results in stagnation (Fath et al, 2019).

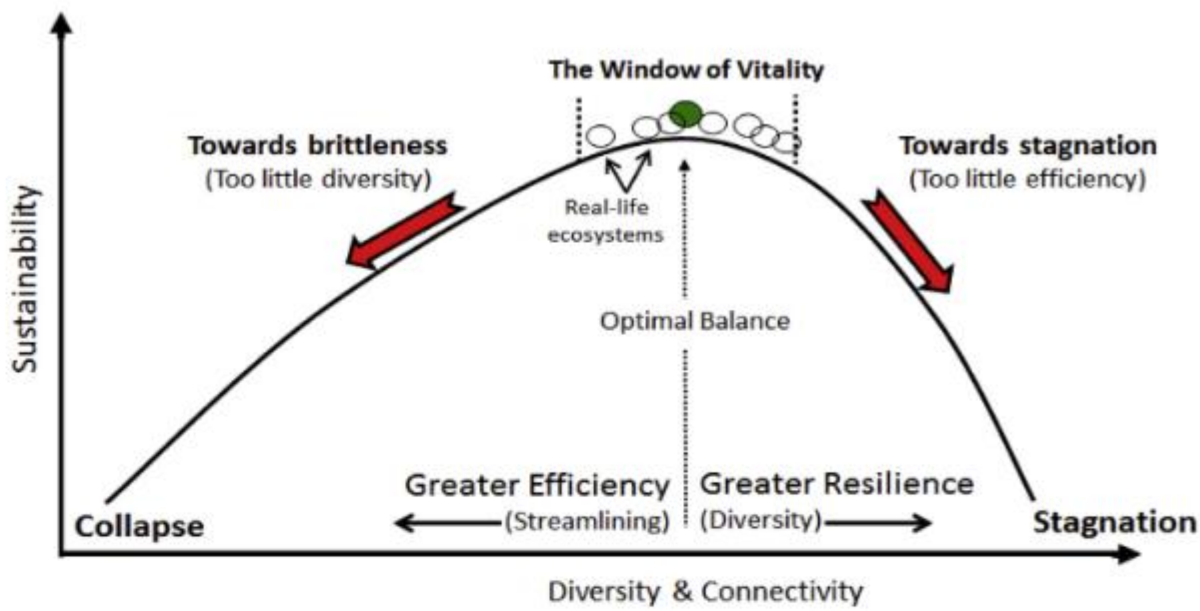


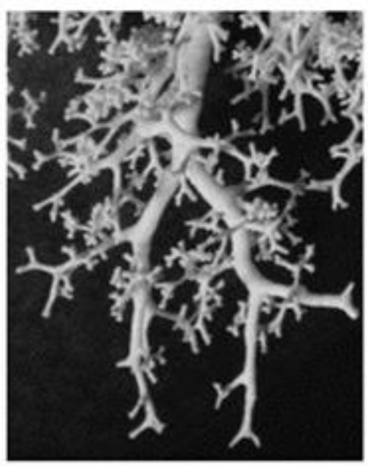
Figure 1: The Window of Vitality delimits a health balance of resilience and efficiency (Fath et al, 2019)

Structural and cross-scale features

The work of Fath et al (2019) identifies effectiveness as an interplay between efficiency and resilience (see Fig. 1). This interplay reminds us that efficiency is a relationship between the input and the output, but it does not characterise the purpose nor satisfy the means to create an enduring system (Polie, 2013). Effectiveness is a description of the characteristics which enable the fulfillment of the purpose of such a system over time.

> "Sustainability of any complex flow network results from appropriate balance between efficiency and resilience, which derives from only two network variables: diversity and interconnectivity." by Bernard Lietaer (2017), building on the work of Bob Ulanowicz.

Switching to an examination of a subsystem like the lungs (Fig 2) shows that the interplay between the main pathways (trachea, bronchia) and the myriad alveoli is, interestingly, not simply a pipework with smaller and smaller diameter. As Christopher Alexander noted in his 1964 essay, *The City is Not a Tree*, the dominant function at the periphery is one of exchange. It was what he described as a 'semi lattice' or network. The structure between cells and connections, between citizens and neighborhoods, between alveoli and bloodstreams is around *exchange* and in its multiplicity and redundancy, creating resilience. These reroutable exchanges can take localised damage and disruption without the overall system, the lungs, the heart being knocked out. The emphasis in the 'efficiency' mode is, by contrast, around structure and flow.



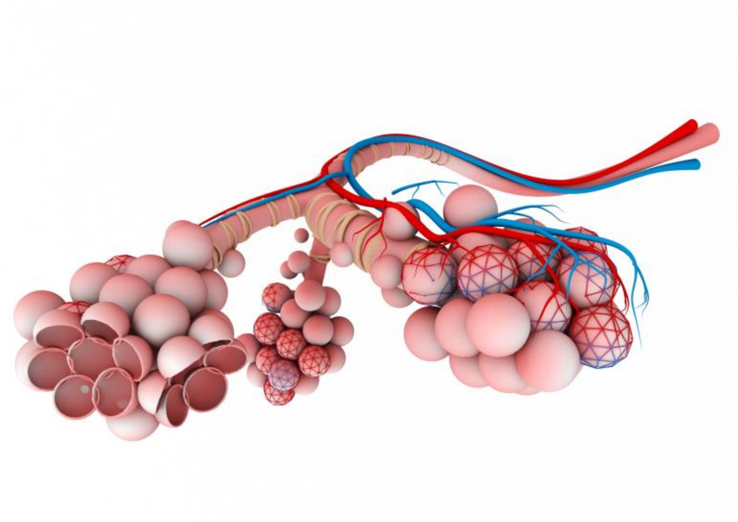


Figure 2a: Cast of the human airway tree (Weibel, 2005) **Figure 2b:** Exchange illustrated by alveoli

In addition to this resilience or ability to repair, recover, reroute and reorientate is the recognition that all these systems are nested (Folke et al, 2002). This means that they are all, in a way, open to the system in which they are embedded and home to dependent subsystems (Gunderson, 2001)

This is self-evident upon reflection, but the authors of this paper would argue it is germane to the discussion of an effective circular economy. An effective circular economy will be systemic (reach all of its participants, systems, and elements), will deal in nutrients and not toxins (since all of the systems are open and interdependent), and will value and engage deliberately in the creation of resilience as it does in the enabling of efficiency ("the rules of the economic game").

As an economy it is like the relationship between organism and its ecology, it is the open loops emphasis as dominant, but it requires the appropriate system conditions to enable a thriving and resilient aspect which is equal to that of the efficient. As Fath et al (2019) describe it the emphasis is on the resilient side; the diagram is skewed to the right (Fig 1).

Towards an effective, cross-scale circular economy

At the time of writing this paper, the COVID-19 pandemic has revealed some major fault lines in the economy. An example of this would be the dependence on overlong supply chains for even some basic products. The supply chains turned out to be brittle and probably outside the "window of vitality" as described by Fath et al (2019). Some companies and industries needed state intervention and support, which included repurposing local business or expanding its capacity by building local or national networks (Penarredonda, 2020).

Gunter Pauli (2010) notes that localised networks are taking advantage of economies of scope (or diversity). Continuing the description of effective systems in the context of resilient supply chains, there is usually a tension between economies of scale and economies of scope: the tension between a few suppliers dominating versus a populated and extensive network of producers. In the conversation about effective systems, the *nature* of the dynamic balance is what is at stake, not whether there should be either global trade *or* local production.

Setting system boundaries and conditions

Systems are determined by both their boundaries and their enablers (generative system conditions) as noted by Ing (2016). Planetary boundaries are a good example of system boundaries and explain why it would be impossible for Godzilla to be alive on Earth:

> "In his latest incarnation Godzilla is 350 feet long, which translates into a weight of about 20,000 tons, about 100 times heavier than the biggest blue whales. To support this gargantuan amount of tissue, Godzilla would have to eat about 25 tonnes of food a day, corresponding to a metabolic rate of about 20 million food calories a day, the food requirements of a small town of 10,000 people. His heart, which would weigh about 100 tons and have a diameter of about 50 feet, would have to pump almost 2 million liters of blood around his body. However, to counterbalance that, it would have to beat only just over a couple of times a minute and sustain a blood pressure similar to ours."

Through this example, Geoffrey West (2017) explains how systems boundaries ensure the limitation of the accumulation of food. Godzilla will probably not survive for a week on earth simply because it will run out of resources that are necessary to stay alive. This is an argument against unlimited growth and inevitable planetary boundaries that restricts anything beyond a certain size of accumulation to a certain extent.

The reason why it is easier to grow cacao in tropical regions around the equator versus in the United Kingdom, has everything to do with system conditions. Hot and humid climates are excellent for growing cacao, whereas the cold and rainy British climate would make it more difficult and practically impossible for this crop to thrive. The current, linear economy enables efficient production and brittle supply chains (economies of scale) almost in the same manner that hot and humid weather enables the growth of a cacao tree. These conditions include below full cost accounting for fossil fuels, tax benefits for capital investment (technologies and other) subsidised transport infrastructure and below full cost accounting for managing waste.

So, what do economies of scope need to thrive? Pauli (2010) emphasised the value of localised economies: using what is available to add value and circulate income locally or regionally to create multiple benefits.

Some of these benefits can be flows of cash, while others are not expressed in financial terms but manifest themselves as, for example, social capital.

A network for exchange and resilience is usually made of small units that are widely distributed. None of these units are necessarily capital rich - like the reality of most economies which are dominated by firms between one and five employees (FSB, 2018). In general, to support these units, it is the infrastructure which can be built-out to firstly, facilitate the exchange and, secondly, access to tools and networks to facilitate the creation of added value (Hadfield, 2019). This echoes with the mid-20th century philosophy of *Distributism*, which put emphasis on providing access to tools and resources (Ahlquist, 2019) or with the work from the Foundational Economy (Foundational Economy, n.d.). This could include, for example, access to land (echoes of the allotment movement), temporary materials storage, maker labs, community kitchens, platform cooperatives, new market and retail opportunities (as in street food markets and pop-up stores). This is a resurgence of the idea of the Commons (Bauwens et al, 2020) and not necessarily one dependent on a global network.

This is an argument for investing in local and regional infrastructure, and on a small scale, but recognises the increasing role of more complex goods and services is evident. Recent trends reveal production to be organised in fewer hands as network effects increase the value of the network exponentially (Fisk, 2020) and financial capital operates easily on a global scale. The advantages of this might be in obtaining access to these goods and services, relatively cheaply in every region (Stahel, 2010), but the macro system conditions in this search for a dynamic equilibrium would probably be orientated to the subduing or redirecting of the monopoly rents and economic rents accruing (Pettifor, 2019). This would be consistent with the aim of ensuring a dynamic balance between efficiency and resilience and ensuring the dominance of a productive *circulatory* economy in relation to the *extractive* linear economy.

Conclusion

The notion of systems thinking is central to understanding a circular economy and its feedback-rich characteristics. Using characteristics inherent in all complex adaptive systems, it is possible to look at the notion of effective systems as a necessary interplay between efficiency (structure and flow emphasis) and resilience (network and exchange emphasis). Policy is currently overwhelmingly orientated toward improving efficiency and is focused on economies of scale. A rebalancing act is needed towards economies of scope (or diversity). New policy is needed which addresses the perceived lack of appropriate system conditions to improve the vitality of the resilience emphasis.

This policy, in following the system structure found in the exchange and network context is likely to be around low-cost access to resources and tools and revised taxation. This would imply a tax shift from renewables, including people and towards non-renewable resources including, but not limited to, fossil fuels, minerals and waste.

Further Research

The intuitive notion of "circularity" and "closing the loop" comes from the dynamic archetype of the world serpent: the ouroboros (the snake eating its own tail) is one of the earliest symbols used by humankind for the notion of regeneration. Like all archetypes it conveys meaning at a more profound level than that of the rational mind and derives much of its power from this. An aspiration for future work would be to apply this metaphor and "the world as a living system" to the thinking around the concept of a circular economy.

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