"Celebrating a decade of changing mindsets"

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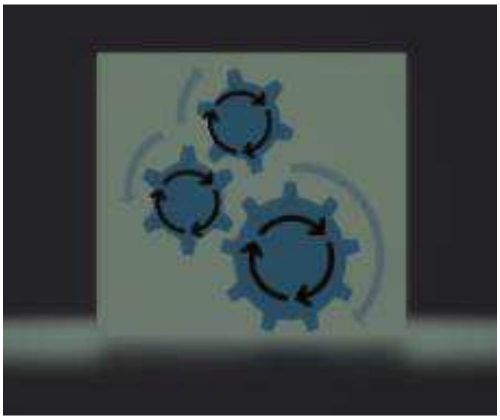
"Transforming our World of Systems"



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Edited by:
Nalini Sooknanan Pillay

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Foreword

We live in a world of turmoil and complexity, worsened by the onset of the COVID-19 pandemic in 2020. Year 2022 saw us experience a welcome reprieve from the soaring infections. Global immunisations reached all time highs and the world started feverish efforts to recover with stringent isolation being lifted in the majority of countries.

The pandemic made us all realise how interconnected the world has become. Information travels globally with little to moderate impedance. The message could be true or false, the rate of data and information distribution is at the speed of electrons. Our improved physical connections through global shipping lines and fleets of aircraft has helped speed up the spread of the pandemic as tourists and business travellers can circum-navigate the globe rapidly. Our activities affect not only our local environment, but that of the planet as a whole. And even energy has become a link between nations, from gas, oil and even electricity networks that extend across national borders.

Just when we thought the world would settle down, we had Russia invading Ukraine. A war fought on our news channels with many nations involved in actively helping the two sides. The United Nations condemns the actions but can do little to effect change.

A spin-off from the events is that Europe is suddenly without oil and gas and are now looking at going back to coal as source of energy. At the same time the European Union is investing massive amounts of money in green energy projects.

As the Systems Thinking and System Dynamics community, it is our responsibility to make the world think in interconnected systems and feedback loops. Very few decisions we take do not have impact in a broader context. The biggest impact we can make is to ensure that economic development happens in harmony with nature.

We have to ask: “How can we find ‘AND’ solutions rather than ‘OR’?” Economic development must happen, but it does not have to be at the cost of the environment. Consistent maintenance of facilities and the environment is much cheaper than dealing with disasters and breakdowns sometime in the future.

Dr Andries Botha

President
South African System Dynamics Chapter

Systems Thinking in Impact Assessment: Where we are and where we're going

Luanita Snyman-van der Walt
Council for Scientific and Industrial Research
PO Box 320, Stellenbosch, South Africa, 7599
+27 21 888 2490
lvdwalt1@csir.co.za

Gregory O. Schreiner
Council for Scientific and Industrial Research
PO Box 320, Stellenbosch, South Africa, 7599
+27 21 888 2419
gschreiner@csir.co.za

Paul A. Lochner
Council for Scientific and Industrial Research
PO Box 320, Stellenbosch, South Africa, 7599
+27 21 888 2486
plochner@csir.co.za

Abstract. Those mandating, commissioning and practising Impact Assessment (IA) have been aware for some time that systems thinking tools need to be better integrated into assessment- and decision-making. The research community has been especially vocal in the call for change. Although true to suggest that IA is mostly reductionist in its conception of social-ecological systems, systems thinking approaches are evident in historical and contemporary IA theory and practice. Some of these approaches explicitly bring the theoretical foundations of systems thinking into IA practice, e.g. systems mapping approaches. While others have tacitly applied systems thinking approaches over many years, consciously or unconsciously, e.g. integrated social-ecological narratives. In this paper, we briefly showcase the main systems thinking approaches used in IA. This umbrella typology of approaches includes narratives, matrices, digraphs, cause-and-effect analysis, flow diagrams and decision trees. We highlight the extent to which systems thinking has been integrated into IA practice, and discuss current limitations and challenges. To make systems thinking more mainstream in IA we propose four key focus areas moving forward: focussing on renewed research, generating practicable systems thinking frameworks, piloting and monitoring novel approaches, and capacitating practitioners and decision-makers with systems thinking skills.

KEYWORDS

Systems thinking, Impact Assessment, Science-policy interface, Causality.

INTRODUCTION

Human-nature interactions in the Anthropocene are characterised by 'wicked' problems. These are issues which are technically insoluble, often interconnected and socially polarising since they are often based on contradictory or incomplete knowledge. Wicked problems do not provide for optimal or universally accepted solutions, and every decision juncture has substantial trade-offs, in multiple directions. Despite the challenges, negotiated outcomes to resolve wicked problems are possible, but only through well-designed science-policy interface processes.

Impact Assessments (IA) are science-policy interface processes which inform political decision-making on projects, plans and programmes, interpreted through the lens of sustainability (Chanchitpricha & Bond, 2013). Research has demonstrated that IA is recognised globally as being effective for providing context to decision-making; establishing procedural guidance and mechanisms for quality evaluation; is supported by a growing body of practitioners and theorists; and encourages diverse practices and perspectives (Pope *et al.*, 2013). But IA is also mostly reductionist in how it frames complex issues within social-ecological systems. It tends to separate system components to promote *analysis* (studying each variable by itself), rather than seeking inter- and transdisciplinary *synthesis* (studying the relationships between variables). This shortcoming is well known to the practitioner community and repetitive calls have been made for the development of novel and practicable systems thinking methods.

This paper provides an overview of the status quo of systems thinking approaches in IA and identifies the challenges that have hampered its widespread application. Recommendations are made for the future direction of IA. A future that better incorporates systems thinking, facilitates sense-making in the face of uncertainty, enhances the transparency of decision-making and promotes a convergence of societal opinions in the face of wicked problems.

IMPACT ASSESSMENT

The science-policy interface is a conceptual 'platform' consisting of various processes and structures aimed at supporting decision-making through facilitating engagement between experts, policymakers and civil society (Van den Hove, 2007). IAs are science-policy interface processes that inform political decision-making on projects, plans and programmes, assessed through the lens of 'sustainable development' (Chanchitpricha & Bond, 2013). It is usually led by consultants with scientists, domain experts, authorities, policymakers and other stakeholders and knowledge holders also playing a pivotal role.

In current practice, several well-established 'types' of IA are recognised: 1) Environmental Impact Assessment (EIA), 2) Strategic Environmental Assessment (SEA), 3) Domain-specific Impact Assessment, 4) Sustainability Assessment, and 5) Policy Assessment (Pope *et al.*, 2013). The choice of IA type depends on factors such as the nature of the policy question/s, the knowledge types needed to answer those question/s, and spatial and time scales.

Within IA practice, some major strengths do exist (Pope *et al.*, 2013). But so too does a prominent and persistent 'meta-challenge' – IA fails to effectively conceptualise, and hence assess, the concept of sustainability (Retief *et al.*, 2007). Three key reasons for this are:

1. In IA, there often lacks an essential feedback loop between predictions and actual monitoring of impacts. With no calibration against real-world data (Beattie, 1995), we have very limited insight into the accuracy of IA predictions (Bond *et al.*, 2015). In the face of the rapid change characteristic of the 21st Century, the likelihood of accurate IA predictions is even further diminished (Retief et al., 2016).
2. Spatial (i.e. geographical study area) and temporal (i.e. time horizon) scales are poorly defined with little rationale provided in IA. The job of actually defining the scale of an assessment usually falls to the practitioner or proponent, with limited broader engagement on the topic (Lenzen et al., 2003). Narrow, weakly defined scales and scopes mean that the more complex problems, often global in scale, fall outside the mandate of conventional IA processes[1] (Bond & Dusík, 2020); and
3. System conceptualisation and assessment can be quite reductionist (Bond *et al.*, 2015). In other words, focused on the main elements of a system (e.g. the different specialist studies), not on the essential system relationships between these main elements (Bond *et al.*, 2015; Burns *et al.*, 2006; Morrison-saunders & Retief, 2012). This makes broader systemic effects virtually impossible to predict and can result in, according to Lenzen et al. (2003: 264), indirect impacts which are *"…several orders of magnitude greater"* than the direct impacts.

Given that the genesis of IA, in the decade or so leading up to 1970, was a rather quick one, its application as a heuristic for 'learning through doing' makes rational sense, although the 'doing' component may have come to dominate the 'learning' component. Equally so, considering this history, it would follow that claims of foundational theoretical gaps, and / or critical assumptions lacking from current IA practice, as they relate to systems thinking, are entirely plausible too, and in need of theoretical attention. As the developed and developing cultures usher in the Fourth Industrial Revolution, technological and paradigmatic change in the IA sector seem imminent (Bond & Dusík, 2020). IA, along with many other science-policy tools, find itself in constant flux, as they grapple with continuous social change, rapid technological development and constant information flows. Systems thinking has been widely touted as an effective approach for dealing with increasingly complex systems and problems (Barry, 1993; Maani & Maharaj, 2004).

SYSTEMS THINKING

In the broadest sense, systems thinking is a way of looking at the world and its phenomena. It's a *perspective*, supported by a *language*, and a set of *tools* (Monat & Gannon, 2015). A systems thinking *perspective* means taking a holistic view of the things around us and their behaviour, by acknowledging the intra- and interconnected nature of dynamic systems. As a *language*, it features a suite of concepts such as "complexity", "causality", "emergence", "leverage point", "pattern", "feedback" and "unintended consequence". This *language* permits system character and behaviour to be modelled and deliberated. Finally, various *tools* have been developed to facilitate systemic thinking and modelling, these include Systemigrams (systems maps), Stock and Flow Diagrams (SFDs), Causal Loop Diagrams (CLDs), and System Archetypes.

[1] In many IA processes, the use of scenarios are rarely adopted, making it very difficult to cope with complexity and uncertainty (Retief *et al.*, 2016).

Even though systems thinking is widely valued as a mechanism to deal with complex problems, thinking systemically, i.e. ’doing‘ systems thinking, is not necessarily an easy thing. Certain disciplines like sociology, physics and chemistry could be considered more conducive for applying systems thinking (Zulauf, 2007), but the literature reports systems thinking approaches in any field where complexity is recognised, for example, in energy planning (Laimon *et al.*, 2022), climate risk reduction (McMillan *et al.*, 2022), water resource management (Wei *et al.*, 2012), and environmental health (McAlister *et al.*, 2022). Many of these knowledge domains highlight the importance of systems thinking approaches to tackle issues of interest, as well as building non-linear, holistic thinking capacity and skills within their respective fields. Having said that, it is not obvious what the uptake of these approaches are in practice and whether systems thinking is actively implemented as practical decision-support.

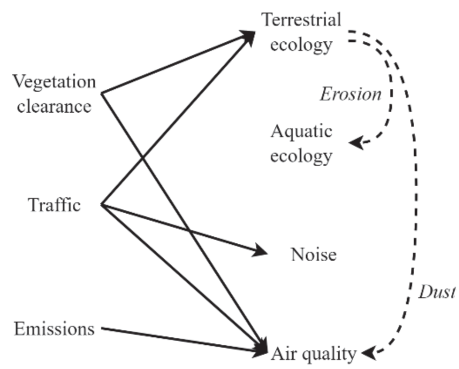
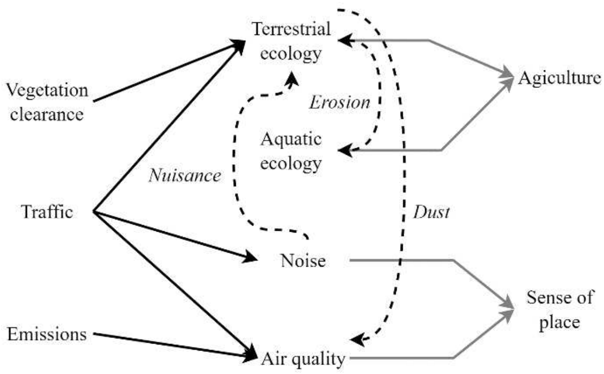
SYSTEMS THINKING IN IMPACT ASSESSMENT

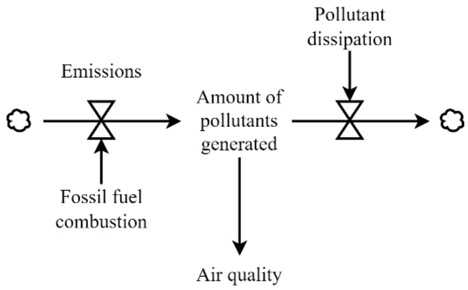
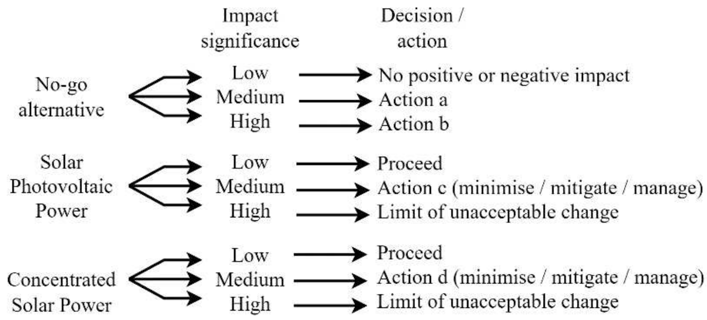
There are an increasing number of systems-based approaches being experimented with in IA (Wiek & Binder, 2005). Looking back, systems thinking perspectives are alluded to in the earliest IA theory and practice, primarily through the lens of causality (cause-and-effect), especially for determining indirect and cumulative impacts. Gilliland & Risser (1977) proposed a systems diagram approach to demonstrate project-environment interactions, contextualise impacts and alternatives, and quantify the resulting environmental impact. Other examples include “Component Interaction Matrices” (Wathern, 1984), cross-impact models (Parashar et al., 1997), and Cumulative Effects Assessment (CEA) (Roudgarmi, 2018). The European Commission (1999) promoted the advantages of “Network and Systems Analysis” and “Modelling” as robust approaches to address cause-and-effect in IA, but also noted that these approaches may fall short in terms of spatio-temporal considerations, time- and budget requirements, and run the risk of being overly complex and therefore fail to garner audience interest.

The examples above have used a suite of tools to integrate systems thinking into IA (**Error! Reference source not found.**). Perhaps the most rudimentary of these tools, but nonetheless successful and widely applied, is through *text narrative*. With increasingly complex systems or issues, narratives may become lengthy, inaccurate or difficult to comprehend compared to more visual approaches (Perdicoúlis & Glasson, 2012). One of the biggest challenges with narratives is that systems language is full of technical jargon. Taking the time to learn the jargon is extremely useful as it enables a much better understanding of systems functioning, plus the ability to dive deep into system elements and relationships with colleagues. On the other hand, writing texts deeply imbued with systems language can be extremely alienating if the content is not adequately tailored to the needs of the audience. This has prompted many organisations to look at bringing simple systems-based approaches into mainstream practice (e.g. the Systems Innovation Network[2]) by relying much more strongly on visual and graphical representation, rather than narrative. That being said, narratives will always be used in conjunction with matrices, diagrams, and graphs to provide supplementary context.

[2] https://www.systemsinnovation.network/about

Table 1: Main types of systems thinking approaches / tools for IA (adapted from European Commission (1999); Perdicoúlis & Glasson (2006)).

<table>
<tr><th>Systems thinking approach / tool</th><th>Description</th><th>Example</th></tr>
<tr><td>1) Narratives</td><td>Text description of the interaction between development actions and social-ecological elements.</td><td>Clearance of vegetation may lead to unstable soil conditions which become susceptible to erosion resulting in the loss of agricultural productivity. Additionally, erosion causes sedimentation of watercourses has an adverse effect on aquatic species, such as fish, which then impacts the livelihoods of communities reliant on fish for income and nutrition.</td></tr>
<tr><td>2) Matrices</td><td>Links specific actions of development proposals to significant impacts on social-ecological components.</td><td>
<table>
<tr><th></th><th>Terrestrial ecology</th><th>Aquatic ecology</th><th>Noise</th><th>Air quality</th></tr>
<tr><td>Vegetation clearance</td><td>- -</td><td>-</td><td>+</td><td>-</td></tr>
<tr><td>Traffic</td><td>- -</td><td>/</td><td>+ +</td><td>+ + +</td></tr>
<tr><td>Emissions</td><td>-</td><td>-</td><td>/</td><td>- -</td></tr>
</table>
</td></tr>
<tr><td>3) Directed graphs (“Digraphs”)</td><td>Consists of nodes and directional links between proposed development actions and social-ecological components, and enables expression of indirect impacts and interaction between impacts.</td><td>
</td></tr>
<tr><td>4) Cause-and-effect / network analyses</td><td>Consists of nodes and directional links between proposed development actions and social-ecological components, and enables expression of indirect impacts, interaction between impacts, as well as secondary impacts.</td><td>
</td></tr>
</table>

Systems thinking approach / tool	Description	Example
5) Flow diagrams	Captures quantitative flows of materials and / or energy instead of actions and outcomes.	
6) Tree diagrams	Captures action, consequence and decision / management options of different development scenarios and alternatives.	

Matrices are also a basic tool to show significant impacts resulting from specific development actions. This approach is the most commonly used in IA, but is not as effective in capturing indirect effects or the mechanism through which impacts manifest (e.g. vegetation clearance may result in compromised air quality through dust generation). Matrices cannot capture the feedbacks that underpin all rapid system transitions

"*Digraphs*" (directed graphs) introduce a visual component through simplistic systems diagrams that link development actions to impacted system components, as well as interactions between components (e.g. vegetation clearance creates exposed soils in the terrestrial environment, exposed soils may erode and result in sedimentation of the aquatic environment). Simple CLDs are an example of digraphs. CLDs are a good medium for constructing models based on knowledge elicitation. They have been widely applied since the 1970s in diverse fields, such as environmental management, urban and regional development, business management, and organisational development (Williams & Hummelbrunner, 2010). CLDs are useful for visualisation and communication with stakeholders in a way which promotes thinking about underlying structures behind observable patterns in a system. From an evaluation perspective, the value of CLDs lies in the fact that they can be used to assess the relationships of a situation through the interaction of feedback loops (Williams & Hummelbrunner, 2010). CLDs are sometimes used in IA processes to conceptualise the social-ecological system and its relationships (Glasson *et al.*, 2013), although it is not clear how common these are in IA, nor does it appear that any standardised approaches exist. Often in combination with CLDs, the interpretive (systems-based) framework of social-ecological 'resilience' is being used to provide a structured way of looking at complexity and uncertainty. The adoption of system resilience as a theoretical interpretative framework in IA is becoming more common which de facto means that systems thinking is becoming more common (Slootweg & Jones, 2011).

Cause-and-effect or *network analyses* are similar to digraphs, but also introduce secondary impacts (e.g. noise and air quality ultimately impacts 'sense of place'). More complex CLDs and tools like "Impact Networks" (Julien *et al.*, 1992), "Action-to-Outcome Maps" (Perdicoúlis, 2007), "Descriptive Causal Diagrams" (Perdicoúlis *et al.*, 2016), and the "Driver-Pressure-State-Impact-Response" (DPSIR) framework, including variations thereof (Cooper, 2013; OECD, 1993), are examples of cause-and-effect / network analyses. DPSIR system components include drivers (D) which are the underlying causes for environmental change which arise from social needs. For example, the human need for food. Drivers initiate a series of pressures (P) which come in the form of human activities, for example, fisheries and agricultural production. The environmental change, which may be physical, biological or chemical, stimulated by the pressure has an impact on the state (S) of the environment which affects its ability to provide ecosystem goods and services, for example, nitrification of water systems and fish stock depletion. Responses (R) are the policy and management actions adopted to mitigate the undesirable changes to the state of the system, for example, regulating fertilizer regimes and introducing fishing stock quotas (Hisschemöller *et al.*, 2001).

Flow diagrams track the flux of material or energy through a system quantitatively – the most common example is SFDs, which are often used in conjunction with CLDs. Although more easily applied to explicitly quantitative issues, SFDs can also incorporate qualitative variables, if those qualitative variables are given some kind of numerical basis (Liu *et al.*, 2011; Monat & Gannon, 2015).

Tree diagrams aim to synthesise the impact and potential interventions for different development scenarios (De Jongh, 1988), often through "if-then rules" (Karka *et al.*, 2019). The DPSIR framework incorporates elements of tree diagrams since it includes responses to impacts, and how that response ultimately changes the driver-to-impact chain. Despite the early recognition of the complexity and connectedness of project, plan and programme proposals and the pathways through which they impact receiving environments, as well as a portfolio of existing systems thinking approaches / tools for IA, very little evidence exists of implementation of systems thinking approaches by IA practitioners. Perdicoúlis (2007) reportedly tried to implement standard CLD and SFD to address causality in IA, but found that practitioners experienced these approaches as being too technical, did not see the value in using them, or felt that the *likelihood* of impacts was not captured satisfactorily using these techniques. Investigating a small sample of EIA reports in Europe, Perdicoúlis & Glasson (2006) found that none of the reports employed tools such as causal networks. Similarly, Wood *et al.* (2006) found that less than 3 % of practitioner respondents reported using flow charts or decision trees to determine significant impacts in EIA (England and Wales).

There is yet to be a similar systematic or case study review to determine the degree to which systems thinking approaches or tools have been employed in South Africa. However, in South African IA practice such approaches seem more prominent in SEA and Sustainability Assessment processes. For example, a system resilience framework was adopted for a Sustainability Assessment of the proposed Maseve platinum mine where a CLD of key social-ecological system relationships which may influence and be influenced by the mining was central to the study (CSIR, 2011). Likewise, a risk and resilience assessment, undertaken as part of an SEA for the Saldanha Bay municipality, used CLDs and "impact strings" (based on the DPSIR technique) to develop an integrated decision-making framework (DEA&DP, 2019). We speculate that systems thinking is more prevalent in SEA-type processes than other forms of IA, because:

- The approach to SEA-type processes is not legislated, so SEA provides more opportunities for knowledge-based innovation for scoping, assessing and generating management actions.
- SEAs are often better resourced than EIAs, e.g. through government agencies, and do not necessarily face the same levels of bureaucracy and time constraints of regulated EIA processes (e.g. "the applicant must, within 90 days… submit to the competent authority a[n]…assessment report" (South Africa, 2017:229)).
- EIAs are often commissioned by individuals or companies who are concerned with meeting the minimum regulatory requirements to obtain environmental authorisation as soon as possible. They are not necessarily interested in funding or participating in novel, experimental IA approaches, although, of course, there are exceptions.

CONCLUSION AND FUTURE DIRECTION

Causality is central to IA (Perdicoúlis & Glasson, 2009), and IA best practice calls for integrated consideration of the biophysical, social, and economic environment as well as assessment of cumulative impacts (IAIA, 1999). Despite the repeated acknowledgement that IA and the decisions they inform would benefit from systems thinking approaches (Morrison-saunders & Retief, 2012; Nooteboom, 2007), these have been slow to permeate the mainstream practice.

Recent advancements in this area are seemingly rehashing fundamental techniques proposed since the earliest days of IA – e.g. Ehrlich (2022) on depicting relationships between "valued components" of a system, and Peeters *et al.* (2022) on "spatial causal networks" – with few examples of these approaches being mainstreamed in IA practice and decision-making. Novel innovations within the systems thinking for IA space that are gaining traction include approaches like geodesign (Campagna & Matta, 2014), strategy games (Garcia *et al.*, 2022) (both of which are participative processes that embrace plurality), and other resilience-based approaches (Slootweg & Jones, 2011).

Mainstreaming systems thinking in IA would require those commissioning and practising IA to go beyond minimum requirements, an undertaking that could be constrained by available time, resources and systems thinking capabilities. Based on these challenges, the following recommendations are made to guide the future direction of systems thinking in IA:

- *Research* – while research on the need and benefits of systems thinking in IA is well established, a systematic review of IA systems-based case studies would be useful to establish the current uptake of these approaches in South Africa. Additionally, the perspective of actors in IA (e.g. practitioners, domain specialists, decision-makers, proponents, developers and representatives of civil society) can help to develop a better understanding of the challenges and / or reluctance to adopting these approaches.
- *Framework* – the development of a "systems thinking for IA" framework that provides workable guidance for IA practice and decision-making. Ideally, such a framework or guide would be endorsed by those who mandate or are recognised in IA (e.g. government departments and practitioner bodies such as the International Association for Impact Assessment (IAIA)).

- *Pilot and monitor* – systems thinking approaches in IA must be piloted in 'real' IA processes, followed by monitoring and evaluation of whether they facilitate sensemaking, and enhance IA and decision-making effectiveness. Most importantly, post decision-making monitoring is necessary to determine the extent to which systems thinking approaches did, or did not, predict system outcomes, and how the accuracy of these predictions differ from conventional, non-system-based approaches.
- *Training and education* – the call to make systems thinking more accessible to IA practitioners and decision-makers through training and education is not new (Barry, 1993; Perdicoúlis & Glasson, 2006). It is unclear to what degree systems thinking skills are focussed on in the education of IA practitioners and decision-makers, especially since they often originate from different discipline backgrounds (e.g. environmental science, social science, engineering, political science) which may be less or more conducive to complexity concepts. It is recommended that systems thinking skills be re-prioritised as foundational in IA education and training by universities, professional registration bodies (e.g. the recently established Environmental Assessment Practitioners Association of South Africa (EAPASA)), organisations like IAIA, and other IA training providers. It is also worth noting that since systems thinking is paradigmatic, i.e. a way of seeing the worldand its behaviour, it is not necessarily a transferable skill. So no matter how much training is offered, some people, however technically gifted, simply 'won't get it', or understand its value.

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