Complex system governance requires systems thinking – how to find systems thinkers

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Abstract: Systems thinking offers a particularly useful worldview for dealing with increasing complexities faced by individuals. This paper explores the nature, assessment, and implications that systems thinking holds for individuals challenged by the shifting landscape of modern complex system governance. Following an introduction that identifies the main attributes of complex systems faced by individuals who engage in governance activities, three major themes are developed: 1) exploration of the concept of systems thinking; 2) suggestion of how enhanced systems thinking can increase the capability of individuals to more effectively design for system governance; 3) a strategic framework and initial findings for application of an instrument for assessment of the level of systems thinking for an individual. Systems thinking is suggested as a critical capability for individuals who must design, analyse, and transform complex system governance and address its derivative problems. Effectiveness in systems thinking is a critical skill for addressing some of the most vexing problems of the 21st century. This paper summarises the findings of a systems thinking instrument developed to identify the systems skills individuals need to engage complex system governance. The paper concludes with future research and application of the systems thinking instrument to better understand complex system governance.

Keywords: complex systems; system governance; systems thinking; multidisciplinary problems.

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1 Introduction

Dealing with complex system governance and its associated problems is a reality for engineering solutions to complex problems of the 21st century. The concept of system governance has grown in the last decade, and while the current body of knowledge on governance is evolving quickly it is still very fragmented (Williamson, 1994; Willke, 2007; Brennan and Solomon, 2008). While the evolution of system governance has similarly been fragmented, it does show considerable promise for addressing some of the most vexing problems facing society. Complex systems are marked by an exponential increase of information, complexity, ambiguity, emergence, and high levels of uncertainty. In responding to these conditions, individuals are frequently faced with the challenge of analysing and designing system governance functions at various levels of their systems amid overwhelming complexities that are inherent in the landscape of complex systems.

The problems stemming from increasing complexity and its associated phenomena continue to confound our capabilities to design governance for complex systems. In response there is a need to have a cadre of qualified individuals to develop and ensure sustainment of governance of complex systems. Individuals in different domains must appreciate the intricacies of complex problems and be able to take a ‘systemic’ perspective. A systemic worldview leads to better thinking, decision making, actions, and corresponding interpretations in a complex problem domain.

Systemic thinking is a high level thinking skill that enables individuals to effectively engage and design system governance. While much has been written about the articulations and perspectives of system governance (Keohane and Nye, 2000) and its associated phenomena, there is nothing in the literature that answers some of the most basic questions: What are the systems thinking capabilities individuals should attain to engage system governance where governing takes place? An inextricably related to this is the question: what are the main attributes of complex systems? To answer these questions, this paper introduces a set of systems thinking characteristics that are essential for individuals to successfully engage governance activities in complex systems.

To have successful system governance, it is necessary to understand the importance of identifying the systems skills so that

1. a solid foundation of individuals who have the systems skills needed to design system governance can be built
2. a good system governance design can be achieved
3. an indicator of which individuals need to be provided training and education to improve the capacity for systems thinking can be offered.

There are several examples of existing governance systems that face the practical difficulties of increasing complexities, change, emergence, and uncertainty. Such difficulties hint at the need for an instrument that identifies the level of systems skills for individuals who operate under these difficulties. Governance, in fact, should be present and pre-planned early during the design and development phase of the system. In this paper, the emphasis is on identifying the set of systems thinking skills for an individual that must be given priority as preparation for designing complex system governance.
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The literature is replete with studies related to governance but they are university framed in the concept of governance within the system. Some studies define governance based on actions and patterns (i.e. top down versus bottom-up forms) (Jose, 2009), while others define governance based on authority and a structure of autonomy. Several studies describe governance from a power and control perspective (Weiss, 2000). While several perspectives were presented about governance, no studies were identified that propose the characteristics individuals need to successfully design for governance in complex systems. The study of systems thinking characteristics in the governance domain is relatively young, and the lack of studies related to systems thinking and governance underlines the need for research in this area.

The purpose of this paper is to provide a perspective and implications for the assessment of an individual’s capacity for systems thinking and thus to successfully design for governance in complex systems. This paper has three main objectives:

1. establish an appreciation of the complex nature of systems that individuals deal with when designing system governance
2. identify the set of systems skills individuals need to successfully design for governance in complex systems
3. suggest implications for research to assess an individual’s capacity to design and develop a system of governance in complex systems.

To achieve these objectives the paper is organised into five sections. Following this introduction, Section 2 presents the attributes of complex systems derived from the review, analysis, and coding of over a thousand different resources. Section 3 explores the concept of systems thinking from a system governance perspective. Section 4 discusses the vital role systems thinking plays in governing complex systems. Section 5 proposes the set of systems thinking characteristics that identify the degree of systems thinking for individuals who engage in governance activities. The paper concludes with recommendations and future research.

2 Attributes of complex systems

The purpose of this section is to show the main attributes of complex systems across domains. It is important to mention that the set of systems thinking characteristics discussed later rests on these attributes. Throughout the history of complex systems, many studies revolved around the definition and characteristics of complex systems (Boardman and Sauser, 2006; Cook and Sproles, 2000; Crossley, 2004; DeLaurentis, 2005; Maier, 1998; Katina et al., 2014; Jaradat and Katina, 2011). Using the inductive approach of grounded theory coding, over a thousand different resources including peer reviewed journal papers, peer reviewed conference papers, books, and book chapters were reviewed, analysed and coded. The boundary of the literature includes complex systems and governance, systems theory, systems thinking, and systems engineering. The purpose of the coding analysis is to derive the set of the most coded attributes in the literature. The histogram analysis study conducted by Jaradat et al. (2014) was used as a foundation to conduct the coding analysis. In this study, they traced the history of complex systems/system of systems from 1920–2011. They identified several perspectives and definitions used to describe complex systems as shown in Figure 1.
In responding to increasing complexity, individuals are frequently faced with the challenges of designing for governance at various levels of their systems amid an overwhelming flow of information. To successfully deal with critical governance issues, individuals in different domains must appreciate the complex problem domain and be able to take a ‘systemic’ perspective that enables them to cope with the complexities inherent in complex system landscapes. This ‘systemic’ perspective leads to better thinking, analysis, actions, and corresponding development in governing complex systems. Based on the coding analysis, the complex system problem domain is marked by the presence of any combination of the seven main attributes shown in Figure 2. It is important to note that while these seven attributes may be present in differing degrees, all of them exist in complex systems, both natural and manmade.
2.1 Interconnectivity

Interconnectivity includes the potentially divergent worldviews, conflicting perspectives, interactions of the systems’ hardware and software components, human social and cultural identities, human interactions, and proliferation of information and people.

2.2 Integration

The process through which an entity (element, component, or subsystem) becomes part of a larger integral whole is referred to as integration. Entities surrender a level of autonomy allowing membership in a whole. This whole produces emergent properties beyond those held by individual entities.

2.3 Evolutionary development

Multiple perspectives, stakeholders and shareholders who have direct or indirect impact on the system and contribute to the complexity and divergence of such systems. This leads to issues such as the evolution of needs (requirements) over time and the necessary reallocation of scarce resources based on those shifts. The environment within which complex systems operate is highly uncertain and dynamic with potentially rapid shifts occurring over time.

2.4 Emergence

Emergence is described as unintended behaviours and patterns that cannot be anticipated and cannot be attributed to any of the constituent systems (Checkland, 1999; Keating, 2009; Holland, 1998), the structural and behaviour patterns only become apparent as a
complex system operates. These unforeseen behaviours occur because of the uncertainty, high level of interactions, ambiguity, and complexity in complex system governance.

2.5 Complexity

Complexity includes the high level of interrelationships among the individual systems and their components, the technical/non-technical components in the system, the proliferation of information, conflicting perspectives and divergent worldviews. Complexity also entails contextual issues – specific external influences, characteristics or conditions that influence and constrain the deployment of a solution(s).

2.6 Uncertainty

Incomplete and fallible knowledge exacerbates the occurrence of behaviours and patterns that were not intended, particularly well-understood, or anticipated. This level of uncertainty increases complexity and therefore makes decisions tenuous, and limits the applicability of more traditional systems based approaches such as algebraic and statistical methods of analysis.

2.7 Ambiguity

The unpredictability of understanding the system’s behaviour and structure comes from the lack of clarity concerning essential aspects of the system (purpose, boundaries, structure). This lack of clarity casts doubt on decisions, actions, and interpretations in complex systems.

It is instructive to note that while an exhaustive review and coding of the associated literature has been accomplished, the synthesis of these attributes continues to evolve. However, there is a confidence that these attributes have reached a sufficient level of stability to meet the present need to have a set of systems thinking characteristics that determine an individual’s inclination to design and analyse system governance.

In 2014, Keating identified six interrelated functions to attain governance of complex systems and enhance capacity for dealing with the increasing attributes described in Figure 2. These functions are

1. provide directions to clearly identify the vision that supports decisions and sustain identity of the system
2. provide oversight and control of the system
3. preserve balance and coordination to withstand emergence
4. monitor performance and ensure resource allocation and utilisation
5. maintain system transformation for system growth and development
6. learn from patterns and behaviours occurring in the surrounding environment.

This paper emphasises that in addition to recognising these functions there is also a need to identify the degree of systems thinking that is compatible for engaging in governance activities. Complex system attributes are likely to continue as individuals grapple with
the interdisciplinary complex governance problems of the 21st century; therefore a knowledge of technological issues as well as an understanding of the associated human/social, organisational/managerial, and political/policy dimensions is required as solutions are developed. In effect a holistic perspective integral to systems thinking is necessary for individuals to engage and navigate effectively in governance activities of complex systems. In the next section, the concept of systems thinking and its implications with regard to governance activities will be discussed followed by a presentation of the systems skills an individual needs to successfully govern complex systems.

3 The concept of systems thinking from a governance perspective

The complex nature of systems and their associated attributes illustrated in Figure 2 make it difficult to design, develop, and maintain a flexible governance system. This section introduces the concept of systems thinking as a way to enhance an individual’s capacity to deal with complex systems and the unique problems they present. Systems thinking, taken broadly as a framework of thought that helps in dealing with complexity in a holistic way, is critical to the future success of individuals who engage in designing governance in complex systems.

Before discussing the role systems thinking plays in increasing capabilities of individuals, it is important to briefly trace the history of systems thinking and provide some representative definitions from the field. The earliest roots to systems thinking can be traced to Aristotle who proposed the idea of holism, which became the foundation of systems thinking. Many works, perspectives, and studies have been presented to describe systems thinking. Systems thinking is the thought process which develops the ability to think in and speak a new holistic language (Checkland, 1993).

In his definition of systems thinking, Checkland emphasised the concept of wholeness to understand complex problems. Senge (1990, p.7) mentioned that “systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively”. Adams and Keating (2011, p.11) stipulated that understanding the principles of system theory, “in conjunction with the thought process developed in systems thinking” is a vital and key step toward understanding complex systems endeavours. Table 1 provides some of the current perspectives concerning systems thinking.

<table>
<thead>
<tr>
<th>Author</th>
<th>Perspectives</th>
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<tbody>
<tr>
<td>Checkland (1999, p.318)</td>
<td>“An epistemology which, when applied to human activity is based upon the four basic ideas: emergence, hierarchy, communication, and control as characteristics of systems. When applied to nature or designed systems the crucial characteristic in the emergent properties of the whole”</td>
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<tr>
<td>Senge (1990, p.7)</td>
<td>“Systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively”</td>
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<tr>
<td>Flood and Carson (1993, p.4)</td>
<td>“A framework of thought that helps us to deal with complex things in a holistic way”</td>
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Table 1 shows that:

1. There is no one accepted perspective or unique definition of systems thinking. There are many perspectives concerning how we think about the complex system-based world.

2. Systems thinking is not germane to a specific domain, but rather it spans several domains including social, managerial, biological, and many others (Hitchins, 2003; Jackson, 1993; Senge et al., 1994; Hoefler and Mar, 1992; Boardman and Sauser, 2008).

3. The principle of holism is the foundation of systems thinking.

4. Systems thinking is not new. In fact the earliest roots to systems thinking can be traced to ancient Chinese work *I Ching* prior to 400 B.C. However, what is new is the research and applications of systems thinking in governance activities. One of the criticisms of the few current tools pertinent to systems thinking is that they are for specific domains and lack the ability to be applied over multiple domains.

### 4 Implications of systems thinking capacity for dealing with system governance

Systems thinking, based on systems theory principles and laws, plays a vital role in understanding and dealing with the complex system attributes outlined in Figure 2. Systems thinking is considered to be the basic foundation necessary for individuals to effectively engage in thinking, making decisions, and constructing coherent interpretations concerning critical system governance issues and how they might be effectively approached. Success in governing system development in many domains (transportation, cyber warfare, industry, etc.) also depends on the degree to which one thinks in a holistic language that enables effective systems thinking, and subsequent engagement, of complex system governance. To understand systems thinking, it is important to understand the principles and laws of systems theory which Von Bertalanffy (1968) defined as a theory to capture general principles applicable to all systems regardless of their domain of existence. Although discussing each principle and law of systems theory is beyond the scope of this paper, a detailed and complete list of the principles, laws, and concepts can be found in the work of Clemson (1984), Skyttner (2001), Jackson (2003), Adams and Keating (2011) and Adams et al. (2014).

Even though there are different perspectives germane to systems thinking (Lane and Jackson, 1995), it is possible to identify some common themes (based on analysing a thousand different sources) that appear to mark the development of systems thinking through the several perspectives. Some of these themes are:

- Holism vs reductionism: in large complex problems the focus should be on the whole instead of the particulars. System performance or behaviour is generated from the interaction of the elements, not from individual elements.
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- Turbulent environment vs static environment: in dynamic environments it is important to appreciate the effect of the environment on the system both negatively and positively. A system is influenced by the externally driven impacts (perturbations) from the environment.
- Optimising vs ‘satisficing’: in large complex problems it is difficult to achieve one best solution. There are often multiple working (i.e. good enough) solutions that need to be considered.

Dealing with complex problems and their associated attributes is one of the biggest challenges for individuals when identifying and designing strategic governing systems. Because present and future environments are characterised by increasing levels of complexity, ambiguity, emergence, and uncertainty, effectiveness in dealing with these environments requires individuals capable of engaging in higher levels of systems thinking. Systems thinking is certainly not portrayed as a ‘panacea’ to singularly guarantee success with 21st century problems. However, it does offer a compelling argument as a necessary, albeit not sufficient, condition to increase effectiveness in dealing with these problems and therefore successfully engage governance activities.

One of the main responsibilities for individuals in governance activities is to select the best governance design required for sustainment of complex systems. However this is not an easy task in complex systems. It is important to note that in order to effectively engage in governance activities in complex systems

1. Individuals must shift to a new paradigm of thinking toward a more holistic perspective.
2. This paradigm is necessary to develop a new mindset for building and enhancing governance for complex systems. This paradigm is more consistent with the issues associated with system governance.

Table 2 presents the implications of systems thinking in understanding system governance development in complex systems marked by the presence of any combination of the seven attributes shown in Figure 2.

**Table 2** Systems thinking implications in governance development

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Explanation</th>
<th>Implication of systems thinking in system governance</th>
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<tbody>
<tr>
<td>Interconnectivity</td>
<td>Interconnectivity includes the potential divergent worldviews, conflicting perspectives, interactions of the systems’ hardware and software components, human social and culture identities, human interactions, and proliferation of information and people.</td>
<td>Treat the system as a whole unit and see the big picture for better design, analysis and development of governance in complex system. This is important to avoid managerial errors such as type III, solving the wrong problem precisely and in the most efficient way (Mitroff, 1998). View the problem from a holistic standpoint. This is imperative to avoid ineffective resource utilisation.</td>
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### Table 2  Systems thinking implications in governance development (continued)

<table>
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<tr>
<th>Attribute</th>
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<tbody>
<tr>
<td>Integration</td>
<td>The process through which an entity (element, component, or subsystem) becomes part of a larger integral whole. Entities surrender a level of autonomy allowing membership in a whole. This whole produces emergent properties beyond those held by individual entities.</td>
<td>Treat the system as a whole unit to understand the rich interaction and integration between the parts within the system, as well as between the systems in relation to other systems. This treatment provides understanding of system governance explorations and activities.</td>
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<tr>
<td>Evolutionary development</td>
<td>Multiple perspectives, stakeholders and shareholders, who have direct or indirect impact on the system, contribute to the complexity and divergence of such systems. This leads to issues such as the evolution of needs (requirements) over time and the necessary reallocation of scarce resources based on those shifts</td>
<td>Employing a holistic perspective can be instructive for individuals looking at the other dimensions of the problem (human/social, organisational/managerial, and political/policy). Looking at the other dimensions of the problem is necessary for better support and design of system governance. The systems thinking based paradigm is much more consistent with the dynamic environment faced by individuals engaging governance activities.</td>
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<tr>
<td>Emergence</td>
<td>Unintended behaviours and patterns that cannot be anticipated and cannot be attributed to any of the constituent systems. The structural and behaviour patterns only become apparent as a complex system operates. These unforeseen behaviours occur because of the uncertainty, high level of interactions, ambiguity, and complexity in complex systems governance.</td>
<td>Emergence is one of the obstacles to successfully execute governance in complex systems. Even though these unintended behaviours are not expected beforehand, treating the problem from a holistic perspective will alert individuals to the need for flexible and resilient system governances. Flexibility is a primary function of governance to cope with any unpredictable behaviours in complex systems.</td>
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<tr>
<td>Complexity</td>
<td>High level of interrelationships among the individual systems and their components, technical/non-technical components in the system. Complexity also entails contextual issues – specific external influences, characteristics or conditions that influence and constrain the deployment of solution(s).</td>
<td>Improving system governance requires individuals to appreciate and assess the degree of complexity and realise that there is no full control and complete knowledge in system governance environments. Employing a holistic perspective will help individuals to identify and address the external influences that affect the design and analysis of system governance functions.</td>
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Table 2  Systems thinking implications in governance development (continued)

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<th>Explanation</th>
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<tbody>
<tr>
<td>Uncertainty</td>
<td>Incomplete and fallible knowledge exacerbates the occurrence of behaviours and patterns that were not intended, particularly well understood, or anticipated. This level of uncertainty increases complexity and therefore makes decisions tenuous, and limits the applicability of more traditional systems-based approaches such as algebraic and statistical methods of analysis.</td>
<td>Holistic thinking helps individuals tolerate uncertainty and ambiguity in a turbulent environment. The high level of uncertainty makes it difficult to have optimal system governance in complex systems. Holistic perspective can provide the basis for understanding the difficulties uncertainty brings to governance activities by tracing and mapping the ongoing changes in needs and social infrastructure</td>
</tr>
<tr>
<td>Ambiguity</td>
<td>The unpredictability of understanding system’s behaviour and structure comes from the lack of clarity concerning essential aspects of the system (purpose, boundaries, structure). This lack casts doubt in decisions, actions, and interpretations in complex systems.</td>
<td>A holistic perspective can provide insight into the relationships among systems, subsystems, and their parts which is necessary for the selection, prioritisation, and screening for the relevant dimensions of the problem. This insight is necessary for a better system governance design.</td>
</tr>
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</table>

Failures in designing tenable system governance can often be attributed to the characteristics of complex systems. In fact a lack of knowledge of complex systems coupled with a lack in systems skills can result in a direct failure of governance activities. Failures in governing complex systems can be related to organisational and individual issues where individuals are an essential, if not dominant, contributor to the failure. These failures can be classified as having socio-technical aspects stemming from both technical and social (human) elements as well as interactions between those elements (Jaradat and Keating, 2014). The problems emanating from complex systems appear to be tenacious given the current level of thinking and ineffective responses provided to address their seeming proliferation into all aspects of human endeavour. From the implications of systems thinking listed in Table 2, it appears that holistic systems thinking would be extremely beneficial in the design, analysis, and strategic development of system governance for complex systems. To have an effective design and analysis of governance for complex systems, this paper emphasises that:

1  It is necessary to determine the degree of systems thinking for individuals that is compatible to dealing with governance activities in complex systems.

2  There is a need for a tool that classifies individuals’ inclination to engage governance activities based on their systems skills profiles.

3  Improving system governance in systems exhibiting these attributes requires knowledge of the other dimensions of the problem (i.e. organisation/managerial etc). This could be obtained by understanding and applying systems thinking.

In responding to this need, the following section proposes a set of research-based systems thinking characteristics that reflect an individual’s level of systems thinking in dealing with governance in complex systems. This set of systems thinking characteristics
provides a better understanding of an individual’s capacity to engage governance activities.

5 The set of systems thinking characteristics proposed to effectively design for systems governance

The concept used for systems thinking in this paper is focused on capturing the systems thinking characteristics that are necessary for individuals to engage in higher level (holistic) thinking about designing governance in complex systems and how they approach problems stemming from these systems (Figure 1, Table 2).

One of the tenets of systems thinking is the application of a holistic approach. This holistic perspective can provide a foundation for essential capabilities to more effectively navigate governance activities. Therefore, for truly complex problems, systems thinking can transcend technical knowledge in developing robust ‘holistic’ solutions. The importance of systems thinking increases as the level of complexity increases (Boulding, 1956; Clemson, 1984).

To derive the set of systems thinking characteristics, a systems thinking tool has been developed based on dissertation research (Jaradat, 2014). It is important to note that the development of the systems thinking tool was based on an understanding of systems thinking in conjunction with systems theory laws, principles, and concepts. Providing a detailed discussion on the development of the systems thinking tool is beyond the scope of this paper, so the focus here is on the outcome of the research tool, which is the set of systems thinking characteristics that would help in determining an individual’s propensity and capacity for systems thinking when dealing with governance activities in complex systems.

The set of systems thinking characteristics consists of 14 scales to measure seven main preferences portrayed in Figure 3.

Figure 3 14 scales of systems thinking
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These 14 labels reflect an individual’s level of systems thinking in engaging system governance issues. As mentioned earlier, the literature of governance is replete with studies related to the different perspectives and articulation of system governance. However, they fail to identify studies pertaining to individuals who design and develop system governance. Thus, these 14 labels contribute to the body of knowledge by identifying the degree of systems skills that determines an individual’s predisposition in engaging governance activities. Figure 4 shows in detail the preference pairs for the set of systems thinking characteristics. Throughout the different profiles in systems thinking there are no intrinsically good or bad combinations; the value of a particular combination depends on the nature of the complex problem and the priorities for system governance issues. However, even though there are no bad or good combinations, individuals who are more system thinkers are usually more suitable to engage in governance activities than individuals who are not system thinkers.

Figure 4  Systems thinking characteristics preferences pairs (see online version for colours)
Figure 4 examines the preference for each systems thinking characteristic. An individual may prefer one characteristic over another or find that both characteristics within each pair are suitable. However, within each pair, (e.g. holism or reductionism) there is one that is agreed with the most or leaned toward more naturally. As illustrated in Figure 4 there are seven levels of systems thinking with 14 categories. The first pair of preferences deals with the level of complexity. This level describes an individual’s inclination to design for governance in complex systems.

When engaging in governance activities, it is important to know an individual’s comfort zone in dealing with complexity. The second pair of preferences deals with the level of autonomy and describes an individual’s comfort level in dealing with integration. Individuals who apply a holistic perspective in dealing with integration are more successful in governing complex systems because integration is one of the main attributes of complex systems. The third pair of preferences, which pertains to the level of interaction, describes the type of work environment an individual would prefer. System thinkers who focus more on the big picture and the overall interaction of the whole system are needed to effectively design and analyse governance in complex systems.

The fourth pair of preferences deals with the level of change. This level describes an individual’s inclination to make changes when dealing with complex problems. The preference pairs are notated as (Y) for embracement of requirements and (V) as resistance to requirements. Identifying an individual’s predisposition to any of the two preferences would indicate their willingness to make changes or modifications to better support system governance. In this pair of preferences a (Y) system thinker has a paradigm that is better fit to engage governance activities in complex systems that operate in dynamic-shifting environments. The fifth pair of preferences deals with the level of uncertainty and ambiguity. This level describes an individual’s preference in making decisions as (E) emergence or as (T) stability. Emergence is one of the main obstacles for system governance. (E) System thinkers with a paradigm focus more on the whole in solving problems are better equipped to manage system governance activities. (E) type system thinkers prefer to design a flexible and resilient system governance to cope with the unanticipated behaviors or patterns of complex system. The sixth pair of preferences deals with the level of hierarchical view of the system. This level describes an individual’s inclination to look at the problems in complex systems as (H) holistic or as (R) reductionist. For successful system governance, a holistic understanding of critical system governance issues is necessary. (H) type system thinkers use a paradigm that applies a holistic view in designing, analysing, and improving system governance. The last pair of preferences deals with the level of flexibility. This level describes an individual’s preference to making decisions as (F) flexibility or as (D) rigidity. (D) type system thinkers most likely apply a paradigm of thinking that is not suitable to dealing with governance of complex systems. This type of system thinker prefers to make only minimal changes and maintain stable system governance. This might work well in simple systems that operate in stable environment, but (D) type system thinkers might not achieve the same level of success when designing system governance in a large complex system.

The seven preference pairs discussed above are used to determine the individual’s level of thinking (worldview) and thus predict his ability to engage the systems thinking required to effectively design for governance in complex systems. Dealing with the turbulent environment of complex systems, individuals need to be more in line with systems thinkers who are more likely to apply a paradigm based on holism than
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Complex system governance requires systems thinking. This is not to criticise the reductionist approach but only to focus attention on the need to have holistic system thinkers who can understand the overall picture of the system before designing and analysing system governance. It is important to note that the importance of systems thinking increases as the level of complexity increases (Boulding, 1956; Clemson, 1984). This paper has provided three main contributions:

1. Establish an appreciation and understanding of complex systems individuals must navigate to design flexible and resilient system governance.

2. Understand the key role systems thinking plays in engaging governance activities in complex systems. The set of systems thinking characteristics capture and test the individual’s fitness to engage governance activities in complex systems.

3. Examine the role and assessment of individual capacity for systems thinking as a key to success in governing complex systems. A set of systems thinking characteristics is proposed to identify an individual’s predisposition to deal with system governance issues. Identify the set of system skills for individuals should be given a priority before the design and deployment of system governance.

6 Conclusions

The central idea of this paper is to propose a set of the systems thinking characteristics and show the necessity of systems thinking when dealing with system governance in complex systems. Seven main attributes of complex systems were derived from an analysis of a thousand different resources from complex systems/governance, system theory, systems thinking, and systems engineering. The seven attributes are **interconnectivity** (high level of human and information interaction), **integration** (level of operational, managerial, or geographical dispersion), **evolutionary development** (dynamic environment and evolution of needs), **emergence** (unexpected events that affect the system), **complexity** (variety of contextual issues and conflicting perspectives), **uncertainty** (incomplete knowledge leads to lack of confidence in decisions and actions), and **ambiguity** (lack of understating of system’s behaviour and structure). Even though it is a sample, it offers a glimpse into the main attributes inherent in complex systems.

Dealing effectively with complex system problems requires understanding of the problem from the social/human, managerial/organisation, and political/policy dimensions. Thus, this paper shows the need to shift from traditional ways of thinking and adopt a more holistic approach to effectively engage governance activities.

The systems thinking characteristics identified in Figure 4 are the outcome of a systems thinking tool that purposefully developed to deal with complex system problems. Discussing the development of the tool is beyond the space allocated for this paper. The set of systems thinking characteristics determines the degree of systems skills that is compatible with engaging governance activities. As can be seen from Figure 4 individuals with (H) holism type system thinking can apply a holistic perspective in designing system governance.

This is not meant to criticise the (R) reductionist system thinkers but only to focus attention on the necessity of using holistic language to see the big picture for better design, analysis, and development of governance for complex systems. The set of
systems thinking characteristics will support better understanding of the individual capacity to effectively engage in governance activities that cross different domains such as transportation, military, energy, industry and others.

In reviewing the literature, it was found that the trend is toward the development of system governance. Some studies focused on the definitions of system governance; others focused on the development of methodologies. However, there are no current studies related to individuals who engage governance activities. This paper focuses on the assessment of an individual’s capacity to deal with critical governance issues. At a fundamental level, an effective response to the system governance issues correlates closely to effectiveness in systems thinking. In responding, a set of systems thinking characteristics has been proposed based on research gathered for a dissertation.

The primary contribution of the set of systems thinking characteristics is to serve as a ‘point of reference’ to start a dialog that might be helpful for future development and improvement of system governance. This dialog is necessary to consolidate and move the field forward. In conclusion, the set of systems thinking characteristics and the underlying dialog that might serve to advance the domain of system governance should include:

1. **Holistic thinking approach**

   The emphasis is on the need of approaching complex systems from a holistic perspective for better design, analysis, and development of system governance. The issues of system governance would be well served if a holistic view was applied.

2. **Assessment of the individual capacity for systems thinking**

   The emphasis should be on the potential to assess the current state of systems thinking capacity of individuals. This assessment capability represents a first step in more effectively designing for governance in complex systems.

Hopefully this paper has achieved the intended purpose of starting a richer dialog for system governance as it continuous to develop. In particular, the set of systems thinking characteristics are suggested to develop and improve the current state of system governance. Important areas of future research include the development of tools and methods to support system governance activities. Specifically the development of methods that is capable of addressing the complexity, interconnectivity, and uncertainty nature of complex system. Research activities should also focus on applying the holistic paradigm to the governance of complex systems for better decisions and actions.

**References**


Complex system governance requires systems thinking


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