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Challenges for Developing Complex System Governance

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Abstract

This paper examines the challenges and practice implications for Complex System Governance (CSG). CSG is presented as an emerging field focused on the *design, execution, and evolution of the higher order (metasystem) functions necessary to provide control, communication, coordination, and integration of a complex system.* This paper is focused on three primary objectives. First, we introduce the complex system problem domain that the CSG field is being designed to address. The pervasiveness of this problem domain is demonstrated by a short examination of the water utilities sector. Second, we expound the nature of CSG and an emerging reference model that defines the functions of CSG. These functions must be performed by any system that maintains viability (continued existence). The CSG reference model rests on the underlying conceptual foundations built from Systems Theory (axioms and propositions governing system integration and coordination) and Management Cybernetics (communication and control for effective system organization). Third, we explore the particular challenges that must be addressed if the potential of the emerging CSG field is to be realized. The paper concludes by suggesting the potential that the CSG field brings for enhancing practitioner capabilities to more effectively deal with complex systems and their associated problems.

Keywords
Complex System Governance, Management Cybernetics

1. Introduction

The problems facing practitioners dealing with modern complex systems appear to be intractable. These problems continue to proliferate into all aspects of human endeavor and the systems designed to orchestrate those endeavors. They are not the privilege, or curse, of any particular field or sector (energy, utilities, healthcare, transportation, commerce, defense, security, services), as none are immune to the effects of this problem domain. Problems stemming from this domain do not have a precise cause – effect relationship that would make understanding and resolution easy or reducible to the precision demanded by mathematical applications. Instead, they are consistent with the notion of Ackoff's [1] 'messes' (interrelated sets of problems that are not well formulated, understood, or easily resolved) as well as Rittel and Webber's [2] 'wicked problems' (problems that are intractable with current levels of thinking, decision, action, and interpretation). This problem domain is likely to continue as we continue to grapple with 21st century complex systems and their associated problems.

Arguably, complex systems and their associated problems have been in existence as long as man has been designing, operating, and maintaining systems. However, the landscape for modern systems has changed appreciably into a much more 'complex problem space'. This problem space (Figure 1) is marked by difficulties encountered across the holistic range of technical, organizational, managerial, human, social, information, political, and policy issues. The different aspects of this 'new normal' complex problem space has been previously established [3-7] as being characterized by conditions identified in Figure 1. To practitioners of complex systems this listing is likely recognizable and represents nothing that is not, or has not been, faced.

Figure 1. The complex system problem domain characteristics.

However, while this listing is not presented as exhaustive, it illustrates two important points. First, the issues emanating from this domain continue without consistent resolution methods. Thus, there is certainly room for new thinking and derivative approaches to address this domain. Second, the conditions identified are not likely to recede in the future. In essence, this domain represents the 'new normal' for the practitioners dealing with complex systems. As a summary of this domain, we suggest that it is marked by the following characteristics:

- ***Uncertainty*** - incomplete knowledge casting doubt for decision/action consequences
- ***Ambiguity*** - lack of clarity in interpretation
- ***Emergence*** - unpredictable events and system behaviors
- ***Complexity*** - systems so intricate that complete understanding is not possible
- ***Interdependence*** - mutual influence among related elements

These conditions are not going away. To ignore them is shortsighted, leaving practitioners (owners, operators, performers, designers) of systems in a precarious position. These conditions are certainly not isolated for complex systems of any particular system or sector but are rather endemic to complex systems in general. As an illustrative example, we can examine the water utilities sector to demonstrate the pervasive nature of the complex system problem domain. Figure 2 is a compilation of challenges facing the water utilities sector compiled from several sources [7-9]. As evident from the circumstances marking the water utilities sector, we can certainly extrapolate those to the complex system problem domain we have established (Figure 1). In addition, we can also project the majority to a wider array of enterprises, sectors, and systems facing similar circumstances.

Effectiveness in dealing with these problem domains beckons for individuals and organizations capable of engaging in a different level of thinking, decision, action, and interpretation to produce alternative paths forward. As one response, CSG is proposed as an emerging field to enable practitioners to build capabilities to better diagnose and effectively respond to deeper level systemic issues that impede system performance. Thus, CSG seeks to identify and 'design through' fundamental system issues such as those identified earlier (Figure 1). Unfortunately, these issues exist at deep tacit levels and appear only as symptomatic at the surface. Thus, efforts to address the problems at the surface level, although providing temporary 'fixes', continually fail to resolve the deeper fundamental system issues. This deeper fundamental system level resolution is necessary to preclude recurrence of the symptomatic issue in another superficial form. Exploration and insight at this deep system level is where CSG is targeted to operate.

Figure 2. Challenges facing the water utilities sector.

The purpose of this paper is to examine the challenges and practice implications for Complex System Governance (CSG). To fulfill this purpose, CSG is developed against the backdrop of the complex system problem domain established above. The remainder of the paper is organized to:

1. Provide a brief overview of the emerging CSG field, focusing on the responsiveness of this field to enhance effectiveness in dealing with the problems of complex systems.
2. Examine the challenges that must be faced to secure the potential gains offered by the emerging CSG field.
3. Explore the potential of the CSG field for improving practitioner capabilities to more effectively engage the complex system problem domain.

2. The Emerging Field of CSG

At first glance, the situation for dealing with complex systems and their constituent problems appears bleak. However, CSG is developing as a conceptually grounded field that can provide insights and a fruitful path forward. In this section we develop a detailed explanation of CSG as *"Design, execution, and evolution of the metasystem functions necessary to provide control, communication, coordination, and integration of a complex system."* [5, p. 274]. The conceptual foundations of CSG are primarily based in Systems Theory [10-13] and Management Cybernetics [14-16] and the field has been built upon their philosophical, theoretical, and methodological underpinnings. Systems Theory has been described as a set of axioms and propositions that define the function of any system [10] while Management Cybernetics has been identified as the science of effective organization [16]. Following from the conceptual underpinnings of Systems Theory and Management Cybernetics, the following elements of the CSG definition are elaborated as an essential foundation:

- ***Design*** – purposeful and deliberate arrangement of the governance system to achieve desirable performance and behavior.
- ***Execution*** – performance of the system design within the unique system context, subject to emergent conditions stemming from interactions within the system and between the system and environment.
- ***Evolution*** – the change of the governance system in response to internal and external shifts as well as revised trajectory.
- ***Metasystem*** – the set of nine interrelated higher level functions that provide for governance of a complex system.
- ***Control*** – invoking the minimal constraints necessary to ensure desirable levels of performance and maintenance of system trajectory, in the midst of internally or externally generated perturbations of the system.
- ***Communication*** – the flow and processing of information within and external to the system, that provides for consistency in decisions, actions, and interpretations made with respect to the system.
- ***Coordination*** – providing for interactions (relationships) between constituent entities within the system, and between the system and external entities, such that unnecessary instabilities are avoided.
- ***Integration*** – continuous maintenance of system integrity. This requires a dynamic balance between autonomy of constituent entities and the interdependence of those entities to form a coherent whole. This interdependence produces the system identity (uniqueness) that exists beyond the identities of the individual constituents.
- ***Complex system*** – a set of bounded interdependent entities forming a whole in pursuit of a common purpose to produce value beyond that which individual entities are capable.

Instrumental to the formulation of CSG is the unique role of the 'metasystem'. The metasystem construct brings several important considerations for the CSG paradigm development, including: (1) the metasystem operates at a logical level beyond the elements that it must integrate, (2) the metasystem construct has been conceptually grounded in the foundations of systems theory and management cybernetics, (3) a metasystem is a set of interrelated functions – which only specify *'what'* must be achieved for continuing system viability (existence), not *'how'* those functions are to be achieved, (4) the metasystem functions must be performed if a system is to remain viable – this does not preclude the possibility that a system may be poorly performing, yet still continue to be viable (exist), and (5) a metasystem can be purposefully designed, executed, and maintained, or left to its own (self-organizing) development. Thus, the metasystem is the cornerstone for CSG.

There is no one right answer with respect to metasystem design and development, just the level of system performance that either meets desired expectations or falls short. In addition, the metasystem functions are enacted through mechanisms, or devices that permit performance of the particular functions (e.g. a requirements board). These mechanisms must also be compatible with the context and supporting infrastructure within which the metasystem is embedded. Figure 3 identifies the primary organization of the CSG paradigm, including the central role of the metasystem.

The CSG paradigm can be stated succinctly as:

> *From a systems theoretic conceptual foundation, a set of nine interrelated functions is enacted through mechanisms. These mechanisms invoke metasystem governance to produce the communication, control, coordination, and integration essential to ensure continued system viability.*

In effect, this CSG paradigm provides the essence of the derivative methodologies (general frameworks to guide development), models (particular representations for articulation of governing systems), and tools/techniques (specific implements or methods that inform practice). The CSG paradigm, and the theoretical underpinnings upon which it is based, provide the foundations for the development of implementing methodologies, models, and tools/techniques. Ultimately, the objective is to improve the practice and practitioner capabilities for dealing with complex systems.

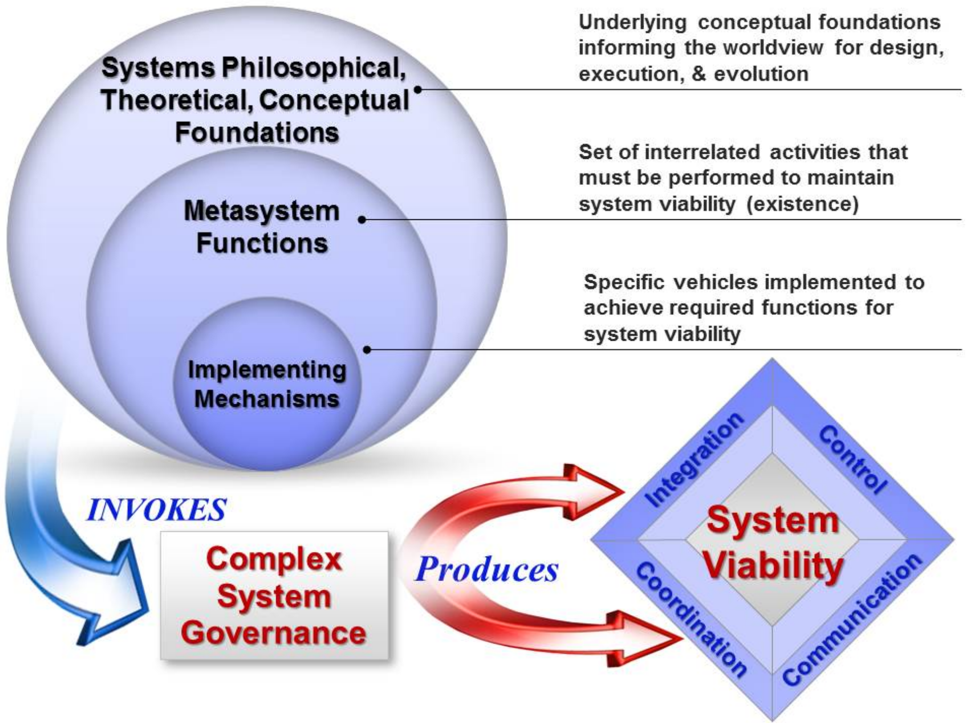

Figure 3. The CSG paradigm.

Critical to understanding the metasystem is the particular positioning of the metasystem in relationship to the environment, context, and system of interest (Figure 4). The following descriptions are provided to focus our discussion:

- ***Environment***: The aggregate of all surroundings and conditions within which a system operates. It influences and is influenced by a system.
- ***Context***: The circumstances, factors, patterns, conditions, or trends within which a system is embedded. The context acts to constrain or enable the system, including its development, execution, and evolution.
- ***System(s)***: The set of interrelated elements that are subject to immutable system laws and are governed through the metasystem functions to produce that which is of value and consumed external to the system.
- ***Metasystem***: The set of nine functions, that are invoked through mechanisms, to govern a system such that viability (existence) is maintained

There are several important points concerning the relationship of these four elements (environment, context, metasystem, system). First, the metasystem, system, and context are embedded in the larger environment. This implies that separation can only occur through a process of *'abstraction'*. The process of abstraction is essential for analysis, but also carries the inevitability of abstraction errors. There is no perfect abstraction, which results in all abstractions having some level of error. Care must be taken to account for the choices (assumptions, judgments) made for abstraction. Second, the metasystem exists as *meta* (beyond/above) to the system(s) that it seeks to govern. While it serves the objective of purposeful analysis and development, the metasystem simply imposes a viewpoint to examine the interconnected mechanisms that perform the functions necessary for integration, coordination, communication, and control for the system. Therefore, the metasystem is a construct that allows for insightful analysis of a complex system by consideration of the mechanisms that perform essential functions. Therefore, the metasystem is *'a'* construct not *'the'* only construct that can provide understanding of the function of a complex system. Third, the system is separated from the environment by the system boundary. The system boundary is established by the criteria that define inclusion and exclusion with respect to what constitutes the system. Although the boundary is imposed for purposes of analysis, care must be taken to be conscious of both the initial establishment as well as shifts in the boundary conditions over time. The establishment of boundary conditions requires a value judgment based on interpretation. Fourth, the system and metasystem are embedded within the context. In essence, the context acknowledges conditions that are more closely coupled to the system/metasystem than those in the environment (e.g. system leadership style).

The separation of the environment, context, system, and metasystem is for convenience and permits analysis. In reality, these four elements exist as an inseparable whole. The separation of these elements always requires judgments. Judgments of boundaries, relevant aspects of the environment, contextual definition, and articulation of the metasystem are always subject to 'abstraction error'. Therefore, CSG requires purposeful decisions with respect to abstraction of the context, system(s), and metasystem from the environment (Figure 4).

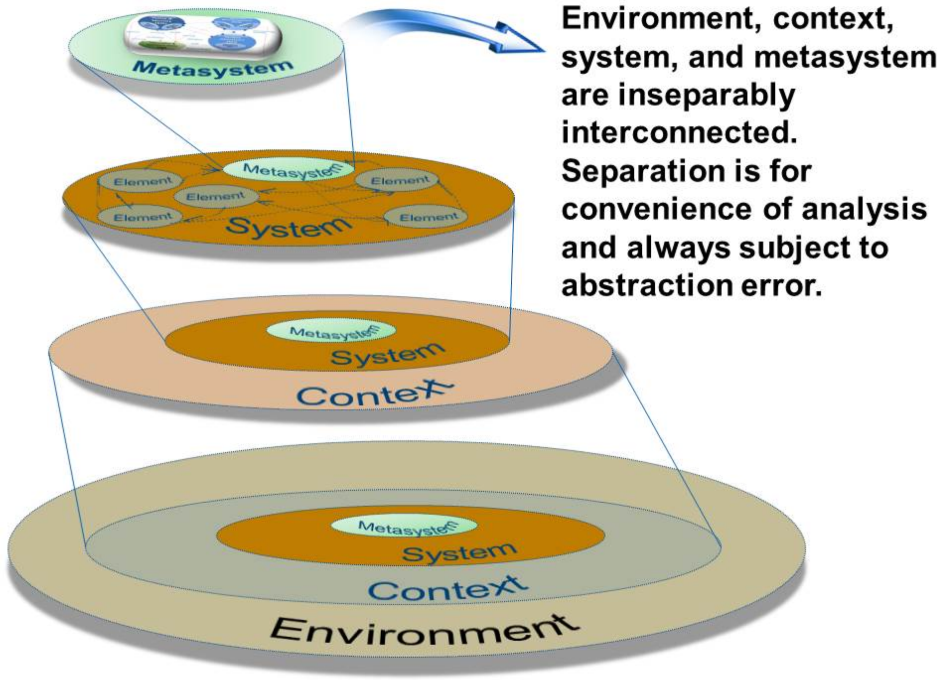

Figure 4. Interconnected elements of environment, context, system, and metasystem.

The fundamental foundation for CSG is found in Systems Theory [11-13] and Management Cybernetics [14-16], including the philosophical, theoretical, and conceptual underpinnings that serve as a grounding for the field. The metasystem is a construct that defines the set of nine interrelated functions that act to provide governance for a complex system (Figure 5).

The nine metasystem functions included in the metasystem for CSG, include:

1. ***Policy and Identity*** – Metasystem Five (M5) – focused on overall steering and trajectory for the system. Maintains identity and defines the balance between current and future focus.
2. ***System Context*** – Metasystem Five Star (M5*) – focused on the specific context within which the metasystem is embedded. Context is the set of circumstances, factors, conditions, patterns, or trends that enable or constrain execution of the system.
3. ***Strategic System Monitoring*** – Metasystem Five Prime (M5') – focused on oversight of the system performance indicators at a strategic level, identifying performance that exceeds or fails to meet established expectations.
4. ***System Development*** – Metasystem Four (M4) – maintains the models of the current and future system, concentrating on the long range development of the system to ensure future viability.
5. ***Learning and Transformation*** –Metasystem Four Star (M4*) – focused on facilitation of learning based on correction of design errors in the metasystem functions and planning for transformation of the metasystem.

6. ***Environmental Scanning*** – Metasystem Four Prime (M4') – designs, deploys, and monitors sensing of the environment for trends, patterns, or events with implications for both present and future system viability.
7. ***System Operations*** – Metasystem Three (M3) – focused on the day to day execution of the metasystem to ensure that the overall system maintains established performance levels.
8. ***Operational Performance*** – Metasystem Three Star (M3*) – monitors system performance to identify and assess aberrant conditions, exceeded thresholds, or anomalies.
9. ***Information and Communications*** – Metasystem Two (M2) – designs, establishes, and maintains the flow of information and consistent interpretation of exchanges (through communication channels) necessary to execute metasystem functions.

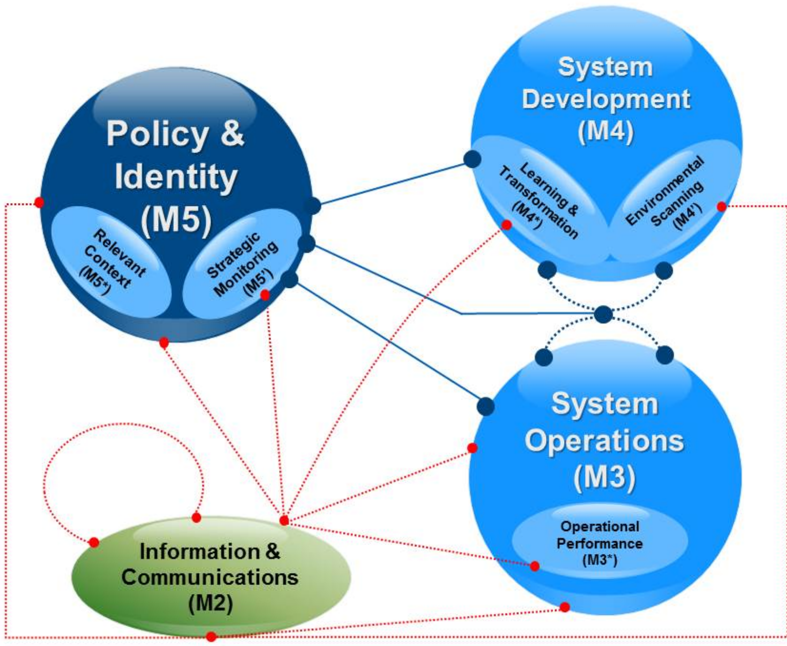

Figure 5. The nine interrelated functions of the metasystem in CSG.

Implementing mechanisms is the final element that forms a CSG triad (Figure 6), complementing *Conceptual Foundations* and *Metasystem Functions*. Conceptual Foundations help to explain and understand *'why'* systems behave and perform as they do, drawing from the laws and principles of Systems Theory and Management Cybernetics. These laws and principles are immutable and cannot be negotiated away or ignored as if they do not exist. The consequences for violation of the laws are real, carry significant impacts, and are influential in the maintenance of system viability. Ignorance of systems laws will not lessen either their existence or the consequences stemming from their violation. Systems laws and principles operate much as physical principles (e.g. the laws of physics). The laws and principles are: (1) omnipresent in explanation of system behavior, (2) cannot be selectively applied or endorsed when convenient, (3) not subject to value judgments regarding applicability, and (4) the principles are value free – meaning that attribution of goodness/badness of the consequences for the performance or nonperformance of a system in accordance with the principles comes from interpretation of the consequence, not the law itself.

The Metasystem Functions identify *'what'* must be achieved to ensure continued system viability. <u>ALL</u> systems must perform these functions at a minimal level to maintain viability. However, viability is not a 'guarantee' of performance excellence. On the contrary, all viability assures is that the system continues to exist. There are degrees of viability, the minimal of which is existence. Implementing mechanisms are the specific vehicles (e.g. processes, procedures, activities, practices, plans, artifacts, values/beliefs, customs, mores) that advance metasystem governance functions for a specific system of interest. These mechanisms may be explicit/tacit, formal/informal, routine/non-routine, effective/ineffective, or rational/irrational. However, all mechanisms can be articulated in relationship to the metasystem governance functions they support.

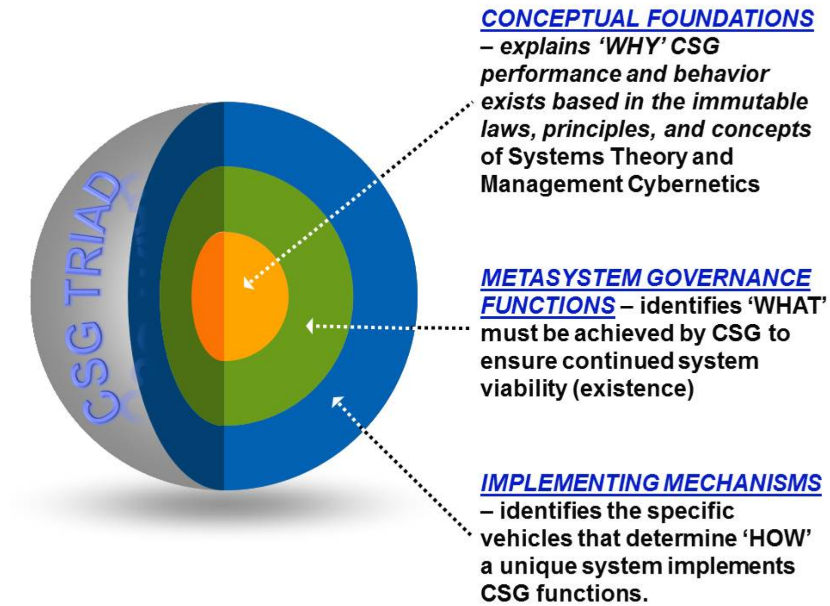

Figure 6. Triad of the CSG Paradigm.

3. Challenges for Developing the CSG Field

CSG is an emerging field with great potential. Therefore, we must certainly expect challenges, additions, extensions and insights as the field continues to evolve through research, development, and application. As the CSG field continues to evolve, the following significant directions for development are suggested. These are consistent with earlier works suggesting development of CSG [4,5,17,18].

- *Holistic field development and application* – continued development of CSG will be well served by research and practice being simultaneously developed. Research must be directed at pursuit of advances across the spectrum of *Philosophical* (worldviews), *Theoretical* (explanations concerning phenomena), *Methodological* (high level guiding frameworks), *Axiologic* (values, value judgments, and beliefs), and *Axiomatic* (underlying principles). Enhanced practice will be the beneficiary of this holistic development of the field. It is shortsighted to only focus on either research or practice exclusively.
- *Focus on Both Practice and Practitioners* – the CSG field should not lose sight of the drive to improve practice and enhance the capabilities of practitioners to deal more effectively with complex systems and their problems. CSG field development should include the need for *methods, tools, and techniques* necessary to support *applications*. However, the need to develop practitioners to effectively engage these methods, tools, and techniques from a 'systems worldview' should also be a primary concern.
- *Emphasis on sustainable field development* – development of the CSG field should focus on long term evolutionary development. The field should not be subjected to a 'faddish' development. Care must be taken such that the field does not create expectations that are unrealistic for the current stage of development. Unrealistic expectations at best will cause disappointment amid initial fanfare. This will either result in the field being minimized at best, or suffering an early demise at worst.
- *Maintenance of theoretical grounding for field sustainability* – if CSG is to maintain coherence in continued development, it will be necessary to ground the field in a strong conceptual base. For CSG this involves development around Systems Theory, Governance, and Management Cybernetics. However, there should be no hesitation to pursue ancillary fields that might provide insights to the further development of CSG as a multidisciplinary endeavor.

CSG development, as with any emerging field, will not be without challenges and issues. However, purposeful development of the field will certainly accelerate the path of development. While the CSG field is certainly not portrayed as a panacea that can cure all of the ills of modern complex systems or produce renaissance practitioners, it offers a different systems-based approach to improve complex systems. Additionally, CSG offers practitioners an additional set of capabilities to more effectively enhance practices related to complex systems.

4. Conclusion

Ultimately, CSG offers significant advances to assist practitioners in address increasingly complex and troublesome systems. Even though CSG is yet another systems-based approach to dealing with complexity in systems, it does offer some distinct advantages. Although it is distinct, it also offers compatibility to other existing systems-based approaches. This is particularly the case with respect to the detailed front end framing of the complex system of interest and the associated problems for that system. The following benefits may accrue from further development of CSG and deployment in operational settings.

- ***Enhance capacity*** of individual practitioners to engage in the level of systems thinking necessary to more effectively deal with the range of modern complex system problems. These problems are a byproduct of the current state of enterprises and their systems. Increased effectiveness can be achieved through development and propagation of CSG language, methods, and tools to assist practitioners in their efforts to design, analyze, execute, and evolve complex systems and their associated problems.
- ***Develop competencies*** at the organizational level for dealing with complex systems and their derivative problems. This involves generation of knowledge, development of skills, and fostering abilities beyond the individual level to embrace problems holistically. For CSG, holism suggests competency development that expands beyond narrow technology centric infusions. Instead, enhanced competencies that span the entire range of sociotechnical considerations endemic to complex systems are a potential outcome from a CSG engagement. Thus, CSG can be a catalyst to propagate systemic development to the myriad of processes, procedures, and practices that drive decision, actions, and interpretations in an enterprise on a daily basis.
- ***Understand infrastructure compatibility*** necessary to support systems based endeavors. This compatibility is necessary to formulate contextually consistent approaches to problems, create conditions necessary for governance system stability, and produce coherent decisions, actions, and interpretations at the individual and organizational levels. The most exceptional system solutions, absent compatible supporting infrastructure, are destined to outright fail in the worst case scenario and underachieve in the best case scenario.
- ***Governance Effectiveness Level Identification*** can be useful in determining the initial state of governance performance. In addition, this set of 'unique' indicators for a system can provide a baseline that can be used to longitudinally establish the continuous progression of governance improvement. In effect, the degree of improvement stemming from initiatives undertaken to improve CSG can be established. Therefore, the state and shifts in governance can be recognized and monitored.
- ***Explicit Models for Understanding*** generated through CSG efforts can provide insights into the structural relationships, context, and systemic deficiencies that exist for a system of interest. These insights can accrue regardless of whether or not specific actions to address issues are initiated. The models can be constructed without system modification. Therefore, alternative decisions, actions, and interpretations can be selectively engaged based on consideration of insights and understanding generated through modeling efforts.
- ***Purposeful Governance Development*** through focused design, analysis, and evolution of the CSG functions necessary to maintain system viability. While all viable (existing) systems perform the CSG functions, it is rare that they are purposefully articulated, examined, or developed in a comprehensive manner. Purposeful CSG development can produce a 'blueprint' against which development can be achieved by design, rather than serendipity. This includes establishment of the set of 'dashboard indicators' for CSG performance. These performance indicators exist beyond more 'traditional' measures of system/organizational performance.
- ***Coherent Decision Support*** can be achieved by the 'big picture' view of the governance landscape. This includes identification of highest leverage strategic impact areas and their interrelationship to the larger CSG performance gaps. Thus, decisions for resource allocation can be better targeted. This allows steering away from activities that are simply 'intriguing' without demonstrating the highest substantial benefit to the larger 'systemic' governance concerns. In light of CSG development priorities, low contribution efforts can be eliminated, or resources shifted appropriately.

- ***Rigorous Guided 'Self-Study'*** into CSG can provide significant insights into how the system actually functions. Although enterprises and their systems function routinely and successfully on a daily basis, as a matter of course practitioners are not particularly skilled, nor do they engage in deep reflection as to why, how, and what they do from a systems point of view. The gains to be made by reflective self-examination, from a systemic point of view, can reveal insights far beyond traditional methods of examination (e.g. Strategic Planning, SWOT analysis, etc.). Thus, practitioners can examine a different level of analysis through 'self-study' and experience insights in a 'safe-to-fail' setting. Additionally, self-study might suggest the level of education/training that might be necessary for individuals and the organization to increase individual capacity, organizational competence, and infrastructure compatibility to support enhanced CSG and the systems thinking necessary for its engagement.

Therefore, the essence of the emerging CSG field is focused on improving the ability of practitioners to more effectively deal with the complex system problem domain. Through development of conceptually grounded tools, methods, and techniques, CSG has the potential to significantly improve capabilities for practitioners (owners, operators, performers, designers) of complex systems.

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