Asset Management, Complex System Governance

Subjects: Economics

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Asset management (AsM) has emerged from engineering as a structured approach to organizing complex organizations to realize the value of assets while balancing performance, risks, costs, and opportunities. Complex system governance (CSG) is an emerging field encompassing a framework for system performance improvement through the purposeful design, execution, and evolution of essential metasystem functions.

Keywords: asset management ; complex system governance ; system viability

1. Asset Management

The concepts of AsM are unique to nuclear power plants and transportation systems. AsM concepts are found in petrochemicals [1][2], power generation, transmission and distribution [3], and infrastructure management [4]. Therefore, AsM concepts permeate routine organizational activities, including finance, planning, engineering, personnel, and information management to assist agencies in managing assets cost-effectively [5]. Again, this resonates, given that the aim of AsM is not “asset care” but rather “management of assets.” Moreover, Nemmers [6] suggests that asset management’s main objective is to improve decision-making processes to ensure the “best” possible return on investment is obtained. However, the term “best” possible return is a relative tern due to the asset systems’ complexity, environment, and interplay.

Nonetheless, to achieve the objective of improved decision-making to maximize return on investment, AsM must embrace all of the processes, tools, and data required to manage assets effectively [6]. Thus, frameworks for effective utilization of resources are needed. Furthermore, such frameworks must effectively carry out this process, encompassing the entire organization, environment, and interplay. An example of such a framework is the risk-informed decision-making (RIDM) model in asset management. RIDM is a structured and rational decision-making methodology in AsM. As a methodology, RIDM contains three key phases (see **Figure 1**): (i) setting the framework, (ii) performing detailed analyses, and (iii) conducting global analysis, deliberation, decision-making, communication, and implementation:

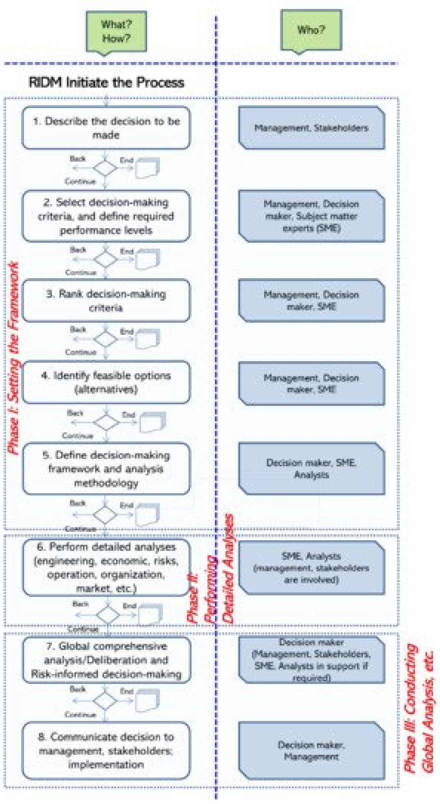

Figure 1. A summary of RIDM framework, modified from Komljenovic et al. [7] (p. 205).

- Setting the framework—this phase ensures an adequate description of asset issues, context, alternatives, decisions, and potential methodologies. Setting the framework is comparable to 'problem formulation' and related to the overall system success. This phase is often referred to as "probably the single most important routine, since it determines in large part…the subsequent course of action" [8] (p. 274).

- Performing detailed analyses—this phase involves performing required detailed analyses and is often carried out by subject matter experts (SME) and analysts using appropriate methods, models, and tools suggested and defined in the first phase. This phase aims to produce results, inputs, and insights and formulate recommendations for the decision-maker. These analyses have to be rigorous and systematic as well as being technically and scientifically sound.

- Conducting global analysis, deliberation, decision-making, communication, and implementation—performed by the decision-maker and supported by SMEs, analysts, and stakeholders. This phase is qualitative and aims to grasp all relevant insights, high-level analysis, and deliberation results. Decision makers have to make extensive use of various quantitative analyses methods with the level of details appropriate for the decision to be made and integrated with other relevant influence factors, often intangible and intangible.

Once deliberations are completed and decisions are made, it is necessary to ensure that the organization has the resources needed for implementation. Thus, with the main elements of the RIDM in AsM defined, an enhanced decision-making framework emerges.

2. CSG: Complex System Governance

Complex system governance (CSG) is an emerging field, representing an approach to improving system performance through the purposeful design, execution, and evolution of nine essential metasystem functions that provide for the control, communication, coordination, and integration of a complex system. CSG was developed at the National Centers for System of Systems Engineering and is anchored in General Systems Theory and Management Cybernetics. It emphasizes the effective performance of metasystem functions necessary to maintain system viability (see, e.g., [9][10]). A methodology, according to Jackson [11], is a set of "procedures for gaining knowledge about a system and structured processes involved in intervening in and changing systems" (p. 134). Interestingly, there is no shortage of methodological approaches used to explore and gain knowledge about systems. **Table 1** provides a summary of systems-based methodologies. Interested readers are directed to Jackson [12] and Katina [13] for more extensive discussions. However, suffice to say that selection and use of a specific methodological approach will depend on the nature of the problem and system at hand as well as the purpose of the analysis [14]). Moreover, issues of ontology and epistemology should not be ignored, especially when dealing with complex situations [15].

Table 1. Systems-based methodologies.

Methodology	A Brief Description of Methodology
Systems analysis	This methodology is largely dependent on feedback loops and black boxes of cybernetic management. It aims to optimize sociotechnical systems based on fixed parameters such as cost and benefits. Systems analysis includes a number of phases discussed elsewhere [16][17].
Systems engineering	This approach places emphasis on defining technical and business customer needs with the goal of producing quality products that meet user needs. A generic life-cycle model for systems engineering along with its stages is discussed elsewhere [18][19].
Operations research	This approach is commonly associated with determining maximum (or minimum) variable (e.g., profit, performance, yield, loss, risk) inventory, allocating, waiting time, replacement, competitive, and combined processes. Operations research was developed to deal with complex organizations that are under the control of management [20][21]. A generic model associated with this approach is discussed elsewhere [20][21].
System dynamics	System dynamics is concerned with limits of growth and understanding of the system structure using feedback loops as the main determinants of system behavior. Mathematical in nature, system dynamics involves four major variables: the system boundary, network of feedback loops, variables of 'rates' or 'flows' and 'levels' or 'stocks', and leverage points [22][23].
Organizational cybernetics	Organizational cybernetics embodies the idea that organizations are black boxes characterized by complexity, self-regulation, and probabilistic behaviors. Central to this approach is the viable system model, which is based on the neurocybernetic model, consisting of five essential subsystems that are aligned with major viable organizational functions. The viable system model [24] is a model rather than a methodology as it does not have a clear set of prescribed phases for deployment. However, two general stages of system identification and system diagnosis are discussed elsewhere [12].

Methodology	A Brief Description of Methodology
Strategic assumption surfacing and testing	**This approach is grounded on the premise that the formulation of the correct solutions to the right problem requires uncovering critical assumptions underlying policy, plan, and strategy. The articulation of critical assumptions should enable management to compare and contrast and gain new insights on their assumptions when dealing with a 'wicked' situation [25].**
Interactive planning	**Developed by Russell L. Ackoff, this methodology focuses on creating a desired future by designing present desirable conditions. It is made up two parts: idealization and realization. These parts are divisible into six interrelated phases [26].**
Soft systems methodology	**Attributed to Peter Checkland and his colleges at Lancaster University, this methodology emerged as a response to a need for methods that can be used to intervene in 'ill-structured' problem situations where it is important to learn about systems while still focusing on 'goal-seeking' endeavors that answer 'what' should be done and 'how' it should be done [12]. Checkland [27] suggests that understanding context was largely ignored in systems engineering. His research was aimed at providing a more rigorous attempt to tackle problematic situations through addressing issues such as context.**
Systems of systems engineering methodology	**This methodology is intended to provide a high-level analytical structure to explore complex system problems [28]. Proponents of this approach suggest that enhancing our understanding of complex systems requires a "rigorous engineering analysis [System of Systems Engineering Methodology] that invests heavily in the understanding and framing of the problem under study" [28] (p. 113). In the research of DeLaurentis et al. [29], a three-phase approach (i.e., defining the SoS problem, abstracting the system, modeling and analyzing the system for behavioral patterns) is suggested. However, Adams and Keating [28] and Adams and Meyers [30] suggest a seven (7)-stage process, which consists of twenty-three (23) constituent elements.**
Critical systems heuristics	**Developed by Werner Ulrich, this methodology is concerned with 'unfairness in society' [12]. This approach promotes emancipatory systems thinking for planners and citizens alike. Synonymous with this methodology are three phases [31].**
Organizational learning	**Developed by Chris Argyris and Donald Schön, this methodology is concerned with single-loop and double-loop learning where management of the organization can contrast 'expected outcomes' with the 'obtained outcomes'. Contrasting these outcomes involves learning based on errors discovered during single-loop learning and provides the basis for modifying organizational norms, policies, and objectives [32]. A key premise of this methodology is that learning and adapting new knowledge must be generated at the individual as well as at organizational levels [33][34].**
Sociotechnical systems	**Attributed to Eric Trist, Ken Bamforth, and Fred Emery and their work at the Tavistock Institute in London, this methodology is concerned with a joint optimization of both social/soft (including human) and technical aspects of organizations [35]. This methodology involves several steps as postulated by Pasmore [35] for redesigning sociotechnical systems [36].**
Total systems intervention	**Developed in the early 1990s by Robert Flood and Michael Jackson, this meta-methodology emerged out of the recognition of strengths of capabilities of individual systems approaches, the need for pluralism in systems thinking, and calls for emancipatory ideas in systems thinking, in reference to critical systems thinking [12]. This methodology is based on the premise that contemporary systems-based methodologies are not complementary. Laszlo and Krippner [37] thus suggested that a successful complex organizational intervention might require a 'combination' of any set of systems-based approaches. This methodology is underpinned by principles of complex situations and consists of three phases of creativity, choice, and implementation [38][39].**

As a field, CSG has been described as the "design, execution, and evolution of the metasystem functions necessary to provide control, communication, coordination, and integration of a complex system" [9] (p. 264). This emerging field has its foundations in GST's aspect of laws, principles, and theorems used for understanding the structure, behavior, and performance of complex systems [40][41][42] and management cybernetics, which has been described as the science of effective organization [24][43][44][45]. Keating and Bradley [46] provided "a systemic representation [a reference mode] of CSG, built upon the intellectual foundations of systems theory and management cybernetics. The purpose of the reference model is to provide an organizing construct for the interrelated functions necessary to perform CSG" (p. 41).

There are four elements of CSG. The first element essential to understanding CSG is the metasystem construct. The metasystem construct brings several vital considerations of CSG development, including [47]:

- operating at a logical level beyond the system(s)/subsystems/entities as elements that it must integrate.
- Being conceptually grounded in the foundations of general systems theory (axioms and propositions governing system integration and coordination) and management cybernetics (communication and control for effective system organization).
- a set of interrelated functions, which only specify 'what' must be achieved for continuing system viability (existence), not specifying 'how' those functions are to be achieved

- functions that must be minimally 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).

- a system that is purposefully designed, executed, and maintained, or left to its own (self-organizing) unstructured development

The importance of the metasystem is its function as a ‘governor’ in the cybernetic sense of providing control for a system —ensuring the system maintains stability (performance) in the midst of internal system flux and environmental turbulence. In essence, *the primary function of control by the metasystem in CSG is to provide the minimal constraint necessary to ensure continued system performance and behavior.* In this sense of control, the maximum level of autonomy is reserved for the ‘governed’ systems/subsystems. This is achieved by only implementing the (minimal) constraints necessary to provide sufficient stability that ensures system performance levels can be maintained. The achievement of this stability is accomplished through the metasystem’s ability to provide sufficient regulatory capacity. This regulatory capacity mitigates the turbulence generated from the environment as well as the flux generated internal to the larger system. In addition, this regulatory capacity seeks to provide the highest degree of autonomy possible to the systems/subsystems being governed. The metasystem provides only the control (constraint) necessary to integrate the entities (systems or subsystems) to support the larger purpose (performance/behavior) expected of the system. Keating et al. [9] posit that control generated by the metasystem is achieved in conjunction with three other primary roles for CSG: communication, coordination, and integration, described in **Table 2**.

Table 2. Metasystem control components with implication for AsM.

Metasystem Control Component	Component Description	Implications for AsM
Communication	The flow, transduction, and processing of information within and external to the system, which provides consistency in decisions, actions, interpretations, and knowledge creation made with respect to the system.	AsM provision for the flow, transduction, and processing of information among different assets and their environment to enable consistent decisions, actions, interpretations, and knowledge creation.
Coordination	Providing for interactions (relationships) between constituent entities within the system and between the system and external entities, such that unnecessary instabilities are avoided.	AsM provision for interactions (relationships) between constituent asset systems/subsystems within the system and between the organization and external assets such that unnecessary instabilities are avoided
Integration	Continuous maintenance of system integrity. This requires a dynamic balance between the 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.	AsM provision for continuous maintenance of system integrity. This requires a dynamic balance between the autonomy of constituent assets and the interdependence of those assets to form a coherent whole. The coherent whole produces a unique organizational identity beyond the identities of the individual assets.

The second element of CSG involves the nine governance functions of the metasystem, including four primary functions and five subfunctions. The metasystem functions find the intellectual roots in Beer’s work [24][43][44] in management cybernetics and the viable system model. These interrelated governance functions must be performed if a system is to remain viable (continue to exist) under conditions of internal flux and external turbulence. In summary, the nine metasystem functions included in the metasystem for CSG include:

- ***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. *For AsM, M5 ensures the overall maneuvering and course of the organization, ensuring a balance between current and future asset management for the organization.*

- ***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 the execution of the system. *For AsM, M5* ensures that the organization is accounting for the set of circumstances, factors, conditions, patterns, or trends that enable or constrain the utility of assets*.

- ***Strategic System Monitoring—Metasystem Five Prime (M5')***—focused on oversight of the system performance indicators at a strategic level, identifying system-level performance that exceeds or fails to meet established expectations. *For AsM, M5' ensures the oversight of the asset performance indicators at a strategic level, identifying asset system-level performance that exceeds or fails to meet established expectations*.

- ***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. *For AsM, M4 ensures that the organization maintains the models of the current and future asset systems while concentrating on the organizations' long-range developments to ensure future viability*.

- ***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 the transformation of the metasystem. *For AsM, M4* ensures that the organization has learning capabilities, especially based on correction, to enable the design and planning necessary for organizational transformation related to assets*.

- ***Environmental Scanning—Metasystem Four Prime (M4′)***—designs, deploys, and monitors the sensing of the environment for trends, patterns, or events with implications for both present and future system viability. For AsM, M4′ ensures that the asset management organization designs, deploys, and monitors the sensing of the environment for trends, patterns, or events with implications for both present and future system asset viability.

- ***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. *For AsM, M3 ensures that the organization has the means to address the day-to-day asset management activities to meet the established performance levels.*

- **Operational Performance—Metasystem Three Star (M3*)**—monitors system performance to identify and assess aberrant conditions, exceeded thresholds, or anomalies. For AsM, M3* ensures that the organization can monitor asset system performance to identify and evaluate anomalous conditions, exceeded thresholds, or anomalies.

- ***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. For *AsM, M2 ensures that the organization is designed to maintain the flow of information and that consistent interpretation of exchanges (through communication channels) can be achieved*.

Figure 2 provides a graphic depiction of the interrelationship between the functions and subfunctions of the metasystem. It is important to note that the metasystem functions (i) do not operate independently and instead are interrelated functions and (ii) are performed by mechanisms (artifacts that permit achievement of the specific function) and that (iii) execution determines the level of governance effectiveness and ultimately system performance.

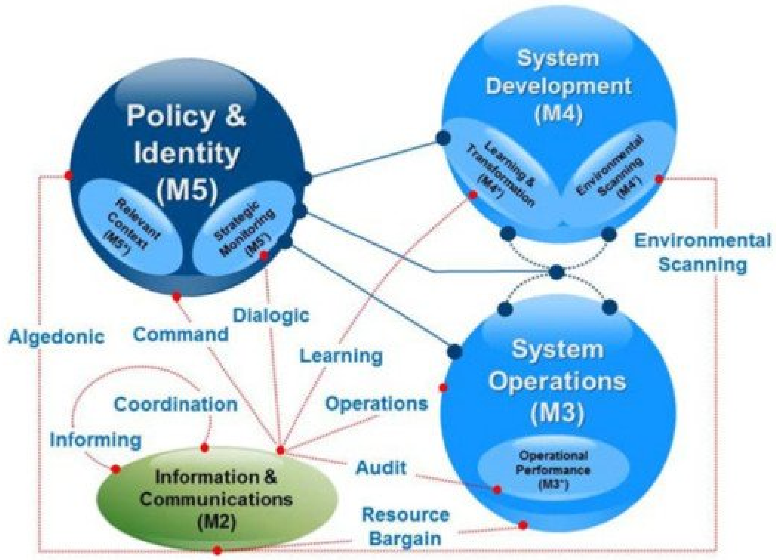

Figure 2. Interrelated metasystem functions and communication channels, adapted from Keating and Katina (2016, p. 50).

The set of communication channels that provide for the flow of information and consistency in interpretation for exchanges within the metasystem and between the metasystem and external entities form the third core element of CSG. The ten communication channels are adapted from the work of Beer [24][43][44] and extensions of Keating and Morin [48] and Keating and Katina [47]. **Table 3** provides a summary of the communication channels and their primary AsM metasystem function responsibility, and the particular role they play in AsM metasystem execution.

Table 3. Metasystem communication channels and implication for AsM.

Metasystem Communication Channels	A Brief Description of the Function of the Communication Channel in the Context of AsM
Command (Metasystem 5)	• Provides non-negotiable direction for AsM metasystem and governed asset systems. • Primarily flows from the AsM M5 and disseminated throughout the system (i.e., asset systems).
Resource bargain/ accountability (Metasystem 3)	• Determines and allocates the resources (e.g., manpower, material, money, information, support) to governed asset systems. • Defines performance levels, responsibilities, and accountability for governed asset systems. • Primarily an interface between M3 to the governed asset systems.
Operations (Metasystem 3)	• Provides for the routine interface concerned with near term operational focus. • Concentrated on providing direction for system production of value (products, services, processes, information) consumed external to the system. • Primarily an interface between M3 and governed asset systems.
Coordination (Metasystem 2)	• Provides for AsM metasystem and governed asset systems balance and stability. • Ensures design and achievement of design and execution of (1) sharing of information within the organization necessary to coordinate activities and (2) ensures the decisions and actions necessary to prevent disturbances are shared within the AsM metasystem and governed asset systems. • Primarily a channel designed and executed by M2.
Audit (Metasystem 3*)	• Provides routine and sporadic feedback concerning operational performance. • Investigation and reporting on problematic performance issues within the organization. • Primarily a M3* channel for communicating between M3 and governed asset systems concerning performance issues.
Algedonic (Metasystem 5)	• Provides a 'bypass' of all channels when the integrity of the system is threatened. • Compels an instant alert to crisis or potentially catastrophic situations for the system. • Directed to M5 from anywhere in the AsM metasystem or governed asset systems.
Environmental Scanning (Metasystem 4′)	• Provides a design for sensing of the external organizational environment. • Identifies environmental patterns, activities, trends, or events with organizational implications. • Provided for access throughout the AsM metasystem as well as governed asset systems by M4′.

Metasystem Communication Channels	A Brief Description of the Function of the Communication Channel in the Context of AsM
Dialog (Metasystem 5′)	• Provides for examination of organizational decisions, actions, and interpretations for consistency with system purpose and identity. • Directed to M5 from anywhere in the AsM metasystem or governed asset systems.
Learning (Metasystem 4*)	• Provides detection and correction of error within the AsM metasystem as well as governed asset systems, focused on system design issues as opposed to execution issues. • Directed to M4* from anywhere in the AsM metasystem or governed asset systems.
Informing (Metasystem 2)	• Provides for flow and access to routine information within the AsM metasystem or between the AsM metasystem and governed asset systems. • Access provided to the entire AsM metasystem and the governed asset systems.

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