Systems Thinking: A Critical Competency for Addressing Complex Problems

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Abstract
This paper explores Systems Thinking (ST) as a critical competency for practitioners to address problems associated with modern complex systems. At a fundamental level ST offers a particular way to view and mentally frame what we see in the world, a worldview whereby we interpret and provide meaning to that which we encounter. ST provides a precursor to making decisions and taking actions from a ‘systemic’ perspective. ST takes a holistic view to understanding of system structure, behavior, and performance as emergent properties that exist beyond those properties held by the constituent elements of the system. The capacity to engage in ST is considered central to dealing with conditions of increasing complexity, emergence, uncertainty, and ambiguity characteristic of modern systems. Our exploration of ST: (1) articulates a perspective set of ST themes and guiding propositions drawn from the literature, (2) suggests a role that ST plays for practitioners in addressing complex systems and their problems, and (3) develops of an approach, Systems Thinking Capacity (ST-Cap) for understanding and developing practitioner capacity for effectively engaging ST. The paper concludes by examining the challenges for development and implications for deployment of ST in an operational setting.

Keywords
Systems Thinking, Complex Problems, Complexity

1. Introduction

Modern systems are conceived, built, and deployed with the fundamental purpose of solving a problems or fulfilling a need for the betterment of institutions, supporting infrastructures, or society at large. Arguably, systems and their constituent problems have been around as long as man. What has changed is the complexity of systems with advances in technology, proliferation of information, and the acceleration of ‘everything’.

The new reality for practitioners in modern complex systems are faced with a very different set of circumstances than those encountered by their predecessors from previous generations of systems. The current landscape requires a constant struggle with: (1) proliferation of information intensive systems and technologies that advance to obsolesce at unprecedented rates, (2) multiple stakeholders with potentially divergent viewpoints, potentially holding politically driven agendas that exist at a tacit level, (3) scarce and dynamically shifting resources without corresponding shifts in expectations, performance demands, or schedules, (4) constantly shifting requirements and uncertainties calling into
question the stability essential to perform rigorous engineering, (5) technological advancements that outpace the
capabilities, and potential compatibility, of supporting and enabling infrastructures, (6) urgency for immediate and
responsive solutions for ‘perceived’ problems, (7) surrender of long term perspectives to deal with emerging crises –
rendering traditional forms of long range planning innocuous at best and potentially damaging at worst, (8) increasing
complexities that create hyperturbulent environments fraught with limited understanding, and (9) emergent
circumstances and factors that make stable planning and operations beyond our best current practices for planning.
These characteristics are not likely to subside for practitioners of modern complex systems. On the contrary, we can
most likely expect that they will continue to exacerbate in the near future and will likely escalate in the future. The
success of future generations of systems engineers assuming responsibilities for dealing effectively in this problem
domain will be directly tied to their ability to effectively think at a level that makes them more comfortable in this
landscape.

In short, the world of the future systems engineer is a ‘complex systems world’ – an increasingly ambiguous, uncertain,
and emergent world [1-3]. There is a need to arm future generations of systems engineers with the mindset,
capabilities, and skills that will increase the probability of success in navigating this world.

We suggest that Systems Thinking is a critical competence necessary to increase effectiveness in this world. However,
systems thinking is not the ‘silver bullet’ or ‘magic solution’, it can add to the arsenal available to practitioners of
modern complex systems as they struggle to effectively cope with the new realities they face. The purpose of this
chapter is to acquaint systems practitioners with the essence of systems thinking and suggest an emerging method to
explore systems thinking capacity. In essence, systems thinking has been captured by Haines [4, p. vi] as “A new way
to view and mentally frame what we see in the world; a worldview and way of thinking whereby we see the entity or
unit first as a whole, with its fit and relationship to its environment as primary concerns; the parts secondary.”

To explore systems thinking and assessment of capacity for systems thinking we have organized the paper around
three primary objectives:

1. Establish the nature of Systems Thinking and the foundations upon which it rests through the examination of
central themes and guiding propositions from the literature.
2. Suggest the role that Systems Thinking can play for practitioners who must engage in the complex domain
of modern systems, and
3. Examine an approach, Systems Thinking Capacity (ST-Cap) that focuses on understanding and developing
the capacity for enhancing Systems Thinking.

2. Systems Thinking Overview

Systems thinking is not new. It is also not an offering of a ‘universal solution’ that is capable of guaranteeing success
with the landscape described above. It has been since ancient times, finding roots dating to Aristotle, who suggested
that in the whole we find something not found in the parts. This was the very foundation for the primary tenet of
systems thinking, holism. Granted, there have been changes in the landscape of systems as well as advances in how
we think about systems. However, it is important to recognize the long lineage upon which systems thinking has been
built. It is instructive to examine the variety of perspectives defining Systems Thinking. Below we list a set of
representative perspectives that demonstrates a variety of viewpoints for systems thinking. This is not to suggest the
superiority of one perspective over another. Instead, this provides the breadth of thinking about systems thinking.

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<tr>
<th>Author</th>
<th>Perspective</th>
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<td>Flood &amp; Carson [5, 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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<td>Checkland [6, p. 318]</td>
<td>“makes conscious use of the particular concept of wholeness captured in the word ‘system’, to order our thoughts.”</td>
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<td>“An epistemology which, when applied to human activity is based upon the four basic ideas: emergence, hierarchy, communication, and control as characteristics</td>
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of systems. When applied to natural or designed systems the crucial characteristic is the emergent properties of the whole.”

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<td>Gharajedaghi [7, p. 15]</td>
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<td>O’Connor and McDermott [8, p. 1]</td>
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<td>Haines [4, p. vi]</td>
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<td>Senge [9, p. 89]</td>
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<td>Capra [10, p. 29]</td>
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<td>von Bertalanffy [11, p. 410]</td>
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<td>Richmond [12, p. 139]</td>
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<td>ESD Symposium Committee [13, p. 8]</td>
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<td>Davidz [14, p. 44]</td>
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<td>Ackoff [15, p.6]</td>
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There is no universally accepted definition, or perspective, of systems thinking. In fact, Lane and Jackson [16] were early to point out the variety of perspectives in the systems movement and the strength that this diversity of the field offers. We suggest that the field continues to evolve and add to diversity of perspectives. However, we can also identify several common themes that permeate the multitude of perspectives. Among these themes that form the common threads in perspectives of systems thinking are: (1) a way of thinking – a distinctly different way of viewing relationships within the whole, focusing at a different logical level to inform a different perspective, (2) holism versus reductionism – focus on understanding the whole (holism) that exhibits behavior stemming from part relationships, as opposed to a focus on understanding behavior as a simple aggregation of part behavior (reductionism), (3) interrelationships – consideration of the importance of the relationship between parts and the behavior those interactions produce, (4) patterns – understanding the particular structure of relationships as well as the behavior/performance they produce, and (5) context/environment – an appreciation that a system exist within an environment and has a particular unique context associated to the system. These common threads provide a representative set of themes for Systems Thinking.

3. The Role of Systems Thinking

A primary role of systems thinking to expand understanding and create insights not available prior to engaging in systems thinking. Additionally, we suggest that there are several interrelated roles that can be provided by Systems Thinking. We have focused on presentation of five primary roles that Systems Thinking, including:

- **Disciplined Structure and Order for Inquiry** – the application of systems thinking can be helpful in providing approaches, grounded in underlying systems principles/concepts, to conduct more effective inquiry.
Approach for Dealing with Complexity – Complexity is a fact of life for practitioners in modern systems. The approaches to deal with complexity, rooted in systems thinking, can provide practitioners increased effectiveness in addressing increasingly complex problem domains.

A Philosophy or Worldview – philosophy provides the basis for making sense of what we perceive in the world. In effect, systems thinking can provide engineering managers with increased capacity to ‘make sense’ of their circumstances and enhance the capability to mount more effective responses.

A Language to Guide Thinking and Action – The language of systems thinking can be instrumental in coming to new understanding of familiar issues. Thus, new and novel courses of action to address complex problems, both new and old, can be established.

Methods and Techniques – Systems thinking provides the basis for a host of implementing methods and techniques that can enable higher levels of inquiry, decision, and action for practitioners.

System practitioners must realize that systems thinking operates and offers value on many levels, including the 5 levels identified above. It can provide enhanced effectiveness on any or all of these levels. It is a misnomer to think of systems thinking as simply a set of tools to be used by engineering managers. To truly engage the full spectrum of systems thinking capability, an engineering manager must seek the contributions across each of these levels.

4. Systems Thinking Capacity

Systems Thinking is an essential capability for individuals and organizations that must deal with the inherent complexities of modern systems. The Systems Thinking Capacity (ST-Cap) Method is an approach that guides identification, assessment, and development of Systems Thinking for individuals and organizations. The ST-Cap Method is conducted in four primary phases (Figure 1).

**Figure 1: Phases of the Systems Thinking Capacity Method**

*Phase 1 – Identification:* This phase administers a web-based survey instrument [17] to identify the level of Systems Thinking for individuals and the composite organization. The primary objective of this phase is to provide an assessment of the current state of Systems Thinking that exist for a unit in focus. This unit can be a team, project, or entire organization. The results are an indication of where the unit lies with respect to their capacity to engage in Thinking. Jaradat’s instrument is a 39 item survey, completed by each individual in the unit. The survey examines the positioning of the individual’s propensity for Systems Thinking along a set of indicator dimensions (Table 2). The composite provides an indicator of the degree of Systems Thinking that exist in the unit.
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<tr>
<th>Systems Thinking Characteristic Level</th>
<th>Spectrum of Individual Systems Thinking Capacity</th>
<th>More Systemic</th>
<th>Less Systemic</th>
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<tr>
<td>Complexity</td>
<td><strong>COMPLEXITY (C)</strong> – Expect uncertainty, work on multidimensional problems, prefer a working solution, and explore the surrounding environment</td>
<td><strong>SIMPLICITY (S)</strong> – Avoid uncertainty, work on linear problems, prefer best solution, prefer small scale problems</td>
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<td>Autonomy</td>
<td><strong>INTEGRATION (G)</strong> – Preserve global integration, tend more to dependent decision and global performance level</td>
<td><strong>AUTONOMY (A)</strong> – Preserve local autonomy, tend more to independent decision and local performance level</td>
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<td>Interaction</td>
<td><strong>INTERCONNECTIVITY (I)</strong> – Inclined to global interactions, follow general plan, work within a team, and interested less in identifiable cause-effect relationships</td>
<td><strong>ISOLATION (N)</strong> – Inclined to local interaction, follow detailed plan, prefer to work individually, enjoy working in small systems, and interested more in cause-effect solutions</td>
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<td>Change</td>
<td><strong>RESISTANCE TO REQUIREMENTS (V)</strong> – Prefer taking multiple perspectives into consideration, underspecify requirements, focus more on external forces, like long-range plans and thinking, keep decision options open, and work best in changing environment</td>
<td><strong>EMBRACEMENT OF REQUIREMENTS (Y)</strong> – Prefer taking few perspectives into consideration, over specify requirements, focus more on the internal forces, like short-range plans and thinking, tend to lock in decisions, and work best in stable environment</td>
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<td>Uncertainty and Ambiguity</td>
<td><strong>EMERGENCE (E)</strong> – React to situations as they occur, focus on the whole, comfortable with uncertainty, believe work environment is difficult to control, enjoy subjectivity, and non-technical problems</td>
<td><strong>STABILITY (T)</strong> – Prepare detailed plans beforehand, focus on the details, uncomfortable with uncertainty, believe work environment is under control, enjoy objectivity, and technical problems</td>
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<td>Hierarchical View</td>
<td><strong>HOLISM (H)</strong> – there exist multiple, potentially divergent, perspectives on the problem domain.</td>
<td><strong>REDUCTIONISM (R)</strong> – assumes that there is alignment of perspectives for the problem domain.</td>
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<td>Flexibility</td>
<td><strong>FLEXIBILITY (F)</strong> – accommodate change, like flexible plans, open to new ideas, unmotivated by routine</td>
<td><strong>RIGIDITY (D)</strong> – prefer not to change, like determined plan, motivated by routine</td>
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**Phase 2** – *System-Environment Complexity Assessment* examines the degree of complexity in the system and environment that must be engaged by practitioners. The work of the unit in focus for the effort must take place within an environment. Establishing the nature of this environment, against the Systems Thinking Characteristics is the focus of this phase. Upon completion, the complex nature of the environment of the unit is captured in relationship to the characteristics.

**Phase 3** – *Analysis* provides a representative mapping of the gaps between the current state of Systems Thinking to that required by the environment faced by the unit. Therefore, the differential between the Systems Thinking Capacity that exist to that required can be established. In addition, the differential along the Systems Thinking characteristics provides an additional level of detail.

**Phase 4** – *ST Development* examines the implications for development of Systems Thinking in the unit. Development can be focused such that congruence with the Systems Thinking required of the environment can be pursued. This supports purposeful pursuit of development of Systems Thinking.

In essence, application of the ST-Cap Method identifies the match between the existing level of Systems Thinking in the unit and that required for dealing with the degree of environmental complexity faced by practitioners and the organization. This supports the potential for informed, purposeful, and directed development for Systems Thinking.
5. Conclusion

Systems Thinking (ST) is a way of framing how we see, interpret, and make sense of the complex world we encounter. In essence, ST is a different level of thinking that opens opportunities for alternative decision and action not previously recognized. As Einstein suggested, ‘We cannot solve our problems with the same level of thinking that created them’. ST offers a different level of thinking for practitioners.

The determination and development of the capacity for Systems Thinking can assist practitioners to better navigate the complex landscape of modern systems by: (1) appropriately matching individuals to the level of Systems Thinking capacity deemed necessary to successfully engage complex system domains, (2) establishing teams with a diversity of Systems Thinking capacity (e.g. providing a variety of perspectives across the range of Systems Thinking characteristics and attributes), and (3) determination as to whether or not sufficient capacity for Systems Thinking exists to engage the desired activities for a particular unit in focus.

In effect, ST can enhance the capacity to deal with complexities encountered in modern systems. Since we are not innately born with the capacity for ST, we have varying proficiency, picked up through training, education, and experience. However, while few would argue the merits of ST, until now we have not had: (1) technologies to identify the level of ST for an individual practitioner and organization, (2) a method to determine the gap between the level of ST that exists and that required to address the complexity of the system and environment, or (3) an analysis approach to explore and prioritize ST developmental implications. The ST-Cap Method provides these capabilities.

References