NAC Executive Insights

Defining Project Complexity and Its Sources

Key Points

- Project complexity is the degree of interrelatedness between project attributes and interfaces and their consequential impact on predictability and functionality.
- When large complex projects come off the rails, they tend to go through a chaotic phase.
- Complexity can arise in engineering and construction programs from a broad range of factors.
- Management of project complexity is greatly aided by objective, tracking metrics and other actions.

Introduction

Complex projects are often described as being large and most large projects face increasing levels of complexity. Scale, however, is not the only determinant of complexity as there are many scientific and research projects much smaller in scale that are equally complex.

This Executive Insight focuses on:

- defining project complexity, providing an easy-to-understand visual analog.
- identifying potential sources of complexity in engineering and construction projects.
- providing a reference to one potential measure of project complexity.

The reader is also guided to the Executive Insight, Coupling in Large Complex Projects .[1]

What is Complexity in Projects?

Complex projects can be defined as:

- a large number of interacting tasks.
- unanticipated emergent properties (see description of emergence).
- extensive coupling[1] (networked nature), which drives nonlinear behaviors.
- the ability to absorb most random disruptions.

[1] Executive Insight, Coupling in Large Complex Projects

- vulnerable to catastrophic behavior under stress.

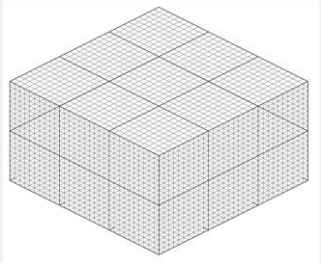
We are now in the "Century of Complexity," according to the late theoretical physicist, cosmologist, and author Stephen Hawking. Accordingly, we are transcending the domain of experts and are moving into a realm of "emergence," where the multi-finality of even well-developed programs must be acknowledged and provided for. The complex may even behave chaotically, amplifying the need for timely, responsive management interventions on project paths not previously well traveled. Returning from chaos to complexity requires both leadership and broadly engaging the wisdom of the team.

Emergence is when projects exhibit properties and behaviors which are attributed to the whole, not to its various tasks. Emergent behavior in projects is a result of the interactions and relationships between project elements and tasks rather than the behavior of individual elements. It emerges from a combination of the behavior and properties of the project elements and the project structure, both physical and execution process, and the potential interactions between them.

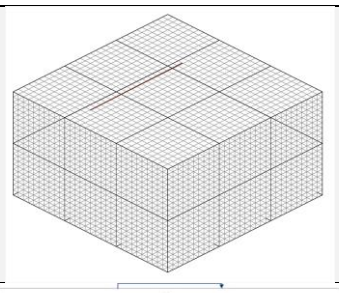
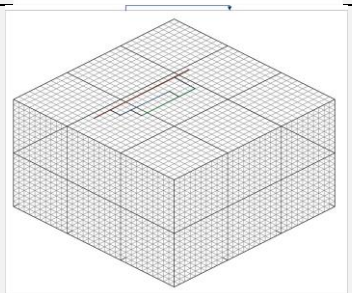
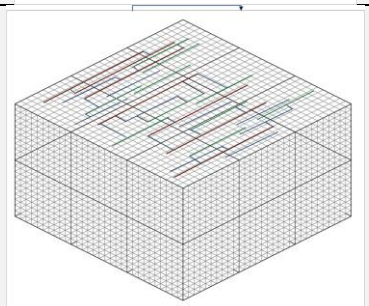
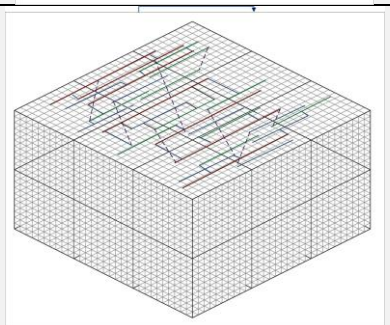
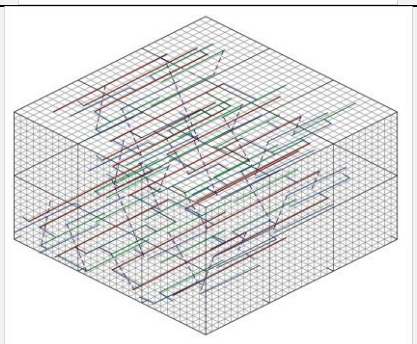
"Project complexity is the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality."[2]

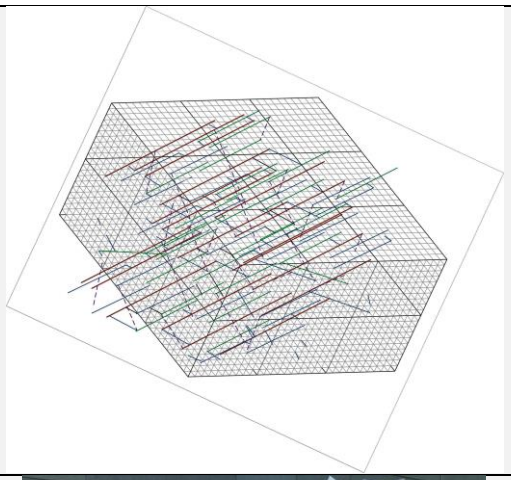
Complex Project Analogy

A complex project is described through the analogy that follows.

Let's think about a stack of graph paper.	

[2] Construction Industry Institute Research Summary 305-1, 2015

On the top sheet we draw a line along one of the horizontal graph lines with each vertical line representing the ending of one activity and the beginning of the next.	
This would represent a simple project and the project would remain simple even if we add a couple of horizontal lines with just a few vertical connecting lines.	
Now let's think about a project with many horizontal and vertical lines essentially encompassing all the boxes on that top sheet of graph paper. We would describe such a project as complicated.	
Finally, let's take that complicated project with many horizontal and vertical connections and add two new elements. The first, diagonal lines between seemingly random nodes on this top sheet representing precedence and constraint coupling.	
And second, lines penetrating down through the stack of graph paper connecting other complicated activity sets.	

Each of these other sheets of graph paper is not static. Rather they are being tugged and rotated by various externalities and stakeholders. We call this very dynamic project, complex.	
To continue with this analogy: when large complex projects come off the rails, they tend to go through a chaotic phase. The stack of graph paper is thrown up in the air and stability does not return until the project manager gathers up and reorganizes that stack of graph paper.	

Sources of Complexity in Engineering and Construction Projects

Complexity can arise in engineering and construction programs from a broad range of factors. These include:

- Strategic Business Objectives (SBOs)
- Organizational
- Stakeholders
- Political
- Project portfolio
- Program execution
- Technological
- Environmental

Each of these source categories is further developed in Table 1.

Table 1 Sources of Complexity in Engineering & Construction Programs	
Strategic Business Objectives (SBOs)	Ambiguity; Visibility; Alignment
	SBO Migration Over Time
	Conflicting SBOs
	Competitive Landscape Changes
	Market Migration
	Economic Susceptibility (Local; Global)
	Owner Complexity (JV; Alliance; State Owned Enterprise)
	Scope/Reach of Defined Outcomes
Organizational	Shared Understanding of Program Management Inadequate
	Clarity of Roles and Responsibilities Inadequate
	Resistance to Change
	Value Destroying Processes and Procedures
	Lack of Sense of Urgency
	Stress Level; Team Fatigue
	Silos that Impact Communication and Knowledge Sharing
	Cultural Issues
	Number of Locations
	Distance of Program from Day to Day Business
	Workshare Systems and Process Experience and Effectiveness Inadequate
	Duplication of Efforts (Owner/PMC)
	Duplication of Efforts (PMC/Suppliers)
	Risk Aversion vs. Risk Management
Stakeholders	Number, Types, Importance
	Conflicting Stakeholder Interests
	Timing & Duration of Stakeholder Processes
	Number & Types of Stakeholder Issues
	Ex-Process Interventions (lawsuits; protests; labor actions)

Table 1 Sources of Complexity in Engineering & Construction Programs	
	Extent of Commitments
Political	Degree of Political Sensitivity (Project of Key Supply Locations)
	Political Stability (Number of Relevant Political Players; Number of Election Cycles or Other Anticipated Changes of Government)
	Role in Power Struggles
	Sustainability of Political Will
	Role of Supply Chain in International Relations (Enabler or Held Hostage)
	Extent of Capacity Building and Feedback Role
Project Portfolio	Number of Projects
	Precedences and Interdependencies
	Uncertainties of Assumptions and Data
	Sophistication of Modeling and Analysis
	Assumption Migration
	Definition of “White Space”
	Number of Constraints
Program Execution	Cyclomatic Complexity
	Structural Complexity of Program Plan, Work Breakdown Structure (WBS), and Schedule
	Degree of Shared Constraints (First; Second; Third Order)
	Degree of Constraint Coupling (Direct and Indirect)
	Number of Changes
	Supply Chain Resiliency; Extent of Common Failure Modes (Common Sub-tier Sourcing)
	Depth of Labor Pool (Total & Critical Skills)
	Labor Predictability (Labor Action; Productivity)
	Physical Complexity of Projects Comprising the Program (Footprint; Degree of Temporary Construction; Duration

Table 1 Sources of Complexity in Engineering & Construction Programs	
	of Discrete Work Activities (Duration of Transition Phases))
	Specialized Equipment Availability and Lead Times
	Permitting and Regulatory Complexity; Timeliness
	Logistical Congestion and Chokepoints
	Flexibility of Sequencing
	Financial and Financing Constraints
	Regulatory Constraints
	Management Tools and Systems Not Adequately Integrated
	Shallow Risk Management
	Extent of Feedback Mechanisms
	Distance of Projects and Key Supply Locations from Day to Day Operations
Technological	New Process
	New Tools
	Technical Design Basis Not Fixed
	Prototyping, Planning, and Analysis Inadequate
	Specialized Materials or Skills
	Limited Number of Suppliers
	IT Complexity
	Systems Integration Extent
Environmental	Extent of Regulatory Processes
	Number of Significant Issues
	Effective Footprint
	Duration of Impacts

Measuring and Managing Project Complexity

The measurement of project complexity remains an industry challenge. Methods related to assessment of the presence and strength of the various factors associated with complexity, similar to many of those in Table 1, have been suggested. Reference 1 (see References below) suggests one method based on precedences that consider coupling, and is in some ways analogous to the cyclomatic coupling used in the programming industry. It provides the benefit of addressing the impacts from modularization as well as assessing how complexity changes as new couplings emerge and precedences are retired through performance of work.

Management of project complexity is greatly aided by objective, tracking metrics. Other actions to manage complexity include:

- Reduce ambiguity (continuously).
- Minimize coupling (correlation).
- Increase transparency of information.
- Engagement and alignment of stakeholders.
- Reliance on capabilities and capacities when processes fall short (contingent execution).
- Timely, decisive action.

Conclusion

Complexity is a distinguishing hallmark of many engineering and construction programs. Efforts to better manage complexity must begin with a clear understanding of what it is, what are its potential sources, and improved focus on measuring and managing it.

References

"Complexity in Large Engineering & Construction Programs," Bob Prieto; *PM World Journal*, Vol. VI, Issue XI, November 2017.

Construction Industry Institute Research Summary 305-1, 2015.

Coupling in Large Complex Projects, National Academy of Construction Executive Insight

For Additional Reading

The following NAC Executive Insights are recommended for additional reading and represent part of Introduction to Large Complex Projects:

- 13.0 Introduction to Complex Projects
- 13.1 Coupling In Large Complex Projects

- 13.15 Location Factors in Large Complex Projects
- 14.4 Human Factors in Large Complex Projects
- 14.8 Considerations in Cross-Cultural Negotiations
- 14.11 Cross Cultural Factors

About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.