NAC Executive Insights

Complex Projects

Key Points

- Complex projects often include extensive coupling.
- Complex projects behave non-linearly and catastrophically.
- Complexity must be considered with uncertainty.
- Uncertainty includes elements of ambiguity, volatility and variability.
- Complexity impacts project safety and execution.
- Processes exist to improve management of complexity.
- Key actions to manage complexity are outlined.

Introduction

This Executive Insight focuses on complex projects and complements Executive Insight: Modeling and Mitigating Project Complexity. In this Executive Insight we:

- Define complex projects
- Decompose complexity and look at some of the drivers
- Describe complex project characteristics
- Look at the process to improve management of complexity
- Define key elements of a complexity management strategy

Complexity can be thought of as arising from:

- Differentiation – variety in parts/ types of tasks
- Integration – variety in relationships

Complex Projects

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

Complex projects can be defined as:

- Large number of interacting tasks
- Unanticipated emergent properties (see emergence highlighted below)

- Extensive coupling (networked nature) drives non-linear behaviors
- Able to absorb most random disruptions
- Vulnerable to catastrophic behavior under stress

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.

Decomposing complexity

A decomposition of complexity, as shown in Figure 1, identifies two principal components:

- Structural complexity
- Uncertainty

Structural complexity consists of technological and individual complexity. It relates the number of internal elements within a project to their interdependencies. This complexity can manifest itself in:

- Individual task complexity
- Sequential task complexity, where the forward transfer of information in required form and timing is essential to execution of the next task in the sequence
- Interdependent tasks that create a coupling or correlation which is too often ignored in risk assessment and modeling

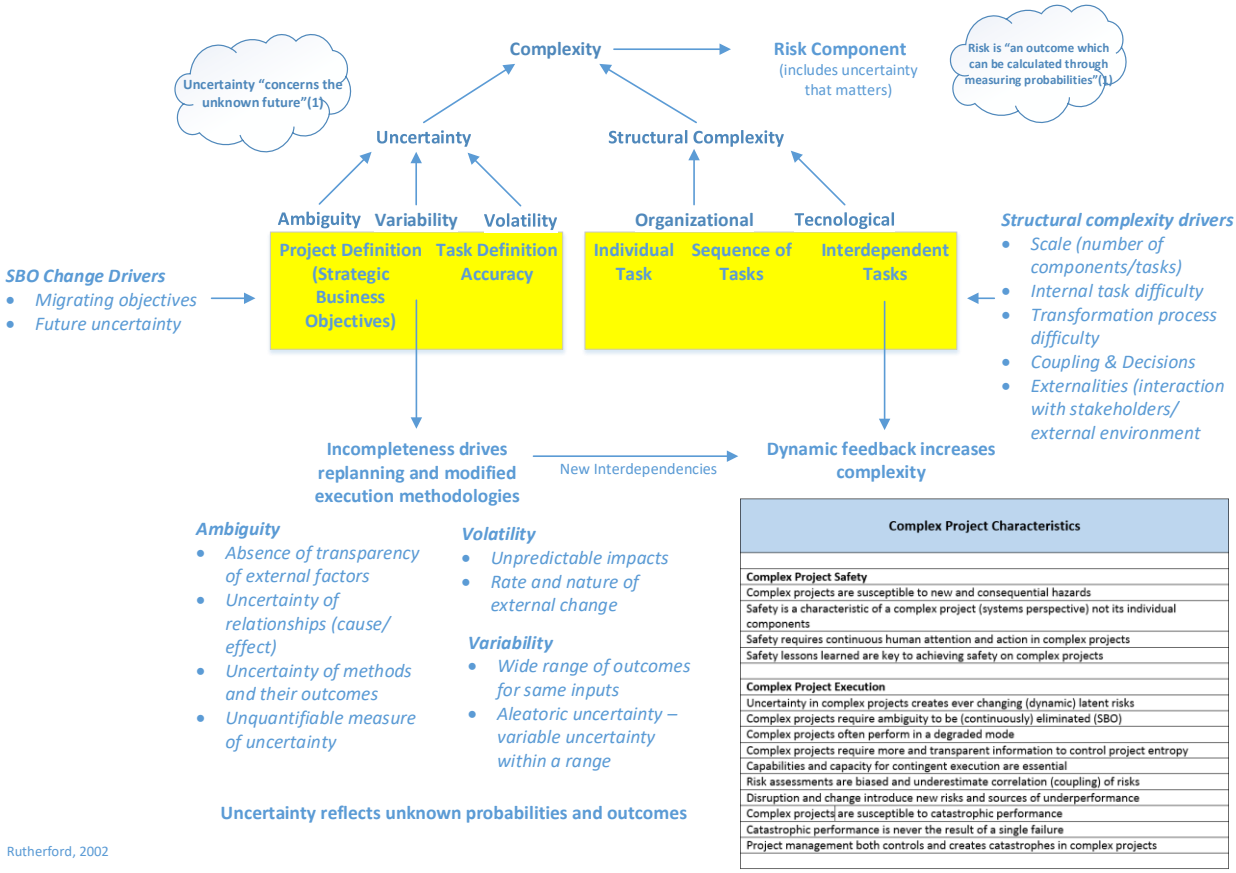
Interdependent tasks are subject to and give rise to dynamic feedback that increases complexity.

Drivers of structural complexity include:

- Scale (number of components/tasks)
- Internal task difficulty
- Transformation process difficulty
- Coupling and decisions
- Externalities (interaction with stakeholders/external environment)

Coupling refers to the interdependencies between activities where modules may be considered a special activity type. Precedence and unnecessary coupling of activities may harm a project's performance in ways that may not be evident on initial inspection. Additionally, these flows are not static or predictable.

Figure 1
Complexity



Complex Project Characteristics
Complex Project Safety
Complex projects are susceptible to new and consequential hazards
Safety is a characteristic of a complex project (systems perspective) not its individual components
Safety requires continuous human attention and action in complex projects
Safety lessons learned are key to achieving safety on complex projects
Complex Project Execution
Uncertainty in complex projects creates ever changing (dynamic) latent risks
Complex projects require ambiguity to be (continuously) eliminated (SBO)
Complex projects often perform in a degraded mode
Complex projects require more and transparent information to control project entropy
Capabilities and capacity for contingent execution are essential
Risk assessments are biased and underestimate correlation (coupling) of risks
Disruption and change introduce new risks and sources of underperformance
Complex projects are susceptible to catastrophic performance
Catastrophic performance is never the result of a single failure
Project management both controls and creates catastrophes in complex projects

Turning to uncertainty, three factors give rise to uncertainty that contributes to project complexity:

- Ambiguity
- Variability
- Volatility

In this context uncertainty may be viewed as concerning an unknown future. Let's look at each of the three contributing factors.

Ambiguity can be described as an:

- Absence of transparency of external factors
- Uncertainty of relationships (cause/effect)
- Uncertainty of methods and their outcomes
- Unquantifiable measure of uncertainty

Volatility addresses unpredictable impacts and the rate and nature of external change.

Variability, on the other hand, includes a wide range of outcomes for the same inputs. This so called aleatoric uncertainty reflects variable uncertainty within a range. Think of this as rolling a dice where the result will be between one and six but random.

These three components of uncertainty may manifest both at the overall project definition level or task level. At the project definition level, we see this uncertainty often associated with lack of clarity on strategic business objectives. This absence of clarity often arises from migrating objectives and uncertainty about the future.

Uncertainty results in a certain incompleteness which drives re-planning and modification of planned project execution strategies. These in turn interact with the project's inherent structural complexity giving rise to new interdependencies.

Complex project characteristics

As a result of structural complexity and uncertainty, complex projects manifest certain characteristics. We have broken these into two groupings:

- Complex project safety, recognizing some of the unique challenges they create and NAC's focus on safety
- Complex project execution

Let's look at each in turn.

Complex projects require a recognition of a changed safety environment as well as some special attributes that set them apart from less complex projects. These complex project safety characteristics include:

- Complex projects are susceptible to new and consequential hazards
- Safety is a characteristic of a complex project (systems perspective) not its individual components
- Safety requires continuous human attention and action in complex projects
- Safety lessons learned are key to achieving safety on complex projects

Turning to complex project execution characteristics we see:

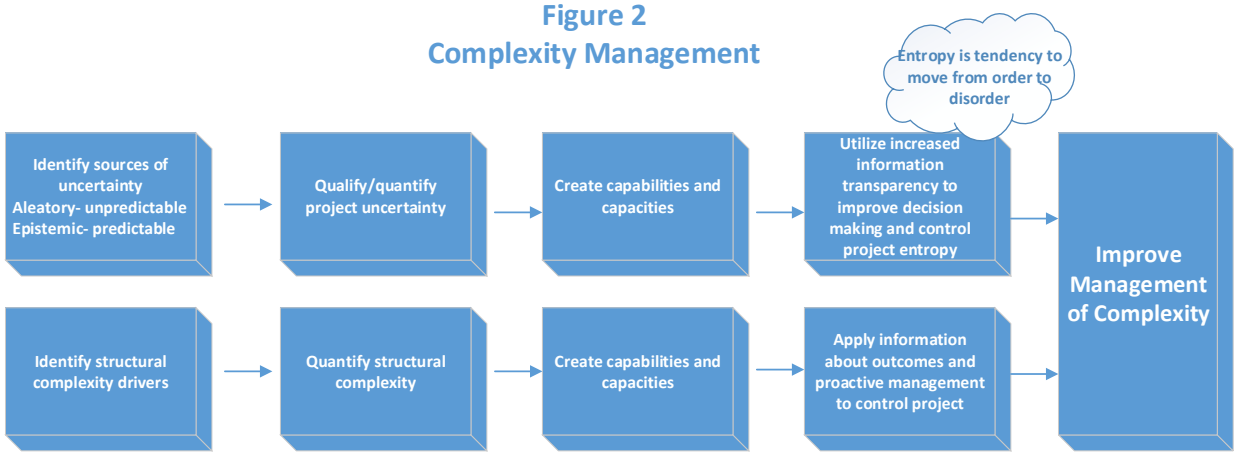
- Uncertainty in complex projects creates ever changing (dynamic) latent risks
- Complex projects require ambiguity to be (continuously) eliminated (Strategic Business Objectives (SBO))
- Complex projects often perform in a degraded mode
- Complex projects require more and transparent information to control project entropy
- Capabilities and capacity for contingent execution are essential
- Risk assessments are biased and underestimate correlation (coupling) of risks
- Disruption and change introduce new risks and sources of underperformance
- Complex projects are susceptible to catastrophic performance
- Catastrophic performance is never the result of a single failure
- Project management both controls and creates catastrophes in complex projects

Process to improve management of complex projects

Figure 2 lays out a simplified flow for management of complexity in projects. The two trains of action correspond to the considerations of uncertainty and structural complexity previously described.

In addressing uncertainty's contribution to complexity, we must first seek to identify the various sources of uncertainty that may contribute to project complexity. Clearly, elimination of uncertainty, where possible, is a first course of action but failing that we must qualify or where possible quantify project uncertainty. Aleatory uncertainty is unpredictable and may best be qualified or described whereas epistemic uncertainty may lend itself to quantification (event risk).

Figure 2
Complexity Management



Complex projects
- Large number of interacting tasks
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Complexity Management
- Reduce ambiguity (continuously)
- Minimize coupling (correlation)
- Increased transparency of information
- Stakeholder engagement and alignment
- Reliance on capabilities and capacities when processes fall short (contingent execution)
- Timely, decisive action

Uncertainty does not lend itself to being fully provided for (having all the necessary resources and materials needed), therefore we are better served by creating capabilities and capacities to undertake contingent execution if uncertainty manifests. Effective management of uncertainty requires increased information and information transparency in order to improve management decision making. Control of project entropy (the tendency to become disordered and more complex) is essential, or uncertainty will drive the project to a catastrophic state.

The second significant contributor to project complexity derives from structural complexity. We must strive to understand the various drivers of structural complexity, and importantly seek to quantify it. There are several industry measures for complexity emerging but no dominant methodology has yet emerged. Similar to addressing uncertainty we must ensure that appropriate capabilities and capacities are put in place. This needs to be done at the very outset of the project since assembling them only when needed delays timely response to emergent behaviors, as risks or as opportunities.

We must apply information about potential project outcomes to proactively manage and control the project. This is an area where advances in AI are particularly promising.

Complexity management

Complex projects require continuous attention. Management energy must be continuously expended at the right levels to control the project's entropy, its tendency to descend into disorder and even more complexity. This requires an awareness of the inherent characteristics of complexity that are present.

Key actions to manage complexity include:

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

Summary

In this Executive Insight we have defined complex projects; decomposed them and looked at key drivers. We have outlined a process to improve management of complexity and defined key elements of a complexity management strategy. Complexity and its impacts on projects are often underestimated but strategies to improve outcomes exist.

For Further Reading – Executive Insights

- Complexity
- Coupling on Large Complex Projects
- Contingent Execution

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.