Large Complex Projects
May 28, 2024

NAC Executive Insights

Rethinking Interface Management

Key Points

- Interface management includes all activities associated with identifying, defining, characterizing, controlling, confirming, and communicating information to enable distinct objects, activities, and actions to function in a coordinated and complementary way, as intended.
- Today's infrastructure and facilities are "smart," with technology and systems dimensions and an increasing focus on environmental, social, and governance (ESG), which expands interface challenges for program and project managers.
- Interface management in this expanded context requires increased attention and different constructs than those previously used, which in essence is a step change in interface management.
- Neglected interfaces lead to degraded project life cycle performance.
- The system challenge is compounded by the expansion from a closed to an increasingly open system, creating battles for interface management at every stage.
- An open system may have sets of changes at interface points beyond the project team's ability to control or limit, forcing early identification of potential interface impacts, assessing the range of impacts, choosing a timely response to optimize outcomes within this changed context, and ensuring all aspects of the interface have been addressed in responding to what may be an imposed change.
- ESG and system performance interfaces are principally contributors to and drivers of an outcomes-focused holistic view. Information and physical properties benefit from a reductionist view, which provides granularity for interface management. Governance, project management, and command and control integrate these two views to deliver the level of interface management that today's complex projects require.
- Interface management is more about informed decision making than absolute control of interfaces.

Introduction

Today's infrastructure and facilities are "smart." These "smart" facilities transcend any given sector and bring new challenges to the engineering and construction industry. In some ways, more traditional projects have become outcomes-focused IT projects with bits of concrete and steel wrapped around them.

This "smart" focus is not limited to technology and systems dimensions. It goes further, demanding an increasing environmental, social, and governance (ESG) focus as well. Together, "smart" and ESG create a greatly expanded set of interfaces for program and project managers to manage. These interfaces, both familiar and new, include:

- Physical
    - Systems, structures, components (existing and new)
    - Supply chain and logistical
    - Intermediate and final states
- Digital
    - Information/signaling
    - Digital twin (design and construction models)
    - Operating models
    - Enterprise asset models
- Human
    - Users (internal to project execution team)
    - Stakeholders (external to project execution team)
- Governance, management, and decision making
    - Communication
    - Contractual — recognize that interfaces may span many contracts and agreements
    - Regulatory and reporting

These interfaces require changed perspectives with respect to:

- Constraints, emerging and changing over time
- Assumptions, activity and timing sensitive, also changing over time
- Coupling (immediate and lagged)
- Life cycle phase (planning; engineering; construction; startup and testing; commissioning; operating, including maintenance; end of life/decommissioning)

Importantly, these interfaces include both direct and nested interfaces (those that use previously defined interfaces as reference, discussed later). Additionally, a "system of systems" perspective must pervade project management's thinking, recognizing that many of the elements above are themselves part of other, broader systems.

Interface management in this expanded context requires increased attention and different constructs compared to prior interface management efforts that primarily focused on physical or other more direct, one-to-one interfaces. The complexity of interface management in today's project environment requires a step change.

What is Interface Management?

Interface management includes all the activities associated with identifying, defining, characterizing, controlling, confirming, and communicating information to enable distinct objects, activities, and actions to function in a coordinated and complementary way, as intended. This co-functioning should be value-adding, efficient, and effective. In the "smart" and ESG contexts laid out above, this requires interface management to support interoperability in an increasingly dynamic and complex world.

Numerous industry interface management standards exist. This Executive Insight focuses on the expansion in thinking that is now required to deal with the open system's nature of large complex projects, especially those with increasing "smart" and ESG requirements and emergent outcomes.

Interface management goes beyond traditional constructs or configuration management. In today's world of increasingly complex projects, practitioners must recognize that desired outcomes themselves are emergent, which requires an interface management approach that will ensure that appropriate, value-adding relationships are sustained even in complexity.

While interface management ensures that all information required to enable co-functionality is present, its role in using various interface performance attributes as constraints is expanded by "smart" and ESG considerations. Interface management now becomes the process to bring the various bits of the project together to achieve the desired outcomes.

Nested Interfaces

Nested interfaces (interfaces that use previously defined interfaces as reference) have always existed in interface management. Now, however, they take on new importance and challenges as today's projects become "smarter" and with expanded ESG needs. In addition, a growing emphasis on preassembly and modularization creates a new layer of interface management for physical interfaces. Similar modular approaches are found within the digital realm as knowledge assemblies develop. Finally, many of today's projects—complex, layered systems—are merely one system in an even broader "system of systems" context.

Special attention must be paid to nested interfaces, ensuring that they are absorbed by other interfaces and not neglected either unintentionally or by organizational design. ***Neglected interfaces lead to degraded project life cycle performance.***

How Does the Interface Management Process Change?

The traditional interface management process begins with a definition of interface requirements from users, system, and program designers. As the project evolves, interface changes arising from technical and project requirements are managed utilizing a set of interface management procedures that work hand in hand with configuration and change management processes. Traditional interface management occurs at a work breakdown structure level (WBS) and occurs as various systems, structures, and components are integrated within a WBS element as well as the integration of WBS elements in the project. Positive control is exerted on interfaces, and interface management reports capture these efforts to provide input into configuration management and change control when requirements have changed.

Moving further into a project setting where “smart” interfaces and ESG interfaces take on an increased importance, traditional interface management processes are found lacking. An expanded interface management process must include several added considerations, including the following.

- Moving beyond traditional interface parameters that specify location (x, y, z coordinates); material properties at the interface (material specification, i.e. material composition/alloy; thickness; pressure/temperature ratings); coupling related requirements (weld type/electrical/ I&C coupler type); cleaning requirements; weld or coupler materials and ratings; and flow characteristics (fluid/current properties).
- Incorporating the various digital characteristics associated with physical interfaces. These could relate to associated digital twin properties; control points or systems in automated information, signaling, and command and control system operating features; and digital information required for effective asset management systems. Think of this as meta data that is now associated with physical elements, not just systems information flows. This is important since information flows have increased interfaces with the characteristics, properties, and performance of various systems components.
- ESG interfaces are becoming increasingly more pervasive into life cycle project systems. Examples of ESG include:
    - **Environmental** — embedded carbon; water footprint; end of life disposal considerations
    - **Social** — flow-down diversity and local sourcing requirements; modern day slavery (when an individual is exploited by others for personal or commercial gain, such as human trafficking)
    - **Governance** — “Buy America;” sub-tier sourcing from embargo countries or sanctioned entities

  This ESG metadata becomes integral to the interfaces at lower and lower levels.

- Substitution of the uncertainties associated with human interfaces, especially in control loops with the probabilistic (vs deterministic) actions of artificial intelligence (AI) and machine learning.
- Addressing the changing nature of interfaces driven by:
    - Changed stakeholder requirements and agreements (these may include changed regulatory requirements or even joint venture agreements)
    - Changed externalities (market; technological)
    - Operating environment and broader system performance (transportation, water, electrical, and other network performance that

act to modify interface requirements either with respect to initial asset deployment or in an operating environment)
    - Component substitution from that initially specified

This is akin to metadata being represented as a function of time, meta(t).

- While interface management focuses on direct interfaces as well as those which may be cascaded down, two other interface criteria are worth calling out:
    - Constraint coupling — this is an indirect interface where changes in one element or activity causes modification in an interfacing element associated with another element or activity.
    - Assumptions may also be thought of as interface criteria. As such, “assumption migration” becomes an area of interface management concern.

Figure 1 illustrates the expansion of traditional interface management stages (design, construction, and operations and maintenance) and the associated physical properties that traditionally defined interface parameters to now include the growing digital project (simulation/scenario optimization, Building Information Modeling (BIM)/digital twin, enterprise asset management).

Governance addresses myriad organizational interfaces. Currently, a reductionist view of interfaces dominates, but the life cycle perspective on more and more projects necessitates an equal focus on the holistic outcomes desired. The addition of “smart” and ESG considerations further drives this holistic view and increases the importance of governance since reductionist and holistic views must both be satisfied.

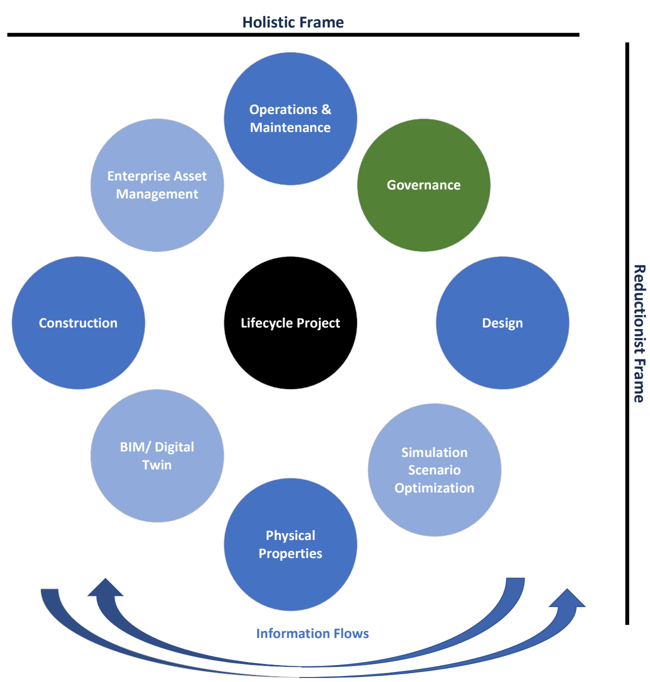

Figure 1

The Systems Challenge

The introduction of "smart" and ESG considerations has expanded the nature of the project system. The systems challenge is compounded further by expansion of the system from a more closed system to one that is increasingly an open one. Interface management in an open system is one in which battles emerge at every stage. Documentation of system boundaries becomes more notional than the well-bounded, traditional approach to interface management allows for. As such, the clarity required for determining where interfaces exist becomes more opaque. Even when it is believed that the interfaces have been comprehensively defined, new ones may emerge.

The systems challenge can only be met if interface management is initiated at the basis of design stage, where requirements are first defined. It is here that the special requirements that interfaces must accommodate first begin to emerge. It is also here where the discussions on "smart" integration into the basic project concept and the commitments to ESG can shape an approach to interface management and the process and procedures that are put into place.

Interface Control Documentation

Development of interface requirements documents begins at the basis of design stage. In addition to the digital elements now central to definition of systems, structures, and components, ESG requirements from a documentation and flow-down perspective must be incorporated, not just from a setpoint perspective. Importantly, these interface requirements documents must now encompass the full project life cycle and do so from a triple bottom line perspective. Development of assumption registers must begin and the relationships of assumptions to various interface points and criteria documented. Tracking of assumption migration now gains a tighter link with the project's change control process.

Traditional interface control drawings representing physical and control interfaces (P&IDs for example) must be complemented by information flow diagrams, logic diagrams, incorporated algorithms (to be tracked as they may evolve over a project's life cycle), and BIM and enterprise asset management system metadata. Interface control documents aim to clearly communicate all potential actions and interactions, whether internal to a system, structure, component (or their digital twins) or transparent to external users and stakeholders. Increasingly, this interface control documentation is database driven. Model-based interface management will likely be required to address these expanded interface considerations.

Interface data definitions now become greatly expanded and the number of organizational elements involved in effective interface control likely becomes all encompassing. The challenge of interface control has grown exponentially, but new tools such as AI and model-based approaches to interface management may make the impossible practical. The introduction of bias in both AI and model-based interface management, however, must be avoided.

In the open systems context, sets of changes may be discovered at interface points beyond the project team's ability to control or limit. The interface management function now shifts to early identification of such potential interface impacts (anticipating is desirable), assessing the range of impacts, choosing a timely response to optimize outcomes within this changed context, and ensuring all aspects of the interface have been addressed in responding to what may be an imposed change.

Additionally, project flows, their anticipation and identification, become ever changing aspects of what now must be model-based interface management. As such, interface control documents must expand descriptions of interfaces and interface types and specifically describe how information is communicated within a subsystem or WBS; across subsystems or various WBS; with external systems or project elements or other related projects; and its ultimate users and stakeholders. This may be accomplished by layering of interface control information, providing for different views of the project system as shown in Figure 2.

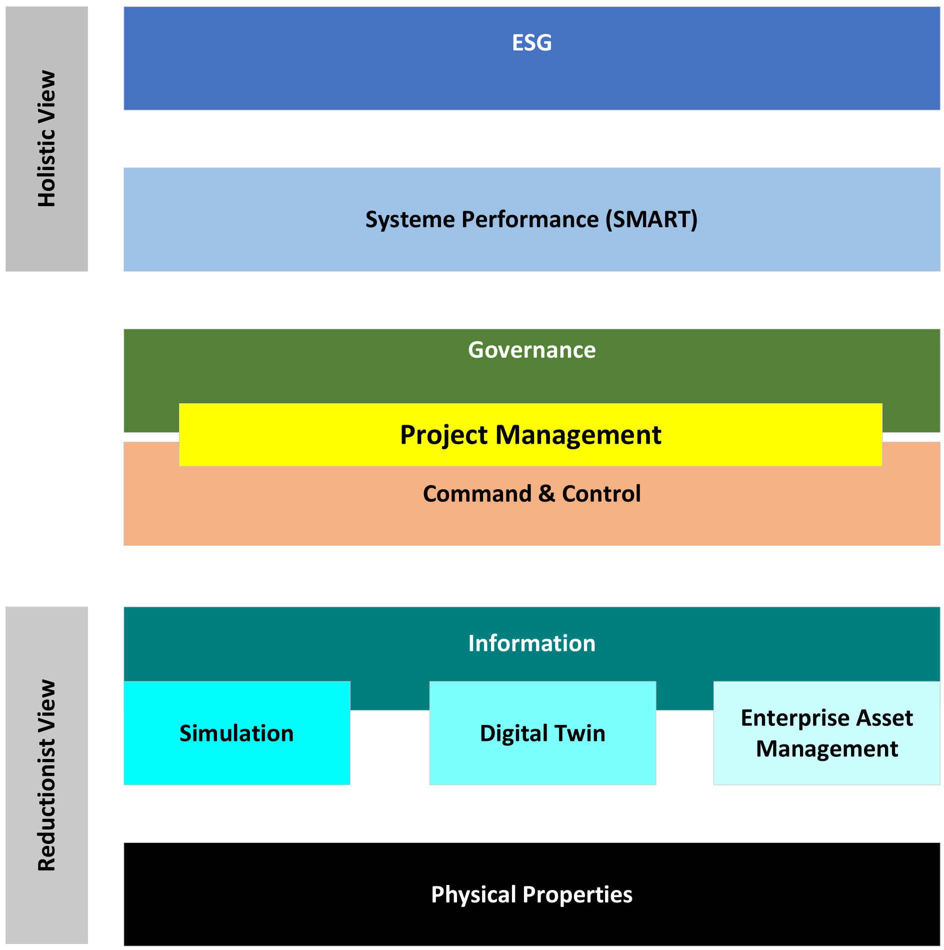

Figure 2

As seen in Figure 2, ESG and system performance interfaces are principally contributors to and drivers of the requisite outcomes-focused holistic view. Information and physical properties benefit from a reductionist view, providing necessary granularity for interface management.

Governance, project management, and command and control integrate these two views to deliver the level of interface management that increasingly complex projects require. Project management addresses the traditional interfaces one would expect related to:

- **Scope** (addressing both outcomes and outputs)
- **Schedule** (engineering, supply chain, and construction physical and temporal interfaces together with attendant information flows)
- **Cost** (assumptions and their migration; required characterizations to be achieved (Buy America; various set asides))
- **Risk** (importantly including emergent risk such as those associated with correlation and coupling)
- **Effective integration** (a primary focus of interface management)
- **Change management**, recognizing the multi-dimensional, multi-level effects of neglected interfaces or inadequate synchronization of the various project activities.

Best Practices

Consideration of this changed and greatly expanded interface management role and perspective is supported by adopting select best practices:

- **Governance is essential**, especially as system complexity and abstraction grow. It must evolve throughout the full life cycle of infrastructure and facility assets.
- **Interface management frameworks and processes must be established** at the outset of development of a future operating asset and fully engage all stakeholders. All too often, stakeholder roles in interface management are added almost as afterthoughts.
- **Establish interface management key performance indicators (KPIs) early** in the project and focus on completing interface definitions and agreements.
- **Match interface management frameworks with project complexity**: not too complex; not comprehensive enough; rather just right. Modular open systems approaches provide flexibility in projects where technology development is an important element and also in long-lived assets that may undergo many stakeholder- or technology-driven revisions over the course of their lifetimes.
- **Ensure interfaces are sufficiently defined** with clarity and acceptance on each side of the interface. Standards should be used where possible, or context should be defined and agreed to.
- **Interfaces must be trusted**. Trust is slowly earned, but quickly lost. Measure the effectiveness of interfaces in delivering the requisite value desired. Do “smart” systems have the information they need to operate and continuously improve their efficiency and effectiveness? Are ESG commitments being met and communicated frequently for ESG interfaces with various stakeholders? Is the provided information satisfactory and trusted? Engage stakeholders continuously.
- **Define interfaces clearly and comprehensively** so that the information at these points may be used for added, often emergent, purposes. Interfaces should

convey the rationale from design decisions and tradeoffs. Recognize that interface decisions introduce system constraints.

- **Interface management must facilitate concurrent but correlated project development efforts**, providing clarity on interdependencies that are sources of uncertainty and risk.
- **Interface management must support cross-domain interfaces**. This is even more important as the range of domains expands with the introduction of “smart” technologies and ESG requirements. Even in more traditional interface areas, cross-domain interface management is often found lacking.
- **Interface management must support synchronization** across WBS elements, interface layers, and broader stakeholders.
- **Both holistic and reductionist models of interfaces must be accommodated** with each adding value in different domains (higher and lower levels of abstraction). Verify that models are fit for purpose.
- **Interface management must support virtual (digital twin) project development and operation** throughout its full life cycle.
- **Ensure interface points are user-friendly, logical, and useful**. Do not make it overly complex. Ascertain the utility associated with various interface points. Are they value adding? Surprisingly, many are not.
- **Test, validate, and verify interfaces**, ensuring sub-tier interfaces have not been neglected and that the trust earned is well founded.
- **Ensure interface information is broadly available** within the project team and others. Avoid setting up competing, or worse, conflicting interfaces. Electronic workflow systems support interface management and tracking.
- **Recognize and capitalize on the risk and performance insights available from interface management KPIs**.

Concluding Thoughts

Recognize that each of the various levels and perspectives associated with interface management provides a valuable insight into the project. Each level and each perspective is a simplified abstraction of the system and its performance characteristics. A fuller view is only gained through the sum of all these levels and perspectives. Even this is an abstraction of the fullness of the project system. How these views link and how they individually interact with each other and evolve over time is the real prize.

Interface management is more about informed decision making than absolute control of interfaces, as desirable as this may seem. More holistic models with higher level interface definitions aid in decision making, outcomes achievement, system optimization, and prediction of system behaviors and performance. Conversely, the more detailed reductionist interface definitions are essential for more traditional interface management. The introduction of “smart” systems and ESG requires that both holistic models and the more traditional reductionist ones coexist.

As the physical configuration of the project takes shape based on an expanded basis of design and accompanying technical design requirements, focus must shift to the various other interface parameters such as those associated with digital and ESG parameters to fix a set of higher-level design and interface criteria. These support the advancement of design and analysis efforts, but the more holistic relationships must not be lost.

For Further Reading – (Executive Insights)

- Large Complex Projects as Open Systems
- Assumption Risk Driver and Constraint Tracking
- Coupling in Large Complex Projects
- Decision Making Under Uncertainty
- Impacts of AI on Large Complex Projects
- Proper Reliance on AI in Project Management
- Mega Projects Joint Ventures
- Coupling in Large Complex Projects
- Business Basis of Design
- Verification and Validation of Project Management AI
- Flows in Large Complex Projects
- AI Ethics in the Project Management and Civil Engineering Domains

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.