NAC Executive Insights

Business Basis of Design

Key Points

- Capital efficiency is improved through the adoption of an "expanded basis of design (symbolized in this Executive Insight as BOD^X)."
- BOD^X is driven by construction and operations & maintenance (O&M) considerations while meeting the performance and functional requirements typically detailed in the owner's project requirements (OPR).
- BOD^X is focused on improving the quality and cost effectiveness of the developed design throughout the full life cycle.
- The construction basis of design (CBOD) seeks to further actualize Construction Industry Institute (CII) Constructability Concepts I-1 and I-5.
- O&M Basis of Design (O&MBOD) addresses unique requirements to be incorporated in design development that reflect owner or contractor preferences for achieving the OPR.

Introduction

Large capital construction projects in both the industrial and infrastructure sectors are challenged in three significant ways:

1. Capital efficiency of the project: this considers both first costs as well as life-cycle costs.
2. Capital certainty: reflecting execution efficiency, predictability, and effective risk transfer through appropriate contracting strategies.
3. Time to market: perhaps best thought of as schedule certainty, but also accelerated delivery of projects, which is often an essential ingredient in capital efficiency.

This Executive Insight focuses on achieving improved capital efficiency in large capital asset projects through the adoption of an expanded basis of design that considers all aspects of a capital asset's life cycle. In many projects today, the basis of design (BOD) largely encompasses the engineering parameters required to meet the owner's project requirements (OPR).

Constructability (defined by CII as "construction input to design") and maintainability are often treated as review items to confirm that the developed design is both constructible and maintainable and to suggest improvements at the margins. Effective constructability and maintainability reviews add value to the project, but do not fundamentally act to shape the design itself in most instances.

The premise of this Executive Insight is that much more is required to develop effective designs that reflect construction and maintenance as fundamental project requirements. In this sense, construction and maintenance considerations are not items to be reviewed but rather fundamental requirements to be satisfied together with other project requirements established by the owner. The change suggested here is about a shift in mindset and perspective as well as in our design work processes.

Terminology and Definitions

The following constitute the key terminology used throughout this Executive Insight and provide the context for a so-called "business basis of design." Business basis of design, expanded basis of design, and BOD^X are all used synonymously in this paper.

Owner's Project Requirements (OPR) – sometimes confusingly called *"design intent,"* but refers to OPR.

BOD – Functional or performance-based description of what the designer will do to meet OPR; finalized at end of construction (as built); includes assumptions and criteria used.

CBOD – Construction Basis of Design – description of construction requirements to be reflected in design (developed by construction manager) and finalized at end of construction; includes assumptions and constraints used including means and methods preferences (for example, specific tools or equipment).

O&MBOD – O&M Basis of Design - description of operations and maintenance (O&M) requirements to be reflected in design (developed by operator/O&M) and finalized at end of construction; includes maintenance philosophy, assumptions, and criteria used. Provides a basis for development of the O&M program and manual.

BOD^X – Expanded basis of design, collectively incorporating the traditional engineering basis of design (BOD), new construction basis of design (CBOD), and a new O&M basis of design (O&MBOD). BOD^X is driven by construction and O&M considerations while meeting the performance and functional requirements typically detailed in the OPR.

Focus of BOD^X

The business basis of design or BOD^X is focused on improving the quality and cost effectiveness of the developed design throughout the full life cycle. Specifically it:

- Ensures all project participants are aligned on strategic business objectives as reflected in the OPR.
- Ensures owner, construction management, and O&M are clear on wants and needs.
- Ensures designer is focused on supporting an efficient construction execution strategy that reflects project construction considerations, opportunities, and constraints.
- Informs the process for identification, evaluation, and selection of design solutions to meet functional or performance specifications.

- Provides expanded criteria to evaluate and validate design solutions and submissions.
- Provides clear acceptance criteria verified during construction, commissioning, and initial operation.
- Informs decisions on equipment selection, layout, installation, operation, maintenance, and replacement until requirements change.
- Delivers a more effective asset management database at startup.
- Improves construction efficiency and effectiveness.
- Enhances construction safety.
- Improves O&M efficiency and effectiveness.
- Supports selection of the best options by considering all life cycle costs.

The BOD^X encompasses the traditional engineering basis of design as well as an expanded basis of design encompassing construction and O&M considerations. The following sections develop the scope and content of both the construction basis of design (CBOD) and operations and maintenance basis of design (O&MBOD). Common to each of the three basis of design requirements are the following three elements:

1. Project narrative
2. Rationale from the defined perspective
3. Validation and verification

This last element is often not adequately addressed in developed basis of design documents, but takes on increased importance as:

- Inspection technologies allow us to "see" previously undetectable flaws.
- Construction means and methods around which a design may be developed are assessed for completeness of design inclusion and actual effectiveness.
- Performance based standards and contracting take on larger roles in facility development and operation.

Let us look at some of the elements that comprise these expanded elements of the basis of design.

Construction Basis of Design (CBOD)

The CBOD seeks to further actualize CII Constructability Concepts I-1 and I-5.

- CII Constructability Concept I-1 states "Constructability program is an integral part of the project execution plan."
- CII Constructability Concept I-5 states "Basic design approaches consider major construction methods."

Specific elements that an effective construction basis of design consider include:

- Comprehensive identification of required or preferred construction strategies, tactics, techniques, and tools to be incorporated in the construction process that influence project management and design.
- Construction labor, skills, equipment, materials of construction, and logistical constraints to be reflected in basis of design.
- CBOD addresses unique requirements to be incorporated in design development that reflect owner or contractor preferences for achieving the OPR.

These owner project requirements may reflect:

- Prior experience of the owner.
- Unique risks, opportunities, or constraints associated with the project.
- Contractor capabilities and experience.
- Special tools uniquely available to the project.
- Broader programmatic objectives required of the owner or independently committed to by the owner that influence construction execution.
- Applicable safety program to be used on project.

CBOD considerations may be broadly grouped as basis of design requirements related to:

- Labor
- Equipment
- Materials
- Means and methods
- Management processes and practices

Labor

- Sourcing
    - Labor relations
        - Work rules and requirements
        - Labor jurisdictional requirements to be addressed
    - Visa requirements, limitations, process durations
    - Multi-national labor force impact on site segregation and development
- Safety
    - Hazard elimination
        - Hazard avoidance or reduction features to be facilitated by design
            1. Eliminate hazards
            2. Pinch points
            3. Heavy lifts minimized or eliminated
                a. Use of jack up construction
                b. Vertical modules
            4. Work at height
                a. Minimized or eliminated by construction at grade (less than 6’)

b. Permanent structures incorporate platforms or provisions for temporary platforms

- Hazard mitigation
  - Reduce the hazard
    1. Equip any required scaffolding with railings and toe boards
  - Improved access to workface
    1. Access requirements for construction identified considering sequence of construction (and maintenance)
  - Enhanced positional awareness through use of RFID (radio frequency identification)
- Knowledge
  - Activity linked safety and skills training reflected in construction resourcing plan and master project schedule
  - Activity linked equipment, materials and tools to facilitate staging and reduction in idle time
  - Reskilling for later stage activities including maintenance phase activities
- Welfare
  - Onsite medical facilities and requirements
  - Camp requirements (facilities and services)
- Productivity
  - Enhance labor productivity through design

    1. Minimize the number of sku's for components and materials to be manually installed (nuts & bolts; welds; fasteners)
    2. Use controlled environments at environmentally challenged sites
       a. Early usage of permanent facilities (warehouse, admin building)
       b. Temporary facilities provided for in plot plan development (dynamic air shelters).

Equipment

- Procurement
  - Labeling/tracking requirements (barcode/RFID)
  - Measurement units in installation (and maintenance) documents (English/metric)
  - Orientation of installation schematics to conform to installation position
  - Hazard mitigation
  - No sharp corners
- Logistics
  - Incorporation of adequately sized and placed lifting points
  - Shipping and packaging to eliminate removal of temporary bracing
  - Single stream protection and packaging materials to facilitate recycling
- Installation

    - Self-alignment
    - Self-leveling
    - Required laydown and movement envelopes including associated logistical equipment
    - Access corridors for installation
- Pre-commissioning
    - Incorporation of pre-commissioning isolation valves and electrical lockouts required
    - Accessible temporary attachment points for test equipment

Materials

- Preferred material sources and alternates and impact on design
- Material tracking requirements to be reflected in design specifications
- Preferred logistical approach and impact on design
- On-site use of batch plant – available quality of concrete
- Concrete placement strategy – pumped vs. bucket
- On-site bending of rebar – quality considerations to be reflected in design
- On-site welding of pipe and structural steel assemblies – impact on design and construction sequence

Means and Methods

- Focus is on means and methods selection rationale for design impacting elements of construction.
- Strategies
    - Reduce indirects
    - Reduce general conditions cost by
        - Shortening schedule elements with high GC costs (specialized labor or equipment)
        - Reducing overall project schedule
    - Reduce need for enabling works
        - Reduce overall project schedule
    - Modularization/fabrication with appropriate metrics such as work-hours displaced embedded in each shipment received
    - Requirements for off-site construction
- Tactics
    - Reduce temporary works
        - Minimize need for scaffolding by incorporating platforms or support for temporary, reusable platforms in structural design
        - Incorporate temporary steel for shipping of assemblies in final assembly design to eliminate removal of shipping steel
    - Reuse formwork and temporary works
        - Size foundations to re-use formwork
    - Minimize excavations

- Techniques
    - Lift many once – high lifts with long duty cycle benefit from lifting many items at once to height and final placing with alternate equipment
        - Daisy chaining requires lift points that facilitate safe lift
        - Racking and packaging for lifts may eliminate lifting skids and pallets
- Tools
    - Unique equipment to be employed
        - Heavy lift
        - Welding
        - RFID

Management Processes and Practices

- Owner's policies, guidelines or other directives affecting construction
- Regulatory limitations on construction practices, means & methods
- Desired sequence of construction
    - Early work packages required
    - Permanent facilities to support construction
    - Trade sequencing or other labor driven sequencing
    - Restricted construction
    - Preliminary execution strategy and plan
    - Eliminate later stage trenching operations impacting site logistics
    - Incorporate commissioning sequence and temporary facilities and equipment
    - Establish "site needs" dates (including mod yard need dates)
- RFI reduction by reflecting means & methods considerations in design model (BIM)
- Sustainability
    - Construction energy, water, waste requirements
        - Energy
        - Waste
        - Water
        - Social
            1. Knowledge transfer
            2. Community development
            3. Industry development
                a. Areas targeted for local sourcing
- Validation and verification
- Quality control and assurance
- Commissioning
    - Provisions to be reflected in design.

        - Systems/subsystems/components should be designed to be functionally, mechanically, electrically, and electronically as independent as practical to facilitate pre-commissioning testing.
        - Recognize that commissioning starts with the first drawings in the feasibility stage.
- Workface planning

Elements of O&MBOD

Operating and maintenance costs often represent over half of the life-cycle costs of a capital asset on a present-worth basis.

Development of an effective O&M basis of design should, as a minimum, encompass:

- Comprehensive identification of required or preferred construction strategies, tactics, techniques, and tools to be incorporated in the O&M process, which influences design.
- O&M labor, skills, equipment, materials (including consumables), and temporary provisions for maintenance are to be reflected in the basis of design.
- O&MBOD addresses unique requirements to be incorporated in design development that reflects owner or contractor preferences for achieving the owner's project requirements (OPR). These requirements may reflect:
    - Prior experience of the owner.
    - Unique constraints associated with the project location; environmental setting; process operations; and labor availability, cost, and skill level.
    - Contracting community capabilities and experience.
    - Special tools required for major maintenance.
    - Broader programmatic objectives required of the owner or independently committed to by the owner that influence maintenance execution.
    - The applicable safety program to be used during facility operation.

O&MBOD considerations may be broadly grouped as basis of design requirements related to:

- Labor
- Equipment
- Materials
- O&M practices and techniques
- Management processes and practices

Labor

- Sourcing
    - Provisions required to address union work rules

- Provisions required to meet workforce cultural or local practices requirements
  - Example: prayer rooms; special food preparation requirements; gender segregation

- Safety
  - Hazard elimination
    - Identify changed safety conditions associated with maintenance activities and eliminate or mitigate new safety hazards
    - Access points and covers should not have sharp corners
    - Design should reflect safe access for maintenance and repair
    - Avoid hazardous access points (manholes in live traffic areas)
    - Reduce weight of components frequently moved (manhole cover; access plate; paving slabs; concrete curbs)

    - Provide for "isolation" of equipment to maintenance under continuous operations:
      1. Lockout valves and switches
      2. Electrical isolation
  - Hazard mitigation
    - Reduce the hazard
      1. Minimize work at height.

      2. Minimize hand operations during maintenance.
      3. Minimize potential pinch points.
      4. Minimize sharp corners.
      5. Minimize exposure time in extreme environments associated with periodic maintenance.
      6. Minimize need for lifts or temporary ladders for routine maintenance.
    - Improved access to workface
      1. Required work platforms and equipment laydown or pull areas to be reflected in design
      2. Space provisions for temporary equipment required for maintenance operations and accessibility envelope

- Knowledge
  - Ensure full engineering, procurement, construction data pull through to asset management and O&M systems.

- Productivity
  - Facilitate grouping or simultaneous performance of maintenance operations.

Equipment

- Maintenance
  - Incorporate maintenance provisions in design development.
    - Reflect maintenance set-up and staging requirements.

        - Identify typical *combinations* of maintenance activities in plant and systems design and layout.
        - Design for rapid replacement of routine maintenance items (plug and play; quick opening fasteners).
        - Systems/subsystems/components should be designed to be functionally, mechanically, electrically, and electronically as independent as practical to facilitate maintenance and testing.
        - Maintenance "envelopes" should be reflected in design layouts.
        - Increase accessibility to areas of frequent maintenance.
            - Provide flat laydown areas for components removed during maintenance or replacement
            - Identify provisions for maintenance (scaffolding, lifts etc.)
            - Identify any maintenance crane or other temporary equipment support points and confirm capacity and clearances
        - Minimize joints and bearings.
    - Incorporate temporary maintenance provisions in base design to avoid use of temporary hoses, power lines, and so forth.
    - Power
    - Water
    - Compressed gases
    - Wastewater including spill collection
    - Attachment points (for lifting equipment for access removal or repair or replacement)
    - Attachment points for temporary crane rails or mobile equipment envelopes
- Repair
    - Reduce spare parts requirements, costs, and risks through design.
        - Minimize spare part types.
        - Identify long lead items for spares planning.
        - Ensure long-term availability for spares.
        - Standardize components to minimize maintenance spares and tool sets.
- Replacement
    - All machines fail at some point and must be repaired or replaced. Provide for this activity.
        - Consider replacement strategies for major components over the project's full lifetime.

Materials

- Minimize maintenance to the extent achievable
    - Improve deterioration and environmental resistance of exposed systems and structures (mildew; organic pollutants).

        - Moisture – eliminate ponding especially on exposed steel surfaces; ensure good drainage.
        - Caustic materials including materials associated with cleaning and maintenance
        - UV light
    - Minimize need for painting.
    - Minimize surface and material wear.
        - Identify potential areas susceptible to corrosion abrasion.

O&M practices and techniques

- Unique O&M practices or techniques to be utilized and provided for in design:

Management Processes and Practices

- Build O&M documentation from initiation of design.
    - Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) should be included in system and component maintenance documentation.
    - Identify all maintenance assumptions and requirements in design documents and consolidate and track.
- O&M information, including equipment and vendor data, should be required to be directly incorporated in the facility asset model (building information model (BIM)) or database.

- Contractual provisions to support long-term O&M.
    - Special warranty or servicing requirements
    - Performance contracting requirements

Summary

The rational and role for an expanded basis of design or a so called “business basis of design” is established and terminology to address the elements of an expanded and more robust basis of design laid out. Initial scopes of a construction basis of design and an operations and maintenance basis of design have been laid out with a framework to support further development.

References

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