Integrating Virtual Design and Construction into Progressive Design Build

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Implementing these practices on any type of design-build project increases the probability of a successful project that meets the expectations of all stakeholders. If these practices are NOT implemented, there is an increased probability that the project's performance will be compromised and that some or all of the stakeholders will be disappointed.
thus, the term “progressive”
Labor Productivity in the United States

Construction & Non Farm Labor Productivity Index (1964-2016)

Sources: US Department of Commerce, Bureau of Labor Statistics

Non-Farm Productivity Index (1964 = 100%)

Construction Productivity Index (1964 = 100%)

Progressive Design Build
Virtual Design & Construction

Stakeholders Trade Crafts
The Case for Progressive Design Build and Virtual Design & Construction

Key Trades
- Mechanical
- Electrical
- Plumbing
- Curtain Wall
- Fire Protection
- Fire Alarm

Progressive Design Build

Virtual Design & Construction

Reshape regulation
Rewire contracts
- Rethink design
- Improve procurement and supply chain
- Improve onsite execution
- Infuse technology and innovation
- Reskill workers

McKinsey Global Institute
Reinventing Construction: A Route to Higher Productivity
February 2017

#DBIABIMForum19  #BIMForum19
The Case for Progressive Design Build and Virtual Design & Construction

Progressive Design Build

Virtual Design & Construction

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1 The impact numbers have been scaled down from a best case project number to reflect current levels of adoption and applicability across projects, based on respondents to the MGI Construction Productivity Survey who responded “agree” or “strongly agree” to the questions around implementation of the solutions.
2 Range reflects expected difference in impact between emerging and developed markets.
Rewire the contractual framework. There is a need to move away from the hostile contracting environment that characterizes many construction projects to a system focused on collaboration and problem solving. To achieve this, tendering processes can be based on best value and be supported by collaborative incentives that introduce incentives that significantly improve performance and alignment not at a trade or package level, but at the project-outcome level. To move toward best practices, appropriate alternative contracting models, such as integrated project delivery (IPD) help build long-term collaborative relationships. Relational contracts will need to become more prevalent than transactional contracts. Sufficient investments in up-front planning incorporating all parties’ input have been shown to raise productivity substantially.

• To move toward best practices, appropriate alternative contracting models such as integrated project delivery (IPD) help build long-term collaborative relationships. Relational contracts will need to become more prevalent than transactional contracts. Sufficient investments in up-front planning incorporating all parties’ input have been shown to raise productivity substantially.

Establishing a “single source of truth” on projects for monitoring progress early, potentially supported by collaborative technology, helps to minimize misalignments and enable joint corrective action. The data already exist to fundamentally improve the accuracy of cost and schedule estimates.
Progressive Design Build

- Integrated Project Delivery
- Qualification Based Selection
- Integrated Technology Systems
- Lean Construction Tools

Exceptions Project Team
- Project Management Team
- Design Team
- Builder Team

Physical Building
- 3D Modeling
- Building Information Management (BIM)
- Integrated Working Environment
- Last Planner
- Target Value Design

Project Outcome
"Design Excellence"

Creativity & Innovation

Collaborative System

Collaborative Alliances
- Owner & Stakeholders
- Designers & Subconsultants
- Builder & Subcontractors

Stakeholder Engagement
- Project Team Partnership
**Progressive Design Build Phases**

- Preconstruction Phase
  - Programming Phase
  - Schematic Design Phase
  - Design Development Phase
  - Construction Documentation Phase
  - Procurement of Trades

- Construction Phase
  - Construction Phase
  - Closeout Phase
  - Operations and Maintenance Phase

**Design Effort/Stakeholder Involvement**

**Ability to Control Cost because of Design Freedom**

**Cost of Changes because of Design Restriction**

(**Modified MacLeamy Curve**)

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- Operations and Maintenance Phase

Incremental Collection & Verification of Model Information

INTEGRATED APPROACH

BIM

LOD 100
LOD 200
LOD 300
LOD 400
LOD 500

Target Systems

An Integrated Seamless Flow of Geospatial & Data Information

Design Excellence

Information Optimization

#BIMForum19

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### Phases of a Progressive Design Build Contract

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**Phase 1: Preconstruction Services**
- BIMx Plan
- Cost Model Target
- Phasing Schedule
- Verify Program RFP
- Select Key Trade
- Scope Narrative
- Stakeholders
- Basis of Design
- Align Scope, Cost, Schedule

**Phase 2: Construction Services**
- Prepare Design Model
- Develop 1
- Prepare 2
- Document 3
- Update Cost Forecast

**Phase 3: Construction Services**
- Incorporate Fabrication into Model
- Design Builder prepares packages for pricing
- Design Builder procures trade work
  - Self Performed
  - Key Trades
  - Subcontracted Work

**Support Activations**
- Verify Project Model
  - is accurate and updated to match as built conditions
  - Complete Equipment Inventory data entry
  - Update Model with Warranty & Maintenance Information
  - Turnover spare parts

**Activation**
Phases of a Progressive Design Build Contract
The Progression of Contract Design, Cost, & Construction
4 Bi-directional Runways

4 Terminals, 100+ Gates, 600+ Structures
- 16,431,155 sqft. (377 acres) Interior
- 5,049,203 sqft. (115 acres) Terminal
- 2,358,000 (54 acres) Public

36+miles Roadway
2,246 acres Land

Over $1B in Utilities

2 Wastewater Treatment Plants
As-Managed Model

Design / Construction

As-Built Models

Conformed Design Models

Handover
People, Organization, Process + Technology
Virtual Design and Construction - Principals

People, Organization, Process + Technology

Collective Collaboration
Organized Data
Established Processes
Model What We Planned
Build What We Modeled
Stakeholder Engagement

**FACILITIES**
- Electrical Maintenance
- Mechanical Maintenance
- BICE
- Facilities Scheduling

**PLANNING AND ENVIRONMENTAL AFFAIRS**
- Communications and MKTG
- SFFD
- SFPD
- Wayfinding
- Safety and Security Services

**OPERATIONS AND SECURITY**
- AVM CAD Group
- Aviation and Parking Mgmt
- Revenue Development and Mgmt
- Finance

**BUSINESS AND FINANCE**
- Airlines
- Tenants

**INFORMATION TECHNOLOGY AND TELECOM**
- Aviation and Parking Mgmt
- Revenue Development and Mgmt
- Finance

**DESIGN AND CONSTRUCTION**
- Subcontractor
- General Contractor
- Project Mgmt.
- Constr Services
- Architecture
- Electrical Engineering
- Mechanical Engineering
- Civil Engineering

**INFORMATION**
- BIM
- GIS

**STAKEHOLDER ENGAGEMENT**
- Designer
- Subcontractor
- General Contractor

**INFORMATION MANAGEMENT**
- PMIS

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END GOAL:
Preventive Maintenance

USE CASE DEVELOPMENT:
Stakeholder Engagement Process

IMPLEMENTATION:
Defining data attributes
Checklist writing
- Fire Life Safety
- ADA review
- Maintenance
- Distribution Systems
- TI As-Builts
- Occupancy Change Coordination
- Tenant Equipment Installation Tracking
- Site use for maintenance and control
- Site Mobile connection
- RFI Capture
- Equipment change-in
- Drawing production (Close-Out)
- Map Stores to BIM
- Paper Trace Procurement
- Laser Scanning
- BIM Quiz
- Photo of Connection
- Advertising Opportunities
- Leasing Data
- Occupancy
- News subscriptions
- Spatial relations
- Central Source of Data
- GIS Sophisticated RM Data
- BIM-GIS Technical Connection
- Rule Checking
- One Code Analysis
- Change-in Coordination
- Future Proofing
- Project Phasing
- Training/Inception (MEP)
- Make Task Interim Access
- Training/Inception
- Digital Handover
- Critical Incident Tracking
- Equipment Tracking
- Commissioning
- Informed Data and Information
- Cabinet Partner View/Access
- Internal/Partner View/Access
- Single Source of Truth (SST)
- As-Builts Access
- As-Builts Accuracy
- Room Naming Standards
- Retail Family Library
- Content Library Standards
- Architectural & MEP Coordination
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People - Model - Data Workflow

Model Data Authoring

Model Content Authors

Trade Partners

Architects & Engineers

General Contractors

Data Collection and Verification

Conformed Design Models

Validated Database

SFO Target Systems

CMMS
EMS
UNIFIER
GIS

Model Content Users

Owner Responsibility

Owner Stakeholders

Project Responsibility

Project Stakeholders

Self Auditing and Verification

Data Collection and Verification

Update Design Intent

Validated Database

Conformed Design Models

GIS

Project Stakeholders

Trade Partners

General Contractors

Architects & Engineers

Model Content Authors

#BIMForum19
#DBIABIMForum19
#BIMForum19
People - Model - Data Workflow

Target Systems

- CMMS
- EMS
- UNIFIER
- GIS

Validated Database

Users

- CMMS
- EMS
- UNIFIER
- GIS

Data Authoring

- Architects & Engineers
- Trade Partners
- General Contractors

Data Collection and Verification

- Conformed Design Models
- Self Auditing and Verification

Contracts, Specs, Standards and Processes

Data Authoring

- Data Authoring
- Users

People - Model - Data Workflow
Virtual Design and Construction - Principals

- Collective Collaboration
- Organized Data
- Established Processes
- Model What We Planned
- Build What We Modeled

People, Organization, Process + Technology
Coordinated Standards
Coordinate System Alignment

Coordinate System Standard
Version Date: July 2019

3. Coordinate the survey of the project's work area based on the Adjacent Control Points file. Coordination should include:
   a. Existing building footprints
   b. Tie-in points
   c. Vertical elevations of exiting adjacent floors
   d. Exiting adjacent site elevation grid lines

4. Review the survey results with the SFO Chief Surveyor.

5. Update the project documentation to reflect any coordination system on the survey.

Figure 2.1 illustrates this process for this step.

Figure 2.3 Reference the Base Map and insert the SFO-B Origin Marker.

3 DOCUMENTATION

All design discipline and trade partner models and drawings shall include the correctly positioned SFO-B Origin Marker. The project-specific process of coordinate system alignment between design disciplines and trade partners must be documented. The process of coordinating with other active adjacent SFO projects must be documented as well, if applicable. The documentation must include the date of when the SFO Base Map and the Adjacent Control Points files were received.

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Part One

BIM at SFO

What is BIM?

A Building Information Model (BIM) is a digital representation of the Airport’s assets and infrastructure that consists of model elements that represent spaces, infrastructure components, and building systems that comprise the facility. The model elements represent physical geometry and attributes that describe functional and performance characteristics of the infrastructure. An important characteristic of BIM is the ability to automatically associate model elements with their containing spaces (locations) in the virtual environment.

In basic terms: BIM = Virtual Model (3D Geometry + Location) + Data (see Figure 01).

The ability to locate model elements in virtual space aligns naturally with Geographic Information System (GIS), which is founded on the association of data and spatial relationships. Finding and querying model elements by location is critical for accessing information by all stakeholders and is supported by the integration of BIM and GIS at the Airport.

Figure 01: BIM and GIS in the project

BIM AT SFO

#DBIABIMForum19

#BIMForum19
How the Airport uses BIM

The Airport uses BIM as part of VICo to support Stakeholder Engagement and Collaborative Partnering processes, and to ensure that design and construction information can flow into the Airport’s target systems, through the implementation of an Enterprise Attributes Dictionary, Data-View Definitions and verification methods.

Furthermore, the Airport has adopted an organization to include a dedicated group of subject matter experts, the BIM Integration Team (BIT), to provide leadership for BIM implementation through each project’s lifecycle. The BIT functions as a bridge for the 15-hour stakeholders, design reviewers, and project teams to ensure thecorreaplement of the SOP BIM Guide. The BIT serves as a house architect and engineers to support their BIM goals. They also engage with capital project teams to develop standards and processes for data collection and verification, and enable Airport stakeholders to collect design and construction information.

Technology changes rapidly and solutions must be aligned with each project’s scope. Project teams and the BIT collaboratively overcome challenges and develop solutions related to implementing software solutions to meet the Airport’s goal.

BIM Uses

The Airport has identified and organized the following BIM uses during design, construction, and operations into five categories. Project teams should use their knowledge and expertise to assess and align the use of BIM with their project specific scope and requirements, and address their plan for achieving the Airport’s vision in the BIMs Plan. Their project specific BIMs Plans supports the definition of responsibilities across the entire team and provides a benchmark for how teams work together to execute BIM and deliver integrated infrastructure information.

Authoring
- Design
- Documentation
- Shop Drawings
- Digital Fabrication

Analysis
- Design Review
- Engineering Analysis
- Clash Coordination
- Virtual Mockups

Execution
- Logistics Modeling
- Supply Chain Management

Verification
- Laser Scanning
- Model Data Verification
- Robotic Layout

Operations
- Facility Management:
  - Geographic Information System (GIS) Integration:
  - Space Management
Appendix C – Element Attribute Dictionary

C.1 Element Naming Conventions

The Element Attribute Dictionary (EAD) - Element Naming Conventions provides a recommended schema and guidelines for creating standardized model element names. Standardization allows easy identification, filter and search capabilities in BIM and in schedules based on known descriptors. Conforming to a naming pattern in BIM also allows for better communication & coordination across project teams based on the readable model element names. The examples in the document are provided for implementation in Revit and can be used for any CAD or BIM authoring software.

### Required / Optional:

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<td>Mechanical Equipment</td>
<td>AHU_SplitSystem_Horizontal</td>
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#### Examples:

- **Category**: Air Terminals
  - **Family Name**: Grill_Return_LayIn_Eggerate
  - **Type Name**: 12inch x 12inch

- **Category**: Mechanical Equipment
  - **Family Name**: Chiller_Absorption_Classic (112-455) Tons
  - **Type Name**: 200Tons

- **Category**: AHU_SplitSystem_Horizontal
  - **Family Name**: AHU_SplitSystem_Horizontal
  - **Type Name**: 30000BTU

- **Category**: Door
  - **Family Name**: Door_Interior_Single_HollowMetal
  - **Type Name**: 36inch x 84inch

### Implementation Guides:

- **Family Name**
  - Can include any combination of letters, numbers, and underscores
  - Avoid using spaces in the family name

- **Category**
  - Use ‘Project_Category’ (i.e. capitalize first letter of word without space) for family names
  - When adding optional descriptors to family names, the order in which the descriptors are listed must ensure that the families appear in BIM and schedules in the most logical and intuitive order.
  - Use an underscore ( _ ) to separate fields in the family name.
  - Performance range can be designated with a hyphen (-) separated range enclosed in parentheses, for example, (1200-2500Tons).
  - Avoid using attributes that are part of the EAD Common Attributes Set, such as Model Number, Classification Codes etc., in the family or type name. OK to use Manufacturer as a Descriptor.
  - Hierarchical order of descriptors may be determined by its importance or level of detail in describing the element using OmnisClass Table 2 Levels.
  - To the extent possible within identity data, the family shall include the CSI Master Format numbering system in the keynotes field and UNIFORMAT Assembly Code.

---

More information and guidance can be found at: https://bimforum.org/Main/Doc/5064-080809/
Naming Convention

Project A

Revit - Daikin-VRV IV-Heat_Recovery-REYQ96_168TTJU_TYDN

Project B

Daikin-VRV IV-HRU -REYQ96168TTJUTYDN
Virtual Design and Construction - Principals

Collective Collaboration
Organized Data
Established Processes
Model What We Build
Build What We Modeled

People, Organization, Process + Technology
Engagement Strategy

0 Internal Team Planning, Alignment, & Setup
- Project Identified – Issue Questionnaire
  - QA - Meeting
  - BT Project Review w/ PM
- Project Approved for BIT Engagement
  - QB - Meeting
  - VDC Standards Download
- Spec Review Process
- Building # Assignment
  - QB - Meeting
  - BMx Creation and Approval
- PCS SPEC APPROVAL / BID
  - QC - Meeting
  - Training Sessions (As Needed)
- Internal Model Setup and Approval
  - QC - Meeting
- Internal Model Setup Completed
  - QD - Meeting
  - Training Sessions (As Needed)

1 External Team On-Boarding, Planning, and Setup
- EXTERNAL CONTRACTOR NTP
  - QA - Meeting
  - VDC Standards
  - Download
  - QB - Meeting
  - VDC Standards Feedback
  - QC - Meeting
  - BMx Review Sessions (As Needed)
- BMx Approved
  - QA - Meeting
  - Training Sessions (As Needed)
  - QB - Meeting
  - BMx Creation and Approval
  - QC - Meeting
  - Model Setup
  - Submittal & MVR Approval
  - Model Setup MVR Approved
  - QD - Meeting
  - Training Sessions (As Needed)

2 Internal and External Design
- Submittal & MVR Approval
  - SCHEMATIC DESIGN
  - SD MVR Progress Review
- Submittal & MVR Approval
  - DESIGN DEVELOPMENT
  - DD MVR Progress Review
- Submittal
  - 100% CONSTRUCTION DOCUMENTS
  - Final Design MVR Approved

3 Construction
- EQUIPMENT SUBMITTALS
  - Submittal & DVR Approval
  - Product Data
  - Field Data
- ACTIVATION / COMMISSIONING
  - Submittal & MVR Approval
  - Substantial Completion
- REQUEST FOR SUBSTANTIAL COMPLETION
  - 4A - Meeting
  - Project Closeout
  - Substantial Completion MVR Approved
  - MDAC Signed and Submitted to PM PCS by BIT
  - Preliminary Model Transfer to GIS by BIT
- SUBSTANTIAL COMPLETION
  - Final Model Transfer to GIS by BIT
  - Submittal of all as-built exterior infrastructure and underground utilities to GIS
- FINAL CLOSEOUT @ SUBSTANTIAL COMPLETION
Life of a Model – Single Model

- **SFO**
- **General Contractors**
- **Architects & Engineers Trade Partners**

**Verify Existing Conditions**

1. **Existing Conditions**
2. **SD Model**
3. **DD Model**
4. **CD Model**
5. **Detail Model**
6. **Shop Model**
7. **Fab Model**
8. **Install Model**
9. **As-Built Model**
10. **Record Model**

**Conformed Design Model**
Life of a Model – Dual Model

- Existing Conditions
- Verify Existing Condition
- SFO
- General Contractors
- Architects & Engineers
- Trade Partners

SD Model → DD Model → CD Model → Record Model → Record Model → Record Model → Record Model → Record Model

Detail Model → Shop Model → Fab Model → Install Model → As-Built Model

Conformed Design Model

Architects & Engineers

General Contractors

Trade Partners

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#BIMForum19
Life of a Model – Design Assist

- Existing Conditions
  - Verify Existing Condition
  - SD Model
  - DD Model
  - CD Model
  - Conformed Design Model

- Detail Model
- Shop Model
- Fab Model
- Install Model
  - As-Built Model
- Record Model

Architects & Engineers
General Contractors
Trade Partners
SFO
BIMx Dashboard

Project Information

Courtyard 3 Connector Project

Owner: San Francisco Airport Commission
Estimated Cost: $145,000,000
Building Number: TBD
Contract Number: 10072
Contract Type: Design-Build
Other Information:

Description:
The Courtyard 3 Connector Project scope will include design and construction of a new pre-security and post-security connector between Terminal 2 and Terminal 3, as well as an approximately 100,000 square foot adjacent building for office space, tenant lease space, passenger amenities and lounges or other Airport and tenant needs. The Project will provide systems connectors and a baggage handling system right of way for future modifications.

The Project will also perform as needed make-ready activities in anticipation of the new building. These may include, but are not limited to, additional shell spaces in Terminal 2 in order to maintain operations and systems related to critical Airport facilities such as the Emergency Operations Center and Security Operations Center and/or any associated systems.

Standard
BIM Guide
CAD Standard
GIS Standard
Revit Standard
Sheet Numbering Guidelines

Version
V2017
V2015
V1.1
4/1/2018

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#### February 2019

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- **Completed Tasks:** 14
- **Scheduled Upcoming Tasks:** 14
- **Overdue Tasks:** 8
BIMx Dashboard

**BIM Uses / Processes**

**Phase**: All

**Facility #**: All

**Discipline**
- Architecture
- Civil
- Electrical
- Mechanical
- Plumbing
- Specialty
- Structural

**Responsible**
- BIM Manager
- DB Team

**Process Category**
- 3D Design Coordination

---

**Clash Coordination - Design**

3D Design Coordination

The process of resolving design conflicts in a federated model using a BIM based coordination software with the primary goal of eliminating design and construction conflicts prior to fabrication and/or installation.

**Required LOD**: 200

**Resulting LOD**: 250

**Process Step** | **Responsible** | **Software/Tools**
--- | --- | ---
1. Setup - Setup folder Structure | BIM Manager | File Explorer
2. Setup - Append Models | BIM Manager | Navisworks
3. Setup - Generate | BIM Manager | Navisworks
4. Generate - Distribute clash report | BIM Manager | TBD by Control
5. Coordination Meeting | DB Team | Other
6. If Clashes remain, repeat Clash Detection | BIM Manager | Navisworks
Element Description
heat removal devices used to extract waste heat to the atmosphere.
Model & Data Validation Report Transmittal

Project Name: Boarding Area B
Submitter: Rahul Thakur
Submission Date: 4/1/2019
Milestone: 5 Gate
Report Author: Ryan Morsch
Report Date: 3/14/2019

Report Contents:
- Cover Sheet/Transmittal
- Coordinate System Alignment
- Model Readiness Results
- Appendix: MVR Corrective Actions
- Data Validation Report

Purpose:
The Airport verifies the incremental development of models to avoid the need for last-minute, extensive design- or reorganization. The checks are based on current industry best practices and SFO BIM Standards which prescribe proper modeling and data techniques. All corrective actions must be incorporated by handover. Follow recommended corrective actions as appropriate after intermediate reports.

List all models submitted below. Check ‘yes’ for models which contain data requiring review. Insert rows as needed. Please note, some checks are mandatory at all milestones and will be reflected accordingly.

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Data Validation Report

Project Name: BAB Model Name: SFA-71-BAB_A.rvt - Door

Attribute Name

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#BIMForum19 #DBIABIMForum19
## Model Validation Report

### Periodic Model Fidelity Checks

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<th>Check Name</th>
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### Instructions

The cell highlight indicates whether a corrective action is mandatory or suggested. If a cell is highlighted red, then the corresponding value is beyond the acceptable threshold and must be resolved by the next BIM Submission.

Please refer to the Appendix of Corrective Actions for more details.
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BIG Room
Virtual Design and Construction - Principals

People, Organization, Process + Technology
BIM to GIS

- 911 Communications
- Facilities Maintenance (CMMS)
- Space Planning
- Commissioning
- Wayfinding
- Indoor Navigation
BIM to GIS Network
Geoffrey Neumayr
Chief Development Officer | Planning, Design & Construction
San Francisco International Airport

Josephine Pofsky
Director of Infrastructure Information Management
San Francisco International Airport