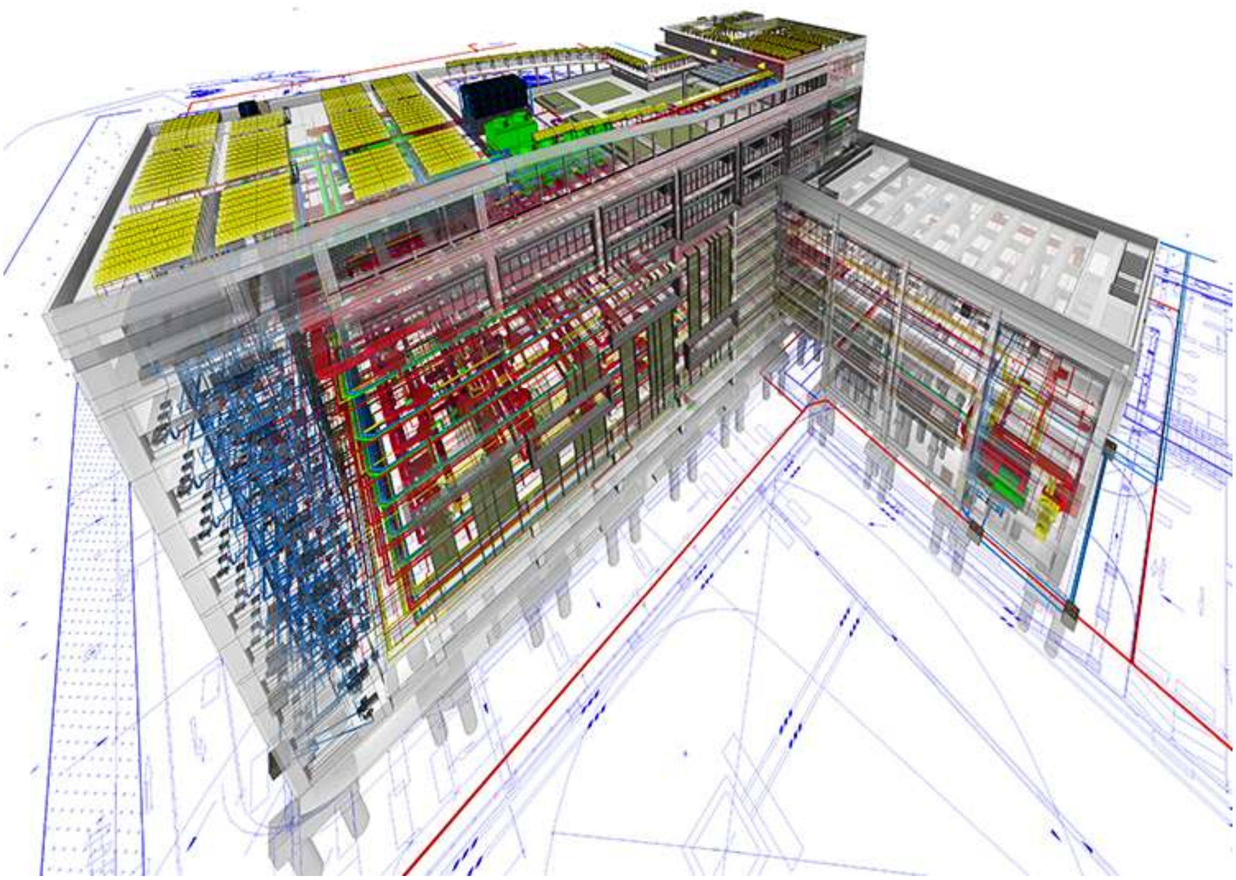
Building and Construction Authority

BIM Essential Guide

For Collaborative Virtual Design and Construction



BCA ACKNOWLEDGES THE LEADERSHIP PROVIDED BY THE BIM STEERING COMMITTEE IN SUPPORT OF THE PRODUCTION OF THE BIM ESSENTIAL GUIDES

THE BIM ESSENTIAL GUIDES HAVE BEEN DRAFTED BY THE CENTRE FOR CONSTRUCTION IT ON BEHALF OF BCA AND THE BIM STEERING COMMITTEE.

BUILDING AND CONSTRUCTION AUTHORITY

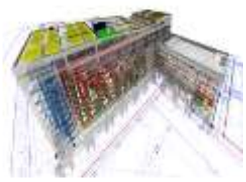
52 JURONG GATEWAY ROAD

#11-01

SINGAPORE 608550

WWW.BCA.GOV.SG

FIRST PUBLISHED FEB 2015



COVER IMAGE AND DESIGN COURTESY OF RSP ARCHITECTS PLANNERS & ENGINEERS (PTE) LTD AND THE BCA ACADEMY OF THE BUILT ENVIRONMENT.

CONTENTS

CEO'S MESSAGE

Dear readers,

Building Information Modelling (BIM) has gained much traction in recent years as digital construction technology that will fundamentally transform the building and construction industry practice in the delivery of an excellent built environment. It is a game changing technology that will improve the construction productivity as well as the level of integration and collaboration across the various disciplines in the construction value chain. It is therefore important for the industry to embrace the technology with clarity.

The BIM Essential Guides are part of the industry's efforts to demystify BIM and to give clarity on the requirement of BIM usage at different stages of a project.

Under the leadership of the BIM Steering Committee chaired by Er Lee Chuan Seng, Emeritus Chairman, Beca Carter, and comprising of leaders in BIM, the BIM Managers Forum has contributed much time and effort to compile the various best practices to make this Guide possible over a short span of time. We would like to thank them for their contribution.

We hope that every BIM user can truly reap the benefits of BIM by integrating it into his/her day-to-day workflow – from feasibility study to facility management. We hope that BIM users can use these guides as a platform to jumpstart their BIM adoption, before they leap to greater heights, innovating and transforming their workflow.

BIM is a journey. We envisage that it will grow with time and will inspire more advanced and innovative use of BIM. I would like to encourage all BIM practitioners to join in this industry effort to grow this Guide into a wealth of BIM knowledge.

Dr John Keung

ACKNOWLEDGEMENTS

BCA would like to acknowledgement the contributions of the following organizations which had provided their valuable inputs in the development of this guide:

Gammon Pte. Limited	Mr Shanmugam Satheeshbabu
Hexacon Construction Pte Ltd	Mr Yap Hong Keng
Kimly Construction Pte Ltd	Mr Choo Tat Jin Mr Pang Por Quee Ms Jolyn Ng Shi Hui
Lian Soon Construction Pte Ltd	Mr Louis Tay Bok Hock
M+W Singapore Pte Ltd	Ms Tian Ai Ling
Obayashi Singapore Pte Ltd	Mr Soe Min Tun
Shimizu Corporation	Mr Gan Chee Meng
Straits Construction Singapore Pte Ltd	Mr Edmund Leong
Takenaka Corporation	Mr Tsukasa Ishizawa Mr Hajime Iseda
Tiong Seng Contractors Pte Ltd	Mr Lim Tee Yoke Mr Ye Zaw Lin
Teambuild Construction Pte Ltd	Mr Stanley Chia
WohHup Pte Ltd	Ms Ang Kooi Fung Mr Phan Manh Quyet
GS Engineering & Construction Corporation	Mr Park Jae Hyuk
China Construction	Mr Rob Sanchez
Centre for Construction IT, BCA	Ms Marianne Amores Mr Chidambaram Chidambaram

OBJECTIVES

The objective of this Essential Guide is to provide project teams an overall framework for implementing Virtual Design and Construction (VDC) on a project basis. The scope of this guide will cover a portion of the design stage, specifically design coordination, and continues all the way to construction execution. All of the various stages as outlined in the framework will be covered in detail in the following chapters.

However, VDC implementation is dependent on several factors such as the client requirements, the availability of technical expertise in the firm, as well as the project delivery method (e.g. traditional method or Design and Build method). This guide also places emphasis that successful implementation is not just a result of good application of technology (BIM), but also an understanding of production theory, application of lean principles, and engagement and commitment of key stakeholders.

The outcome of the implementation of VDC is to truly address constructability in a rigorous way so as to remove all forms of constraints that could otherwise be missed until actual execution. The potential benefits would include reduced schedule variability, smoother workflow, and increased productivity.

AN INTRODUCTION TO VDC

Virtual Design and Construction is a visual management process which integrates technology (BIM) together with project team organizational and production processes from design to construction in order to achieve explicit results, most specifically, to improve overall project productivity.

The framework for VDC shall cover four stages, namely:

1. **DESIGN COORDINATION**
2. **CONSTRUCTION COORDINATION**
3. **VIRTUAL PLANNING**
4. **EXECUTION**

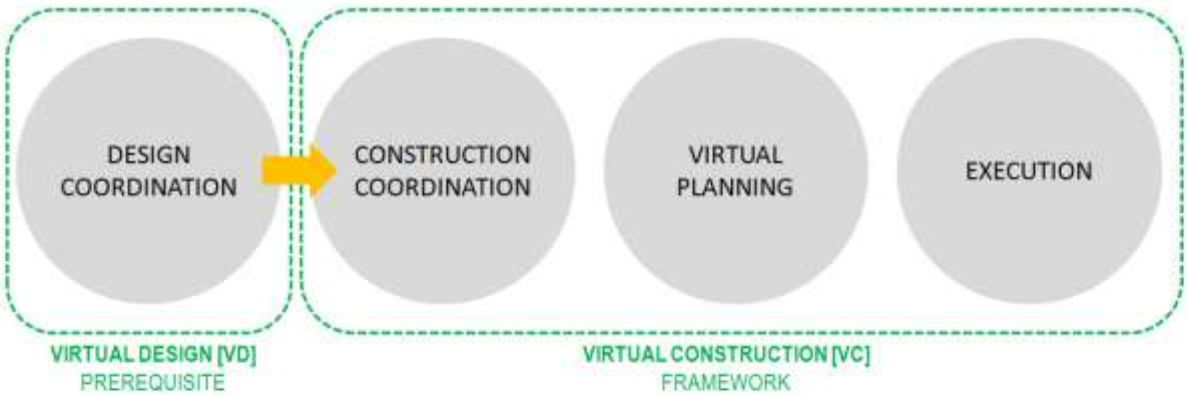


Figure 1: Scope of VDC

Wherein Design Coordination shall serve as the Virtual Design (VD) prerequisite especially when it comes to:

- ✓ A development of a design-intent model which contains a minimum level of quality, coordination, and information that is useful for construction
- ✓ Model handover

Model handover is crucial as it ensures that (1) the main contractors have a good early understanding of the project as per design intent and (2) that they do need to go through the tedious process of recreating the model from scratch based on the issued 2D drawings.

The Virtual Construction [VC] framework then starts after handover. Though it is acknowledged that the range of BIM uses for construction goes beyond what is listed here, to include BIM-based cost estimates, preparation of as-built and FM models, etc, the focus of the guide shall be on the specific BIM uses that directly contribute to on-site productivity and elimination of on-site rework, namely: construction coordination, virtual planning, and execution. In the implementation of the VC framework, the following are considered:

- ✓ A rigorous and thorough study of construction methodology for the purpose of building truly constructible models
- ✓ A removal of all form of constraints at all stages
- ✓ An application of Lean Principles

To streamline the process, it becomes necessary to ensure connectivity between all four stages. To do this, three key strategies have been identified:

1. MODEL WHAT IS TO BE BUILT - develop the design intent model to a construction model that is fit for planning and execution. This is to ensure that the BIM model is developed to a level of detail and coordination to a point where it becomes a true virtual representation of what will actually be executed.

2. "REHEARSE" WHAT IS TO BE BUILT - Utilize the construction model to perform virtual planning for the purpose of removing time, space, and resource constraints before actual execution

3. BUILD WHAT WAS MODELLED AND REHEARSED - Bring BIM to Field and ensure that the crews who will execute the work have a good understanding of the scope "what to build" as well as the method and sequence of construction "how to build".

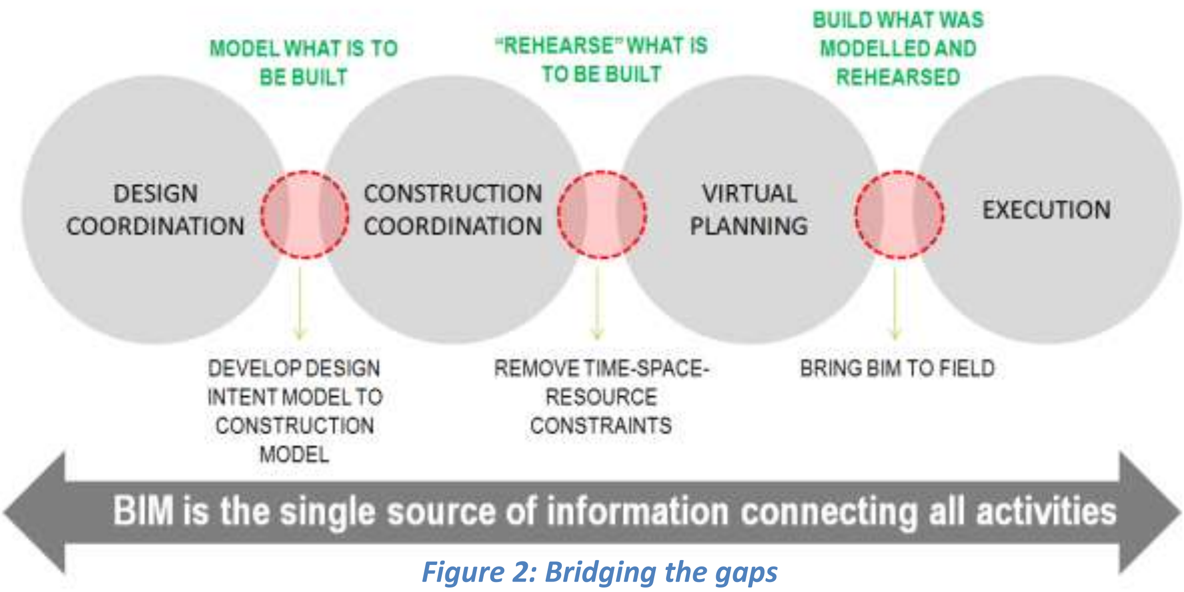


Figure 2: Bridging the gaps

The overall objective is to bridge the existing gaps in our current implementation wherein BIM shall serve as a unifier - a single source of information that streamlines the abovementioned phases as well as serve as a sole platform for communication between project stakeholders.

LEAN PRINCIPLES

The following lean principles shall be taken into consideration as a basis for VDC implementation:

Focus by location and activities per location

1. Focus by **LOCATION**

- During the construction stage, align coordination with the master schedule by focusing on which locations or zones will be executed first in order of priority.
- From the master schedule take the start dates of each zone, list in order of execution sequence, and then backtrack the coordination dates accordingly while ensuring to provide enough buffer time for resolution.
- Critical areas which may require intensive coordination may need to be pushed up front.

2. Focus by **ACTIVITY**

- Activity affects the nature and focus of coordination as well as all deliverables including shop drawings and virtual planning sequences. For instance, the focus of coordination for concrete casting works is different for coordination in preparation for interior fit-out even if it is for the same location.
- The nature of activity also tells us if there are long-lead items that require earlier coordination.

Figure 3: Multiple activities occurring at multiple levels and zones

Coordination by both location (zones) and activity need to be carefully planned and scheduled especially in large projects where multiple activities are occurring at every level simultaneously.

Implement a make-ready process

Make activities ready for work by removing constraints and ensuring all prerequisites have been provided for to release that task. Applications of this principle include:

- Ensuring on-time or early involvement of subcontractors especially for trades in which input is required for coordination.
- Further developing design intent models to constructible models to make them ready for use in coordination, shop drawing extraction, quantity take-off, and detailed virtual planning. Thorough and accurate coordination and quantities depend on accurate models.
- Making use of the construction model to do look-ahead planning in order to remove time, space, and resource constraints when it comes to actual execution.
- Briefing the crews on the scope of work before actual execution, highlighting critical items and areas to watch out for to make sure they understand what and how to build.

Figure 4: The make-ready process

Get the right people involved at the right time

Making any task ready would require input from key stakeholders, most especially those who will actually execute the activity (subcontractors and specialty contractors). For different stages, stakeholders involved would typically be the following:

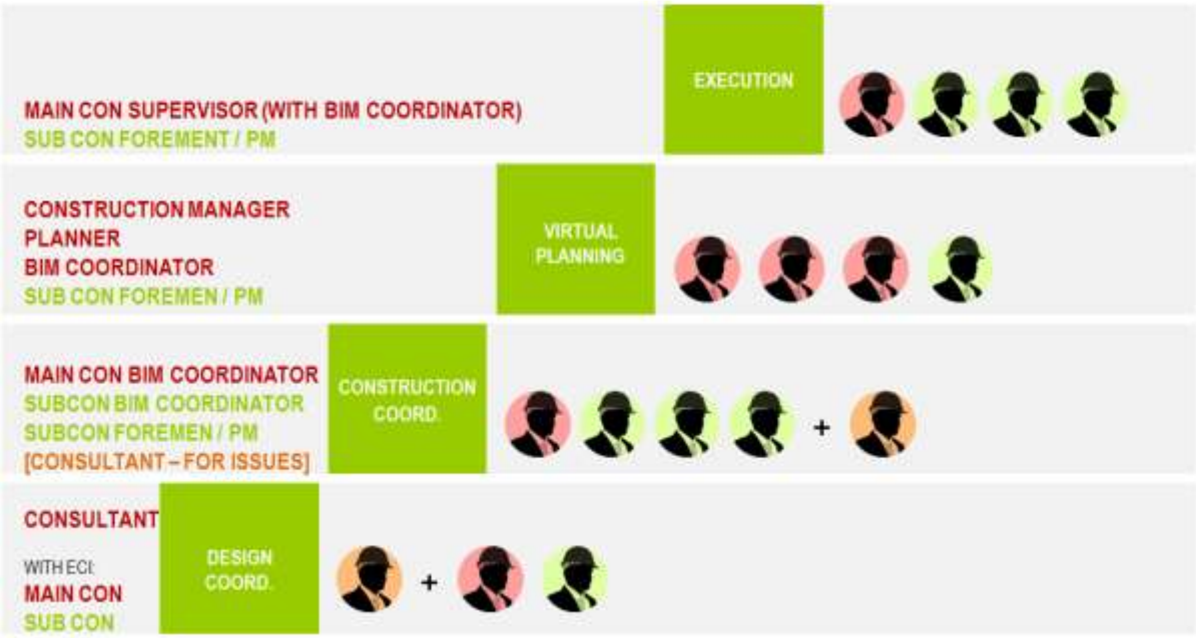


Figure 4: key stakeholders involved by stage

*ECI: Early Contractor Involvement

- During design coordination, the consultants take the lead to clear all design-intent related issues. In projects where there is Early Contractor Involvement (ECI), the main contractor (and subcontractor if on-board) will be providing their input especially when it comes to construction methodologies and coordination.
- After the model is handed over for construction, the contractor takes over to start trade coordination together with sub-contractors. Ideally coordination is done through co-location as in a "big room concept" in order to resolve issues together and receive updates instantaneously. Any issue that cannot be resolved internally can be raised to consultants through coordination meetings.
- Virtual planning combines both methodology and BIM to arrive at an optimized plan and therefore the expertise of the people who know the methodology (the construction manager, planner, subcontractor foremen, etc.) need to be integrated into BIM and the model must update accordingly.
- Translation of the coordinated model from BIM to field requires that the actual crews (or at least their foremen) be engaged and their scope of work and method of work is communicated to them.

DESIGN COORDINATION

This chapter will focus on the level of model quality and coordination that is to be achieved during design phase. Coordination will focus on three aspects:

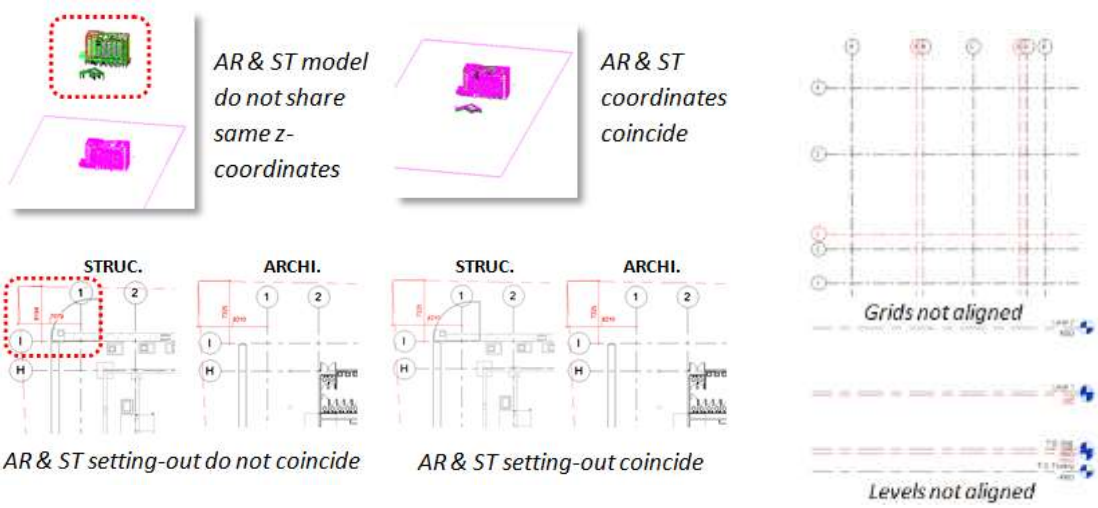
- ✓ Control elements
- ✓ Intra-discipline checks
- ✓ Intra-discipline coordination

Control elements

The teams shall agree and define common key project control elements like origin point, orientation, boundary setting out, grids and levels. The architectural team shall define the control elements and rest of the project team need to follow the settings. First step in coordination is to check the alignment of control elements between various models.

- **Origin point** of the project shall be drawn in the SVY21 coordinate system and with reference to the SLA Vertical Control Point (VCP) plus 100m.
- **Orientation** of the project shall be based on true/actual north.
- **Setting-out** of the project shall be based on the known boundary points and boundary lines.
- **Grids** are the planner control elements used to set-out the building elements on site. Grids also used in communicating the location of issues during coordination process.
- **Levels** are the vertical control elements used to set-out the building elements floor by floor. Levels also used in communicating the location of issues during coordination process.

  Note: Structural consultants may opt to have separate structural floor levels from the finish floor levels given in the architectural model. This is may be acceptable so long as the difference in drop from the FFL is logical and consistent and that there is a corresponding structural floor level for every finish floor level.



Intra-Discipline Quality Checks

Models from every discipline must ensure a minimum level of model quality, consistency, and intra-discipline coordination specifically in terms of the following:

- **Modelling using correct objects** - elements have to be modelled using the correct system family and/or category in order to avoid errors and missing elements in quantity takeoffs and schedules
- **Object information** - All model elements must contain minimum information for construction. Model practices which contribute to ambiguity and inconsistency include:
  - Use of generic types such as walls or pipes
  - Inconsistent naming conventions
  - Insufficient / ambiguous information embedded in type names
- **Overlaps and duplicates** – this is to check that there are no multiple instances of the same element and no major overlaps of the same category which might lead to inaccurate quantities especially for the following elements:

ARCHITECTURAL	STRUCTURAL	MEP
Floors Walls Windows Doors Ceilings	Columns Footings	Mechanical equipment Air terminals Plumbing fixtures Lighting fixtures Electrical equipment

- **Intra-Discipline clashes** - This is to ensure that there are no major clashes and overlaps between element categories e.g.:
  - wall to floor
  - duct to duct
  - footing to footing
  - wall to ceiling

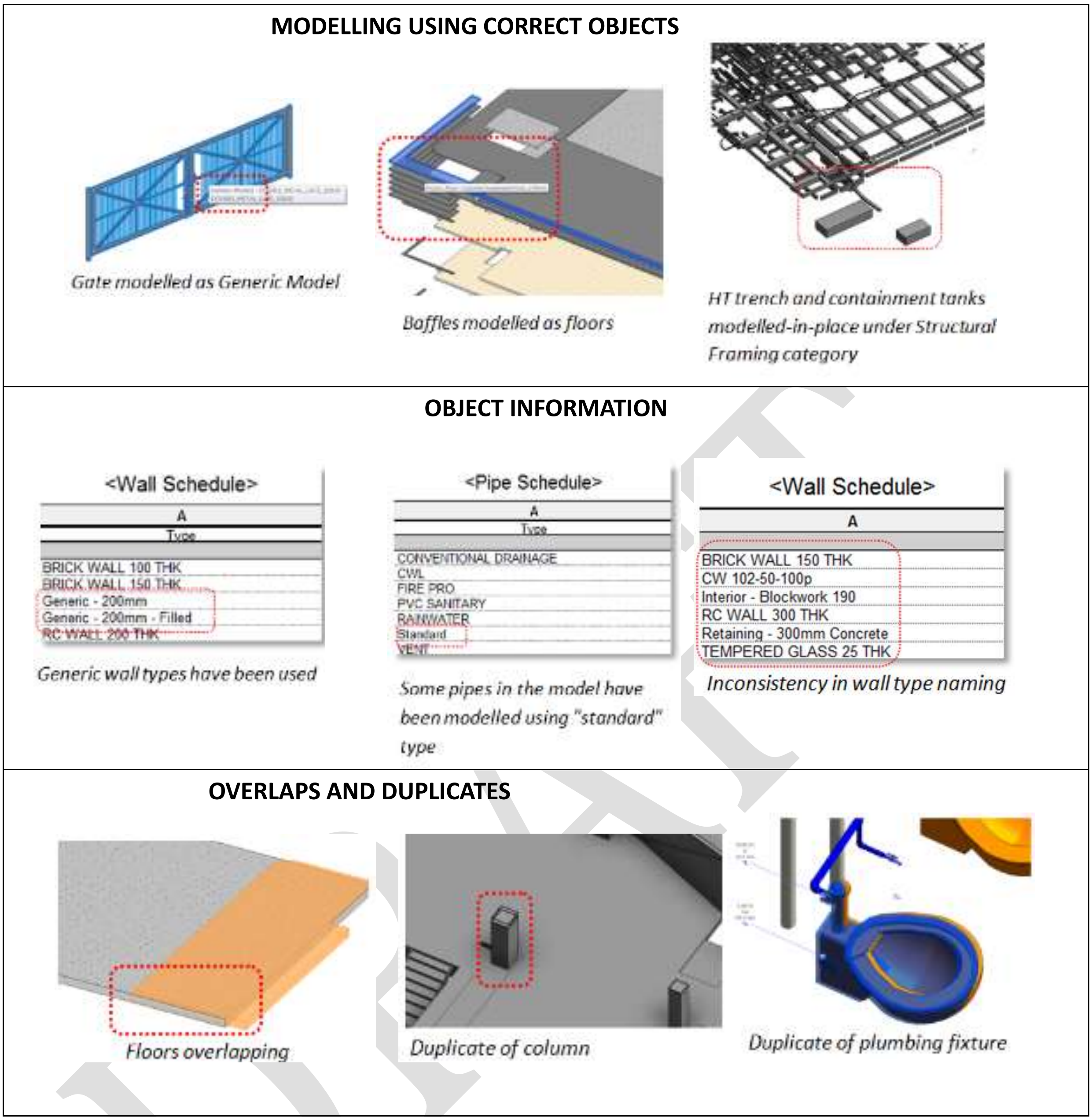


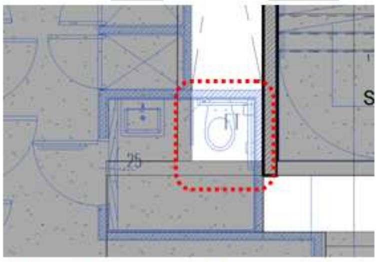
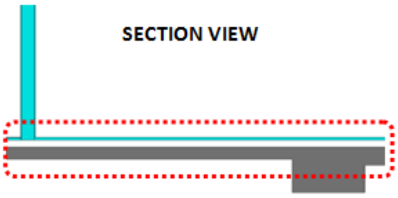
Figure 5: samples of intra-discipline issues

Intra-Discipline Quality Checks

Intra-Discipline checks do not just include hard and soft clashes but also alignment and consistency between key elements. Critical items for coordination are the usually the following:

- **Architectural-Structural alignment of floor plate** - Since the architectural layout is the key reference for structural setting out, this is ensure that the structural elements such as beams and slab align with the architectural model with allowance for finishing thickness specifically along the **perimeter and the openings of the floor plate**.

- **FFL & SFL** - This is ensure that the structural slabs and beams are in their correct levels considering architectural finish thickness and drops in levels.
- **Columns and structural walls** - The focus is mainly on the load bearing columns/walls. This is to make sure the columns/walls coincide in both the models and the size were reflected respectively. This is required for clear space checking in Architectural model and for design checking in Structural model.
- **Architectural openings through structural walls -** This is to ensure that all architectural openings such as windows and doors that go through structural walls have a corresponding opening in the structural model of the correct size. This is also to check that there are no major clashes between doors and windows and the structure.
- **Ceiling to structure** - This check is to ensure that there are no interferences between the structure and all elements of the architectural ceiling, including coves, pelmets, framing, etc.
- **Duct system to major structural elements** - This is to check that there are no interferences between mechanical system and major structural elements such as columns and beams. Also, all ducts that penetrate into slabs and structural walls must have a corresponding structural opening with sufficient clearance all around.
- **MEP services to Ceiling**- This is to ensure that there are no interferences between architectural ceiling and concealed MEP services.
- **Pipe chases and service ducts** - This is to check that all duct and pipe risers fit inside within their assigned pipe chase in the architectural model with sufficient allowance for installation/brackets.

ARCHITECTURAL-STRUCTURAL ALIGNMENT OF FLOOR PLATE	**FFL & SFL**
 *Portion of toilet with no slab in structural model; outline of opening not coinciding.*	 *Gap between structural slab and architectural finish*

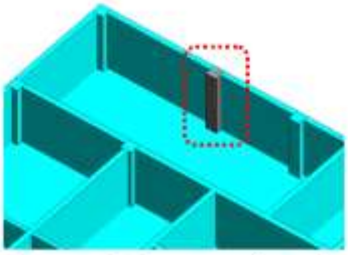
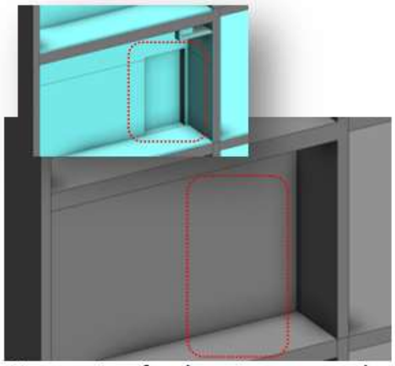
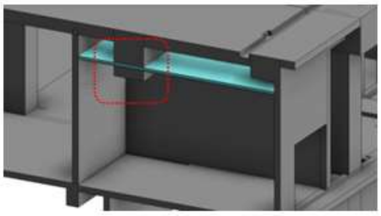
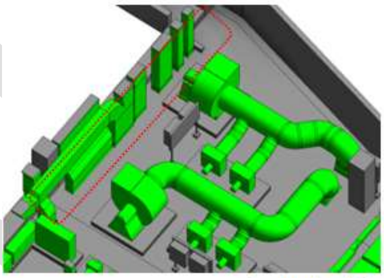
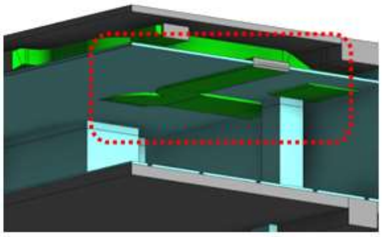
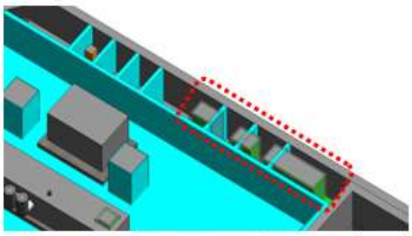
COLUMNS AND STRUCTURAL WALLS	ARCHITECTURAL OPENINGS THROUGH STRUCTURAL WALLS
 *Structural column not reflected in architectural model*	 *No opening for door in structural model.*
CEILING TO STRUCTURE	**DUCT SYSTEM TO MAJOR STRUCTURAL ELEMENTS**
 *Beam clashing with ceiling.*	 *Duct risers penetrate through slab.*
MEP SERVICES TO CEILING	**PIPE CHASES / SERVICE DUCTS**
 *Ducts clashing to ceiling.*	 *Ducts not fitting inside duct chase*

Figure 5: samples of inter-discipline issues

Apart from the abovementioned issues the project team may refer to the **BIM Coordination Matrix** below as guide to which other groupings of categories to focus on in coordination. Each cell in the matrix signify an interaction between two different categories and they have been colour-coded according to the degree coordination it requires.

Figure 6: BIM Coordination Matrix

Legend:	
1	Always require coordination
2	Sometimes have issue
3	Seldom have issue
4	Not related
	Check for duplicates

*Note: The sample is an extract from file **BIM Coordination Matrix.xls**, which can be downloaded from _____________. Please use the excel file as a template and define the project specific BIM coordination matrix.*

The coordination process

The coordination process is similar to the current practice, the main difference is better visualization and communication when done with BIM models. The typical coordination process shall be as shown in the below figure:

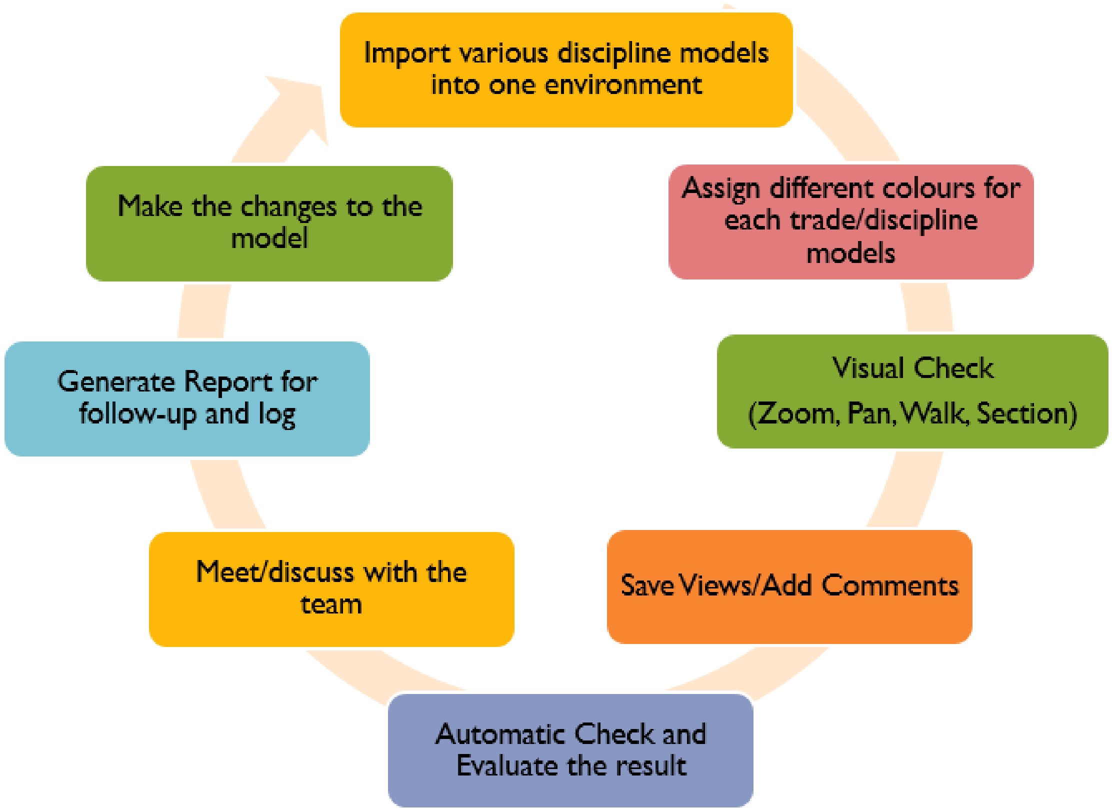


Figure 7: BIM Coordination Step

Coordination Steps

1. **Linking the Models:** The coordination team shall link various discipline/trade models into one environment, simulating the site situation and check each discipline/trade content in relation to others. Most of the BIM authoring and coordination tools allow the team to link multiple models.
2. **Colours:** Assigning different colours for each discipline/trade models is necessary for better visualisation. This will ease the identification of elements when communicated through reports. The team shall agree on common colour code, document in the BEP and follow closely in the coordination process.
3. **Visual and Automatic Checking:** The coordination team may use either visual checks using the navigation tools like walkthrough, sectioning, etc. or automatic checks using checking tools for clash, overlaps, clearance, code compliance etc.
4. **Coordination Meeting:** The project teams shall meet on a regular basis with clear target. Discuss issues identified by the coordination team in visual and automatic checking and decide the resolution and assign responsibility. This need to be document in a report for follow-up.
5. **Report:** The report shall contain issue details, location and process related information. Ex. image with comments, coordinates, levels, grids, element id, date,

time, found by, assign to and resolution. The team shall add additional items based on their project's requirement.

6. **Model Update:** The responsible team shall update the model as per the agreed resolution and re-issue for the next round of coordination.

Tips for efficient coordination

- ✓ Coordinate **location by location**
- ✓ Perform space allocation
- ✓ Coordinate incrementally

- **Coordinate location by location** - Based on a logical sequence, focus coordination location by location. Since the project construction schedule and construction zoning is not yet known at construction stage, sequencing can be by major phase, blocks, or level by level.

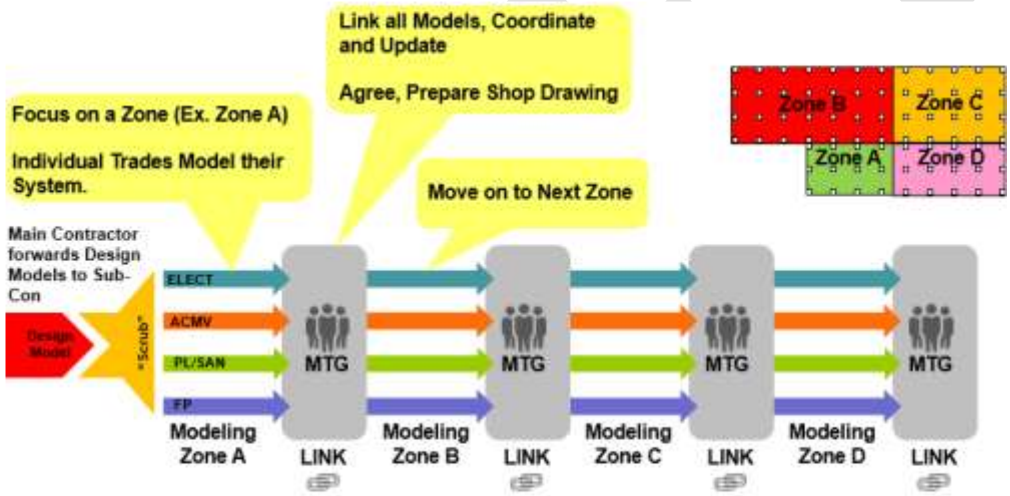
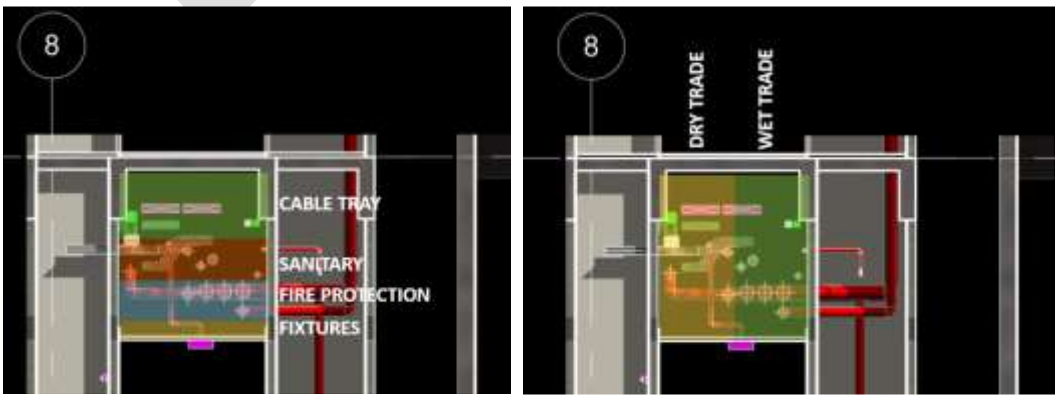


Figure 8: Coordination by location (construction stage)

- **Perform space allocation** - In the case of MEP coordination, avoid unnecessary clashes by performing space allocation for each trade especially for main runs at corridors. Each trade shall model and arrange their services within their zone only.



Model by sequence and coordinate incrementally - another good practice for efficient coordination is to coordinate incrementally, focusing on the items or that will affect coordination downstream.

- ✓ Coordinate architectural and structural disciplines first, making sure to fix and finalize items that will affect MEP coordination downstream, e.g. ceiling height and details, clear headroom height, etc.
- ✓ Perform space allocation and model MEP trades using the AR-ST base model while taking care to avoid clashes and model errors within the individual discipline. Since the ceiling has been fixed, every MEP trade has to ensure that their service fit above the ceiling. If not, highlight the issue at this stage.
- ✓ Coordinate all disciplines and check for inter-discipline clashes. Recheck coordination with architectural and structural disciplines as well as the rest of the trades.

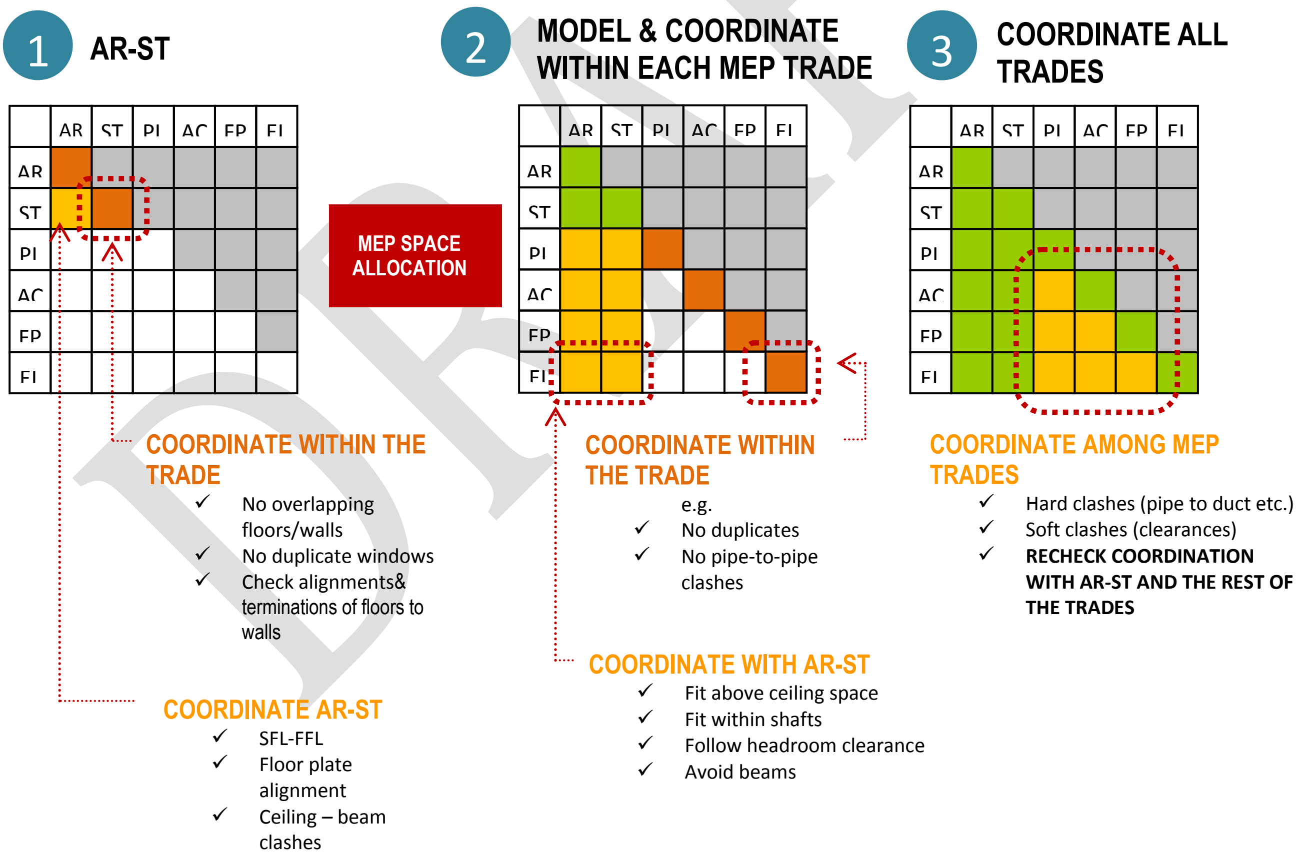


Figure 9: Incremental Coordination

MODEL HANDOVER

Once the design models are sufficiently coordinated, they are handed over to the main contractor for use in construction. Handover may be done by level, zone, etc., according to the order of priority in the construction master schedule. The project team may also opt to issue a tender model to be used as reference. Details of model handover to the contractor such as key dates, break-up of models, etc., shall be written into the BEP.

Model transformation

In the BIM process BIM models were authored by Consultants and issued to Contractors for further development and construction. After construction the As-Built model may be given to Owner or Client or Facility Management team for operation and maintenance. This chapter covers on how the model transforms through this process and when the coordination will take place.

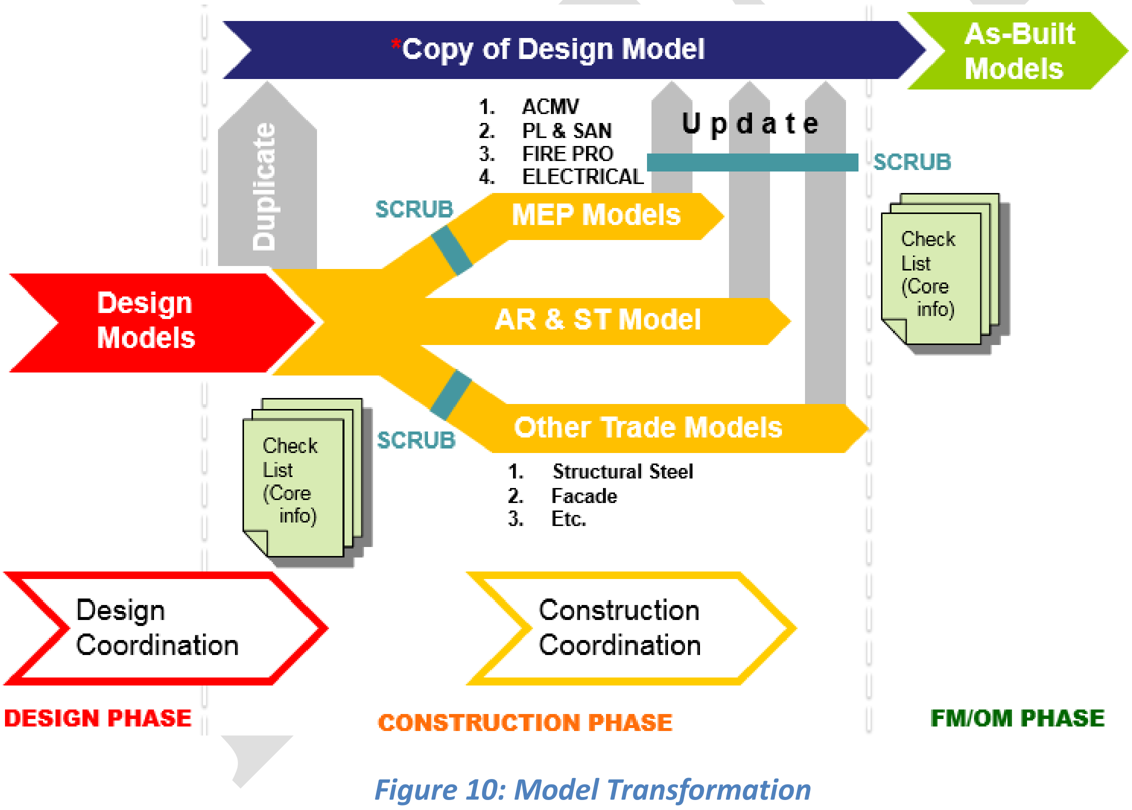


Figure 10: Model Transformation

- Scrub - Cleaning up after review, process and select only the information necessary for the next step or trade.
- Check List – Quality Assurance list based on the Core Information to make sure the expected data is delivered.
- AR & ST model – Architectural and Structural Model.
- *Copy of the design model issued by the Consultants during tender.
- Project team need to decide and agree on responsible party to update the copy of design model as per construction.

Suggested Workflow:

1. Main Contractor receive design models from the Consultants and perform quality assurance.
2. Main Contractor prepares Architectural and Structural Models for Construction and issue only the relevant models (contents) to the respective Sub-Contractors after scrubbing.
3. A Copy of the design models need to be saved as design intent model and updated continually as per construction.
4. Main Contractor coordinates the models from Consultants and Sub Contractors. Once the model is approved the teams shall produce with shop drawing preparation from the models for construction.
5. Project team to issue As-built model during the handing over for the next stage of the project.

Quality assurance

Quality assurance needs to be done before proceeding into the actual process of coordination to make sure the expected data is available from relevant project partners without modelling mistakes. The coordination team shall prepare a checklist based on the following requirements

- **General Quality Checking** – This is to make sure there is no modelling mistakes. Ex. missing elements, misplaced Elements, Duplicates, etc
- **Core Information Checking** – This is to make sure there is no missing elements or parameters specified in the core information requirement.
- **Code Compliance Checking** – This to make sure the model meets Authority's requirement.
- **Constructability Checking**– Checking for issues that leads to potential difficulty and productivity loss in the actual construction. This shall be done in the actual coordination at a later stage.
- **Maintainability Checking**– Checking for issues that leads to potential difficulty in operation and maintenance after construction. This shall be done in the actual coordination at a later stage.

Once the check list is ready various methods and tools shall be used to quality check the model. Ex. Schedules, Intelligent Objects, Colour Coding, Interference Checking, Add-on Tools, etc.

Schedules

Schedules can be created in all BIM authoring tools. This shall be used to check both geometric and non-geometric data specified in the Core Information.

<Columnd Schedule>

A	B	C	D	E	F	G
ID	Name	Type	Length	Existing	Loading	Concrete Grade
Level 1						
A1	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B1	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C1	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D1	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A2	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B2	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C2	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D2	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A3	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B3	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C3	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D3	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A3	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B4	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C4	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D4	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A4	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B5	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C5	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D5	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A5	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
B5	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
C6	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
D6	Concrete-Rectangular-Column	300 x 450mm	3000		0.00 kN	C40
A1	Concrete-Rectangular-Column	300 x 450mm	300		0.00 kN	C40
SB1	Concrete-Rectangular-Column	300 x 450mm	300		0.00 kN	C40
SC1	Concrete-Rectangular-Column	300 x 450mm	300		0.00 kN	C40
SD1	Concrete-Rectangular-Column	300 x 450mm	300		0.00 kN	C40

Missing Data

Figure 11: Column Schedule

Door Schedule

Family	Door Type	Height	Width	Count
1st Storey Level				
Dbl Glass (3)		2375	1975	1
1				
M_Double-Flush		2100	1600	1
M_Double-Flush		2100	1800	2
M_Double-Flush		2100	1852	5
M_Double-Flush	FD	2324	1200	6
M_Double-Flush		2324	1900	12
M_Double-Flush	FD	2324	1950	4
30				
M_Single-Flush		2324	500	6
M_Single-Flush	FD	2324	600	6
M_Single-Flush		2324	800	20
M_Single-Flush		2324	1000	5
M_Single-Flush	TD	2324	1050	3
40				
Single - Steel Frame		2100	600	1
1				

Non-standard size, shall be grouped to standardise

Figure 12: Door Schedule

Intelligent Objects

The checking requirements like clear space, coverage, etc…shall be added to the objects and perform the checking. Applicable for maintainability checking as well.

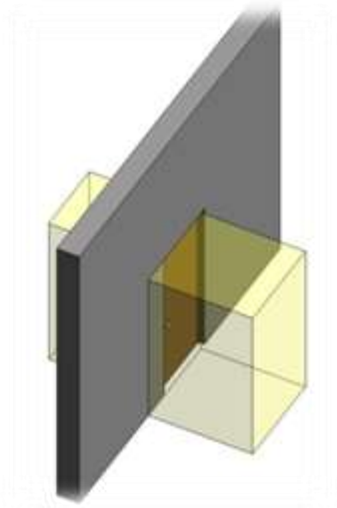
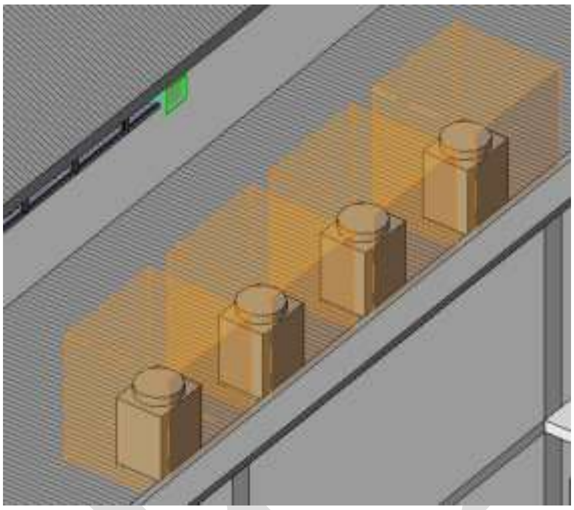



Figure 13: Intelligent object samples

Colour Coding

Colour coding shall be used to visualise the model better based on

- **Elements** – Colour code the elements based on category that allows the identification of wrong usage. Ex. Walls are used for Columns, etc.
- **Parameters** – Colour code the elements based on the parameters that allows the identification of missing or wrong values. Ex. Material, Fire Ratting, Dimensions, Levels etc.
- **Disciplines/Trades** – Colour code the elements based on the disciplines or trades that allows the identification of alignment issues. Ex. Structural Column placed outside Architectural finish, part of the pipe or fitting embed into the wall, etc…
- **Adjacent Structures** – Colour code the elements of adjacent structures to check the interfacing part. Ex. The link bridge between two blocks was connected without any constructability issue.

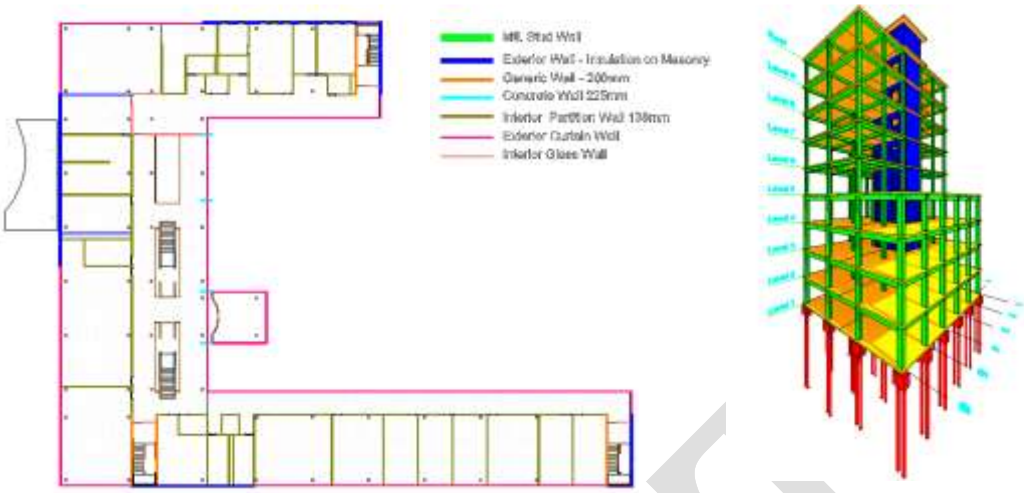


Figure 14: Colour Coding based on Wall Type and Structural Elements – Core Information

Interference Checking

Most of the BIM authoring tools allow the users to perform simple interference checking that can be used to identify overlapping and duplicate elements.

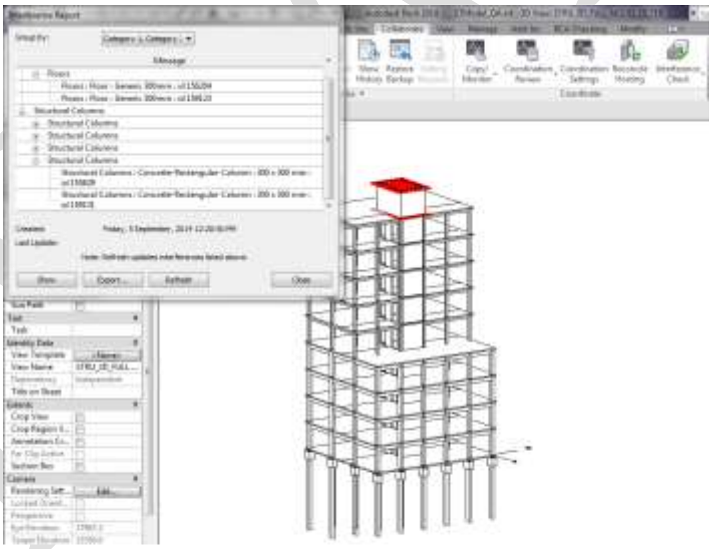


Figure 15: Overlapping and Duplicate Elements

Constructability Checking

Part 3D views shall be created for the critical areas in the design model and alternatives shall be evaluated to ease the construction process.

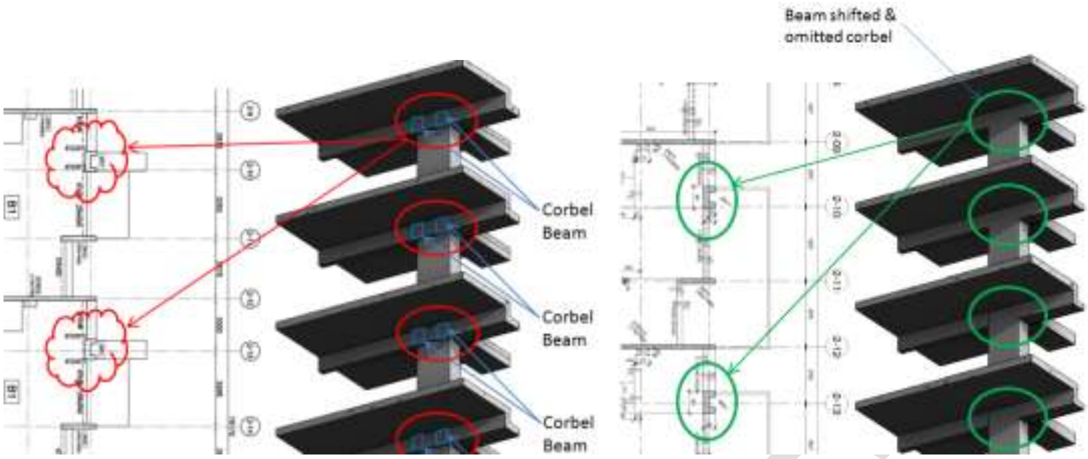


Figure 16: Proposed Design Alternatives – Constructability Checking (Image courtesy of WohHupPte. Ltd)

Customisation and Add-on Tools

Most of the BIM authoring tools have APIs or options to create add-ons that can be used for quality checking.

POST HANDOVER MODEL UPDATING AND COORDINATION

After quality assurance, model updating and coordination ensues to **develop the design model into a construction model.** The objective is to produce a constructible model that is a true virtual representation of the actual installation. This is the most important step in ensuring a very high degree of usability in terms of many aspects in construction, including shop drawing generation, quantity takeoff, visual planning, etc.

> **LEAD:** Main contractor with input from subcontractor. Further issues found are raised to consultants.
> **NOTE**: It is crucial that all relevant subcontractors, especially owner-nominated sub-contractors are on-board early on especially if their input and scopes of work are crucial for coordination.

During Post-Handover Coordination, the model is updated in terms of the following:

- ✓ Model completeness
- ✓ Model accuracy
- ✓ Integration of trade knowledge
- ✓ Provision of tolerance and clearance
- ✓ Actual and as-built conditions

Model completeness

- **Completeness of trades** - If required for coordination and layout, model minor trades that have been missed out in design-intent modelling. Examples of which include:
  - Rainwater down pipes
  - Drainage
  - Water feature
  - Landscape and irrigation
  - BMS
  - System furniture
- **Completeness of BIM elements**- The level of completeness is dependent on the actual BIM usage. Though there may be rules of thumb stating that anything smaller than a certain size need not be modelled, it is important to note that if these items are omitted in the model, it may become very likely that they might also be missed out in actual installation, especially if all layout drawings are extracted from BIM.
- **Further detailing -** some portions of the model may require further detailing if required for coordination, e.g. facade details.

Model accuracy

This pertains to accuracy of the model with regards to manufacturer and subcontractor details especially in terms of the following:

- Update MEP equipment to actual overall size
- Update ducts, pipes, cable trays, trunking, to final, reviewed sizes
- Use actual fittings or at least adapt overall fitting size
- Update connector locations especially for plumbing fixtures
- Update ceiling frame thickness to subcontractor details (there may be no need to model in the actual frame, but the frame thickness is required for coordination)
- Update curtain wall to subcontractor details (level of detail may be dependent on what is required for coordination)
- Update key methodologies such as pre-cast, PPVC, etc. according to subcontractor details.

Integration of trade knowledge

- Bending constraints and requirements for pipes, ducts, cable trays, etc.
- Grouping or clustering of services
- Proximities or adjacencies between wet trades and dry trades
- Verification of compliance of codes of practice

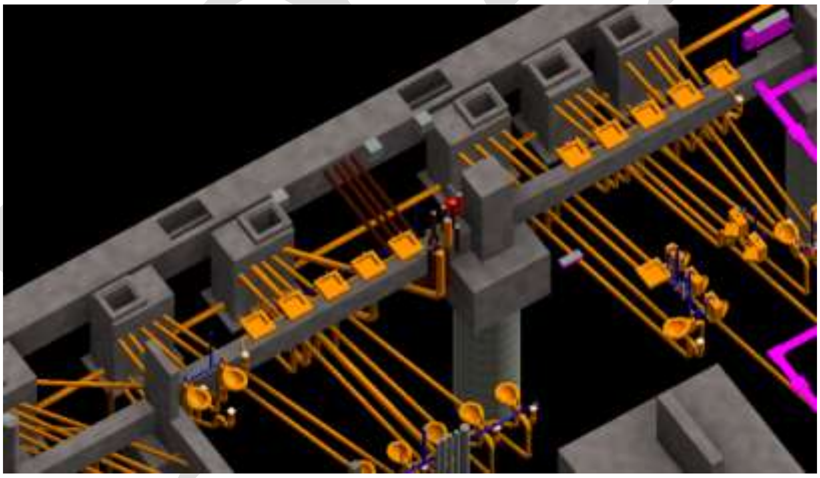


Figure 17: Code compliance for ICs (inspection chamber)

Provision of tolerance and clearances

- Maintenance clearance and accessibility for:
  - Equipment access above ceiling
  - Ceiling access panels
  - Cable trays
  - Service clearances around equipment

- Installation clearance (e.g. 100 mm all around every pipe, duct, cable tray or enough for a hand to reach)
- Tolerance for installation error (this may double or occupy the same space as installation clearance)
- Service clearances around equipment
- Bracket spacing and clearance

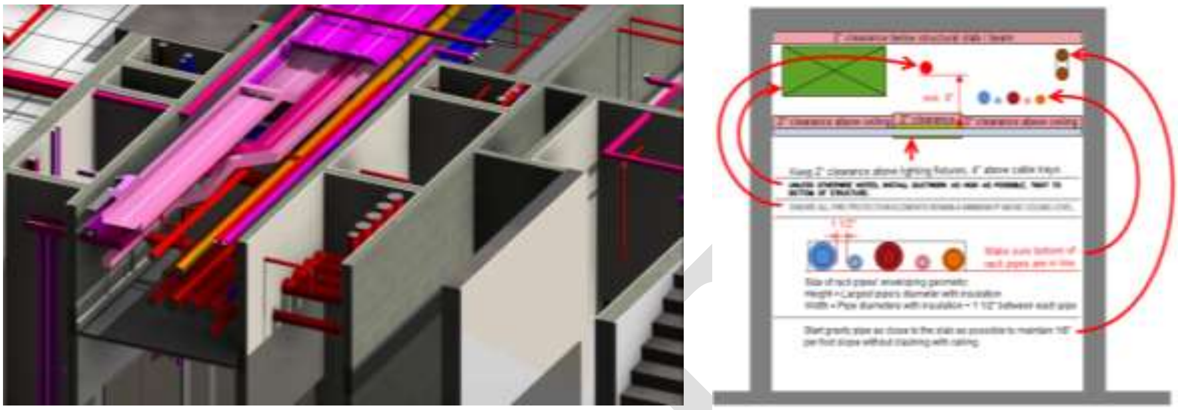


Figure 18: MEP arrangement across service corridor

Actual and as-built conditions

This includes a physical assessment of the actual condition at site. For better accuracy and efficiency, It may be worthwhile to capture this through technology such as laser scanning, and then import the point cloud data into the model to develop into an as-built model or even just to superimpose as reference. Some samples of these key existing conditions include:

- Existing underground services, drains, etc.
- Actual surveyed topography, road levels, etc.
- Existing building (in the case of A&A works) with special focus on where and how the new portion connects in terms of levels, location of beams, etc.
- As built information on newly constructed areas (i.e. exact location of piles to check for eccentricity, installed location of MEP services to check against coordinated model, etc.)

Construction Coordination

Recheck coordination after or while updates to the model have been made. Focus coordination on critical items that are specific to the actual activity.

For instance, if the activity is casting works for a suspended slab, the points of focus for coordination would be everything that would affect casting, such as:

- Coordinated SFL/FFL

- Final and coordinated outline of both architectural and structural floor plate (especially around perimeter and openings)
- Openings / block-outs through slab and walls
- Penetrations and embedment through slabs, beams, concrete walls

RFIS

Through the course of coordination with sub-contractors, if there are any issues that need to be resolved with the consultants, they may be raised during technical meetings or even through communicating the issue directly through BIM-based RFIs.

Communicating through BIM is necessary for easy identification of the issues and location. BIM Collaboration Format (BCF) is one of the best options available to communicate through BIM. BCF is in XML format with very small file size. In BCF, there is an option to attach elements orsitephotos to the issues. Most of the BIM authoring tools and collaboration tools supports BCF import and export.

- Revit and Navisworks has 3rd party plugins from the link http://matteocominetti.com/category/bcf/
- TeklaBIMSight's note is a BCF file.
- Solibri Model has abuild-in function to export and import BCF files.
- ArchiCAD has a build-in function to export and import BCF files.

Figure 19: Autodesk Revit

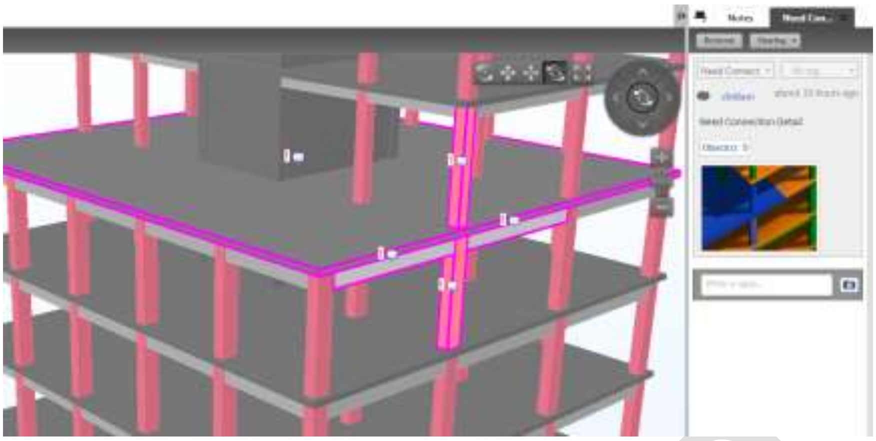


Figure 20: TeklaBIMSight

VIRTUAL PLANNING SEQUENCES

By the end of the Post-Handover Coordination period, the model for that specific area must now be an accurate representation of what is to be actually built on site. Though a fully coordinated model may not be a prerequisite to do all detailed virtual planning sequences such as site logistics, excavation, etc., it may be required activities such as MEP planning and sequencing.

The purpose of virtual planning is to "rehearse" actual execution in terms of methodology, sequences, movement of equipment and crews, etc. This exercise helps identify and remove constraints related to the execution of this particular activity, especially with regards to accessibility, logistics, and resources.

It may not be necessary for detailed virtual construction sequences to be carried out for all activities, only those that are absolutely critical.

Identifying critical areas and activities

Activities may be critical in terms of the following:

Figure 21: Sample of critical areas and activities

1. **Critical by SCHEDULE**

   - Is this activity part of the critical path?

   - Will reducing the cycle time for this activity, (e.g. typical casting of typical floors) potentially compress the overall master schedule?

2. **Critical AREA**

   - Does this particular area have a high level of interaction between trades? (e.g. MEP Plant room, above ceiling corridors, building envelope)

   - Is this area particularly complex and/or unique?

   - Is the space congested? Will it restrict access for equipment or other items to be installed?

3. **Critical by RESOURCE**

   - Is the activity constrained by a limited number of resources such as cranes, crews, equipment, temporary works, etc.?

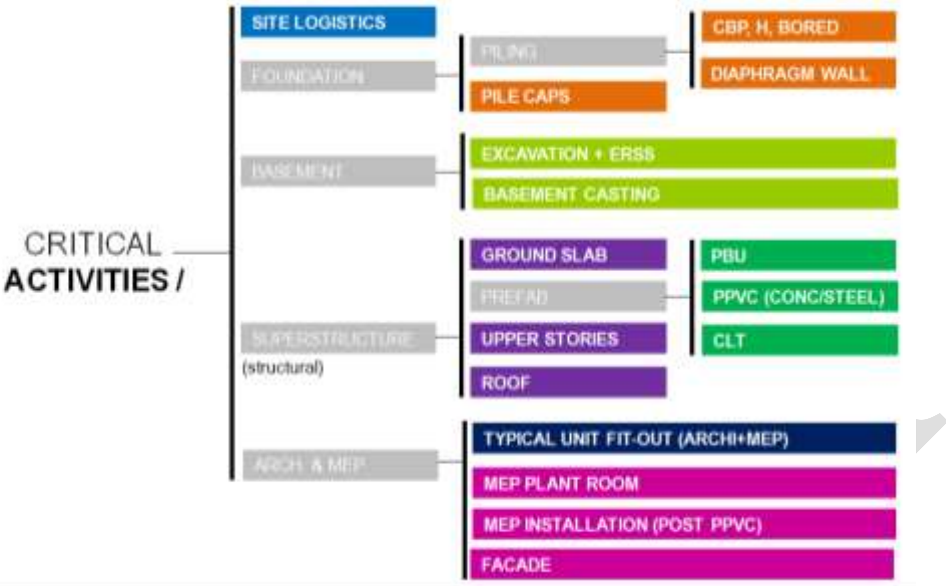


Figure 22: Sample of critical areas and activities

Identify key stake holders who should be involved in visual planning

Sometimes, the valuable inputs are just from those who direct the work, but also from those who are actually responsible for physical construction, i.e., the subcontractor foremen and supervisors. As such, they must be engaged in order to ensure that the virtual planning sequence is as feasible and as realistic as possible. The key personnel who should be engaged in virtual planning sessions are typically the following:

- **Construction manager** - and/or the person responsible for methodology, sequence of works, zoning, dependencies of tasks, constraints etc.
- **Planner** - provides durations and translates the planned sequence into a detailed schedule
- **BIM manager / coordinator / modeller** - updates the BIM model in terms of the methodology, zoning, sequencing, etc. and prepares a simulated model and / or snapshots.
- **Subcontractor project manager / foreman** - provides information in terms of resource, installation procedure, and verifies workability of the virtual plan. Since their input in terms of these aspects have been acquired, at the end of the virtual planning exercise, the subcontractors much provide commitment to what has been planned and sequenced.

Identify KPIs

Identify objectives for each virtual planning exercise. KPIs must be identified and communicated up front in order to focus the project team on key deliverables. Samples of which may be:

- Reduce cycle time
- Reduce variability
- Reduce batch size

Virtual Planning Pre-requisites

- **BIM model** - the model must be reasonably complete, updated, and coordinated to do a virtual construction sequence, though it will depend on the activity to be planned. For example, it is logical to expect that virtual sequencing of MEP installation requires that the services to be installed need to be complete and modelled according to the actual intended routing as verified by the trade contractors. As was mentioned, not all activities require a fully coordinated or even complete model.
- **Information** - information as to actual methodology, resources, constraints, etc.
- **Resources** - number of crews, number and types of equipment, temporary structures, etc.

Virtual Planning Steps:

METHOLOGIST	BIM MODELLER / COORDINATOR
ZONING: Determines casting or execution zones (according to access, tower crane reach, etc.	**ZONING**: Groups or split the model accordingly to the determined zones. i.e.: - Split the slab and beams into pour zones - Split concrete walls and columns into casting heights - Group piles and footings according to zones - separately model off-site or prefabricated items **BIM TOOLS:** Splitting and grouping may be done in most authoring tools, but this is perhaps the most tedious way especially in terms of change management. Alternatively, there are 4D planning tools which allow for non-destructive model splitting within the 4D software.

TEMPORARY STRUCTURES: Identifies required temporary structures such as formwork systems, scaffolding, etc. Obtain method statements and shop drawings from the supplier / subcontractor.	**TEMPORARY STRUCTURES:** Models temporary structures as per supplier shop drawings, details, and method statements. NOTE: model what is only required for visual planning. For example, modelling scaffolds may not be necessary unless in a unique scenario where it is critical to study sequence of scaffold assembly and disassembly.
SEQUENCE: Determine sequence of work (which zone to cast first, which footings to pour first, etc.)	**SEQUENCE**: Assigns special parameters to the model elements, or apply "phases" to assign them to a specific order NOTE: At this point applying phases and taking "snapshots" may be sufficient to convey as site instruction, if relaying exact sequences is needed and durations are unnecessary.
SIMULATION: Planner converts methodology into detailed schedule format and provides durations	**SIMULATION:** Links model elements to activities in 4D tool and runs simulation. Movement of equipment such as cranes may also be animated if required. After the simulation is run, it is reviewed and optimized until final.

Virtual planning may require numerous iterations as the sequence is reviewed and optimized after every exercise until such time the objective has been achieved.

Virtual Planning Output:

Since the model has been even further detailed and split into exact execution zones, more information may be extracted at this stage such as:

- Cut and fill quantities
- Concrete quantities (by zone)
- Phased model and phase-by-phase snapshots
- Simulation

COMMUNICATION AND TRANSLATION FROM BIM TO FIELD

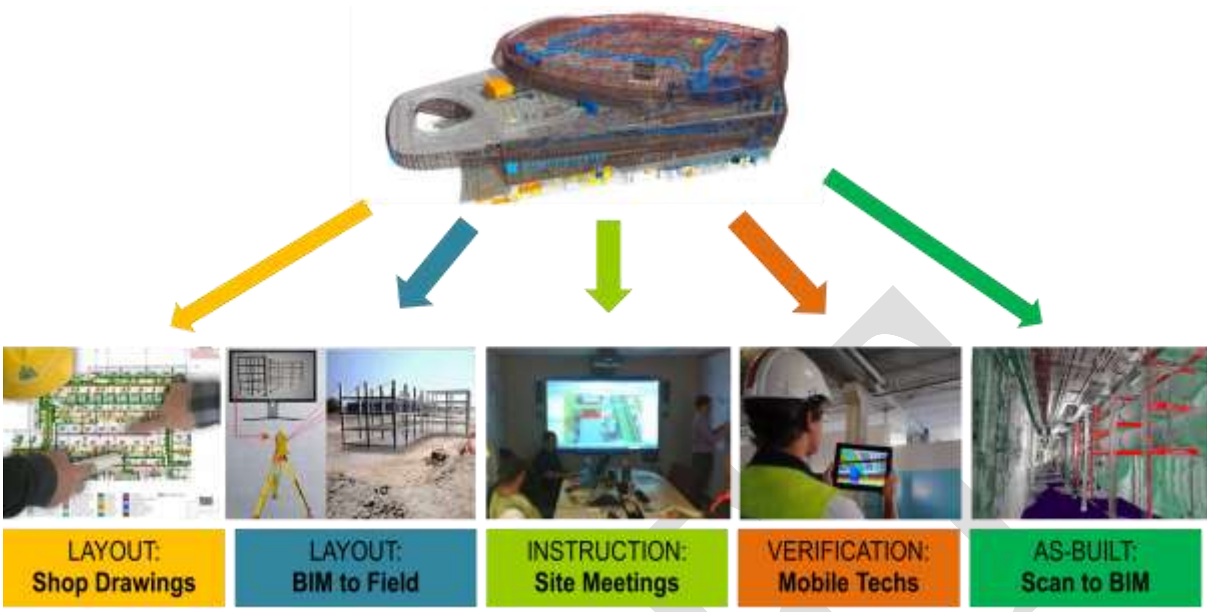


Figure 23: Various means of field translatioin

Proper translation from BIM to Field ensures that the actual installation (1) does not deviate from the fully coordinated BIM model and (2) is executed according to the pre-planned sequence in which both are important so as not to render all of the prior "make-ready" exercises to be in vain.

Communication to field comes in many forms. Traditionally, shop drawings have always been used to convey the scope of work and all of the information that is required to execute a specific activity. Some subcontractors who are not BIM-capable may be producing their shop drawings in CAD while others in BIM. Others may make use of survey technology to bring the model coordinates to site. Whatever the methodology however, If it is not properly managed, certain gaps and inconsistencies may result to error in installation as some of the trades may not have the correct information. This is why it is important that the project team verifies with their subcontractors as to how they make the translation from the coordinated model to field and make sure that everyone is on the same page.

Shop Drawings - It is preferable to extract all if not most of the required shop drawings from the coordinated model to be used as basis for lay-out. Samples of shop drawings that may be extracted from the model include:

- Concrete Body Plan (CBP)
- Coordinated Services Drawings (CSD)
- Reflected Ceiling Plan
- Room books

- Individual MEP trade setting out (to be extracted from CSD)
- General finishes plan

Direct BIM to Field - BIM to Field technologies include special survey equipment such as layout navigators or total stations which are capable of transferring 3D points directly from the model to the field. This method is not only accurate, but it may also potentially save both time and manpower as it requires only one or two people to perform the survey. Examples of applications:

- Layout of hanger inserts and embedment in slab
- Location of vertical studs for dry walls

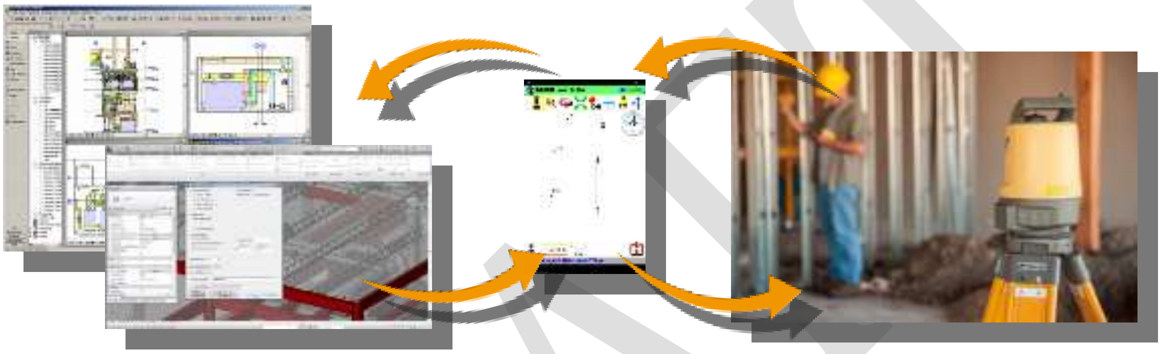


Figure 24: BIM to Field (image courtesy Topcon)

Site Meetings - Convey site instruction as per rehearsed virtual construction sequence, and highlight critical items, constraints, etc. This is the opportunity to explain exactly what is to be done to the foremen and supervisors who will oversee the work.

Mobile Technologies - Bring the BIM model directly to the field through the use of cloud services and mobile technologies which allow you to preload the model in a tablet, take it to field, and use navigation and view controls to visually compare if

Laser Scanning - verify accuracy of the executed work by scanning the area and bringing the point data back into the model for comparison.