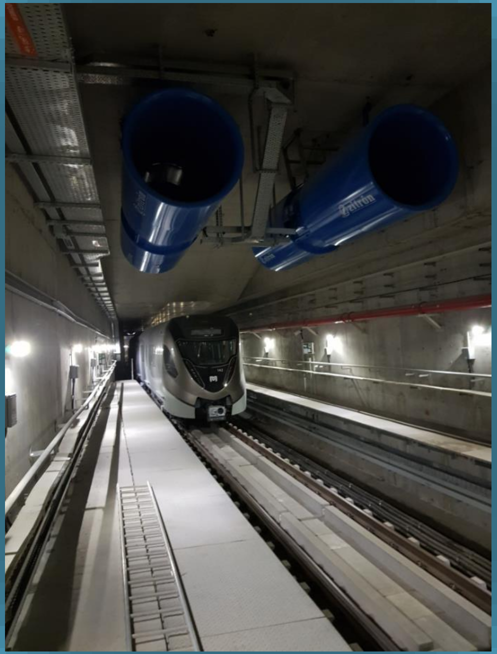

DESIGNING AND INTERFACING THE TUNNEL VENTILATION SYSTEM IN DOHA METRO PROJECT. THE VALUE OF BIM IN MEP SYSTEMS COORDINATION

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INTRODUCTION

1

Introduction

Doha Metro Project: a massive challenge

Doha Metro Project Phase I is the most challenging recent TVS Project in the world including a short-time execution package consisting of: integral design, manufacturing, transport, installation and commissioning which covers all the underground stations (and some other specific locations) distributed along the four new metro lines.

One of the biggest challenges of this fast-track Project, was the extremely-tighten schedule due to the vicinity of the incoming FIFA World Cup 2022, which is the main motor of most of the successful civil developments recently addressed in the State of Qatar.

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Introduction

TVS (Tunnel Ventilation System) scope of works

4
Metro Lines

42
TVS Locations

(underground stations, vent shafts, switchboxes & others)

116
Jet fans

700 & 1250 mm nominal diameter
30, 45 and 75 kW motor power

1024
Motorized smoke and fire dampers

(250 deg/2h fire rated)

158
Axial fans

Nominal diameter range: 2200 to 2500mm
Motor power range: 180 to 450 kW

84
Air handling units

2 modules per AHU
45 kW each

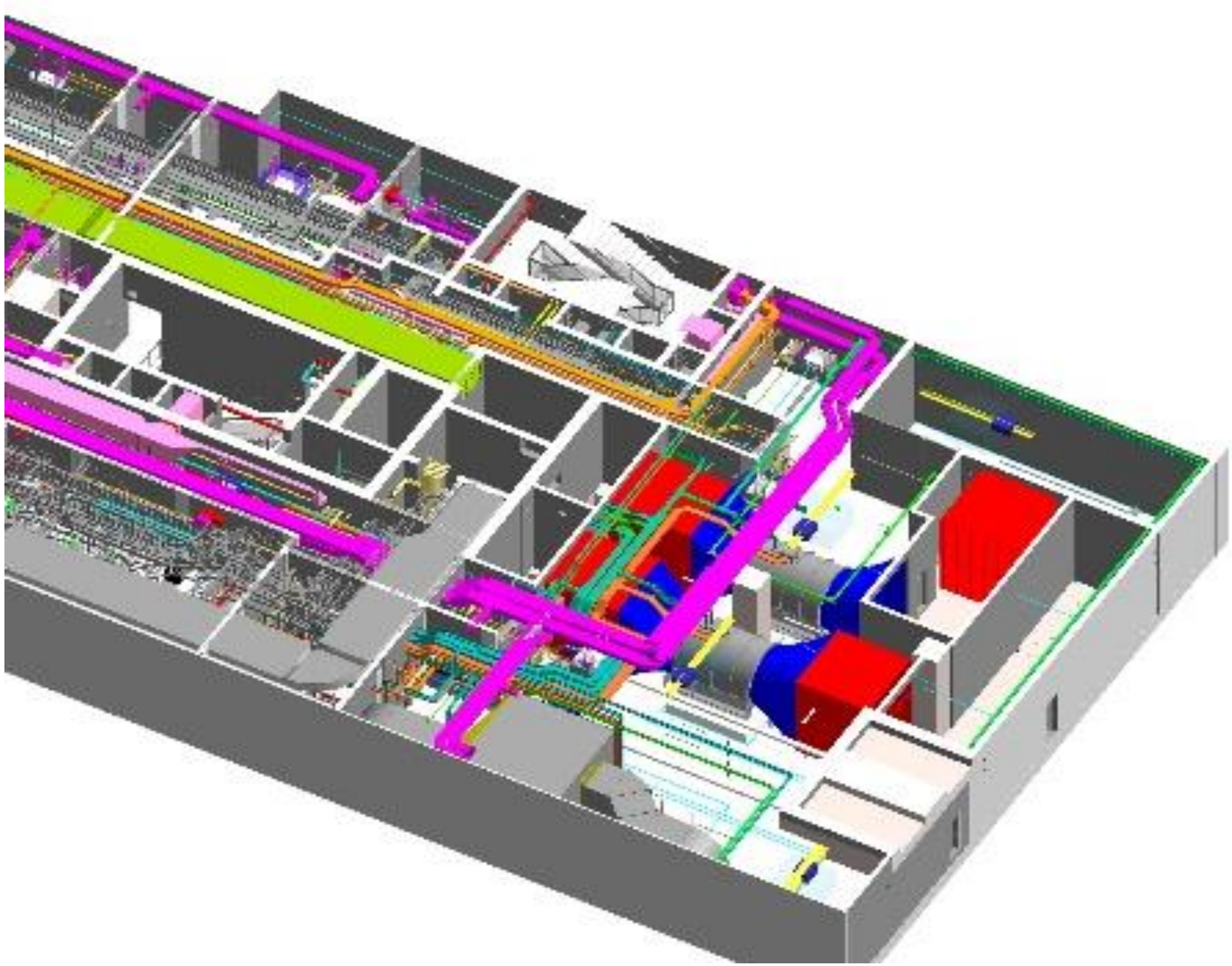
1400 km
Fire rated power and control cable

(250 deg/2h fire rated)

470
Electrical and control panels

Distribution, VSDs, CCs, soft starters

TVS INTERFACE MANAGEMENT IN DOHA METRO PROJECT



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TVS interface management in Doha Metro Project

Design Interface. The key discipline to achieve a coordinated project completion

The concept of Project interface can be defined as: *“The boundary between two (or more) parties or systems involved in a project”.* There is an interface between two or more parts when one of them (Lead) needs for its conception or realisation to take account of inputs from another party (Partner).

Interface Management is the discipline which involves the resources, processes and tools to ensure that all relevant specifics about these touchpoints are addressed and shared in a consistent, timely and efficient manner.

Building collaboration lines and a fluid communication with other concerned participants was a difficult challenge to be addressed in each case. Documenting interfaces and providing solid communication allowed the different contracting parties to be aligned and helped to establish clear lines of responsibility and scope whilst bridging the space between them.

TVS interface management in Doha Metro Project

BIM software as the principal interface tool

BIM implementation as an interfacing working platform was mandatory for all the Project contractors. As an outcome of the Project, it can be evaluated as an efficient tool for obtaining an accurate feedback, reliable information and a prompt analysis of the designs coordination conflicts in order to establish clear work guidelines for solving the arising issues.

The main profit obtained was an overall project improved performance and the limitation of costly mistakes and reworks occurrence. Successful interface management led to the avoidance of time-consuming disputes, guaranteeing complete understanding of, and agreement with, all decisions regarding project interface issues.

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TVS interface management in Doha Metro Project

Why interfacing the TVS design is critical in Metro Projects

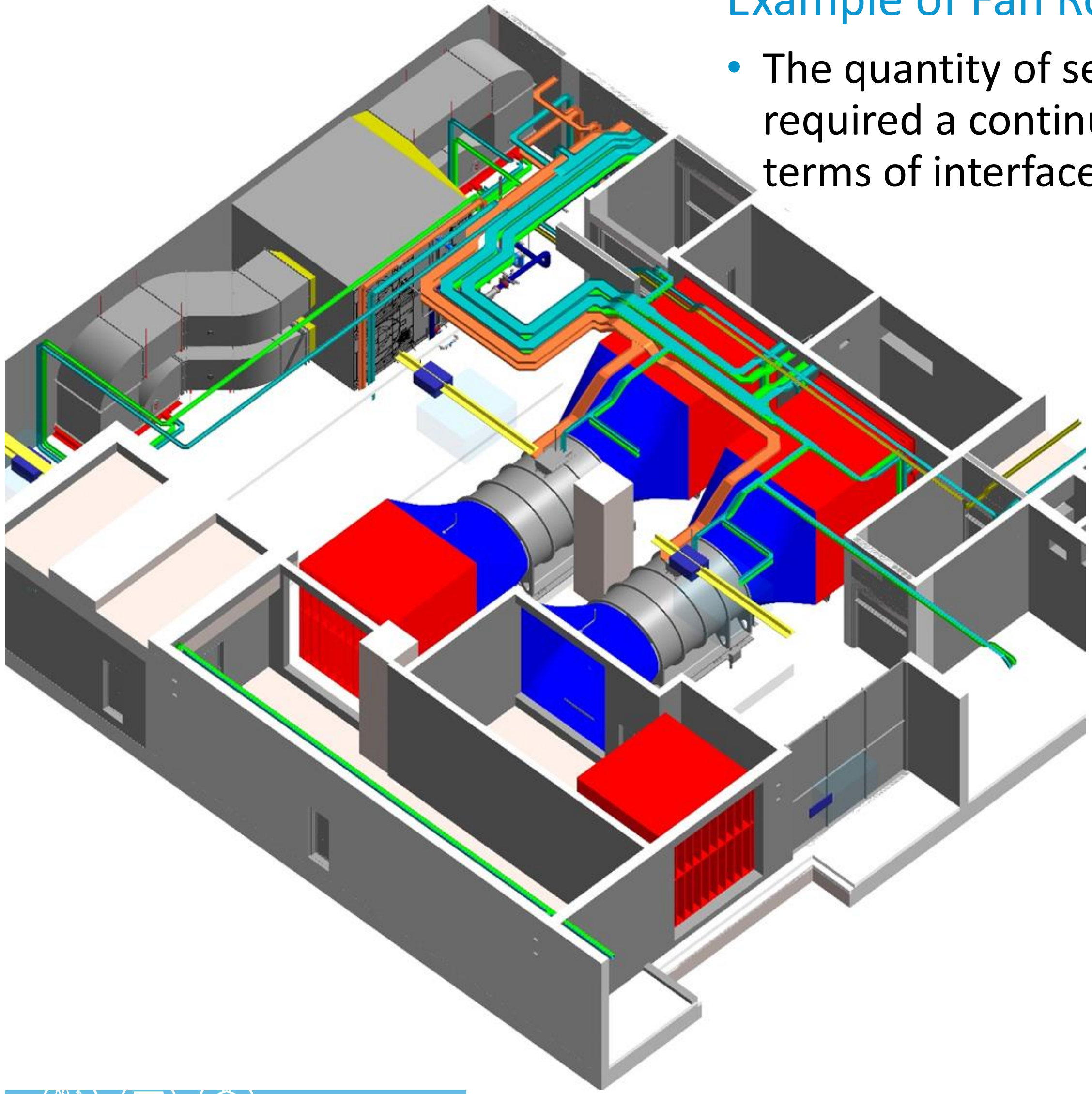
Considering the large TVS SOW, the TVS Design is the one which created the biggest impact in terms of coordination and in consequence, the most complicated to interface. The main reasons were:

Substantial space proofing requirements for equipment installation. The size and weight of the equipment involved compromises its fitting and coexistence with other civil structures and MEP instrumentation/equipment (i.e., the installed axial fans are weighing 10 to 15 tons and their maximum dimensions are approximately 2500 mm x 4000 mm x 2500mm).

Equipment dispersion throughout the underground network. At the stations, the equipment is installed in different technical rooms at all station levels (ground, intermediate, concourse, platform and underplatform). In tunnels, the equipment is mainly located at the station track area, tunnel portals and switchboxes. Cable routing coordination also affected tunnels, station corridors and other technical rooms. Such equipment dispersion created a big variety of different clashes and interfaces to be solved.

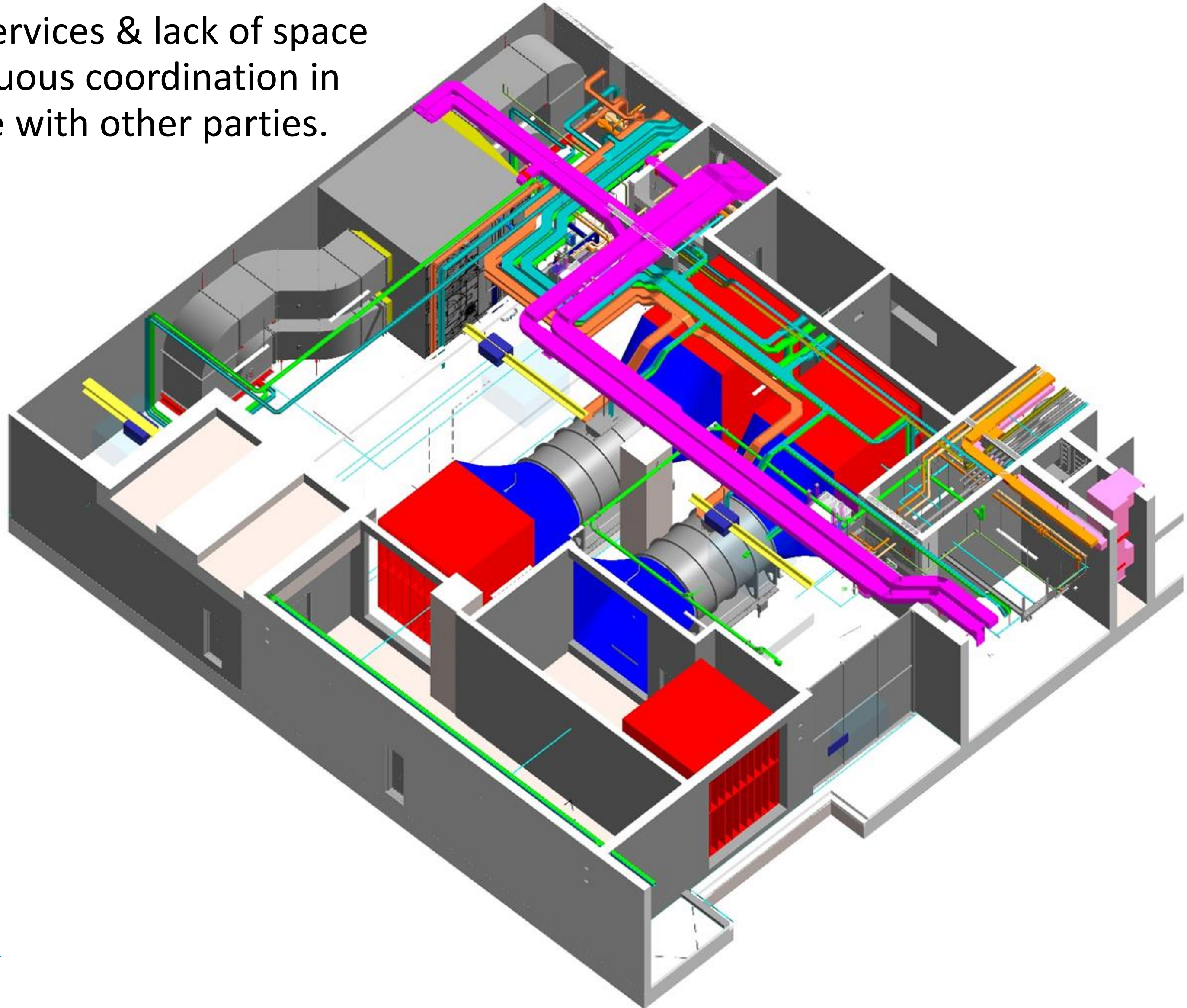
Constraints related to the equipment delivery routing. Complicated and customized delivery routes (station wise) were faced due to the equipment dimensions/weight and its dispersion throughout the underground network. Safety at works was also a big concern, hence top detail interface documents - considering all the necessary measures and methodologies to be followed- was highly requested.

TVS interface management in Doha Metro Project

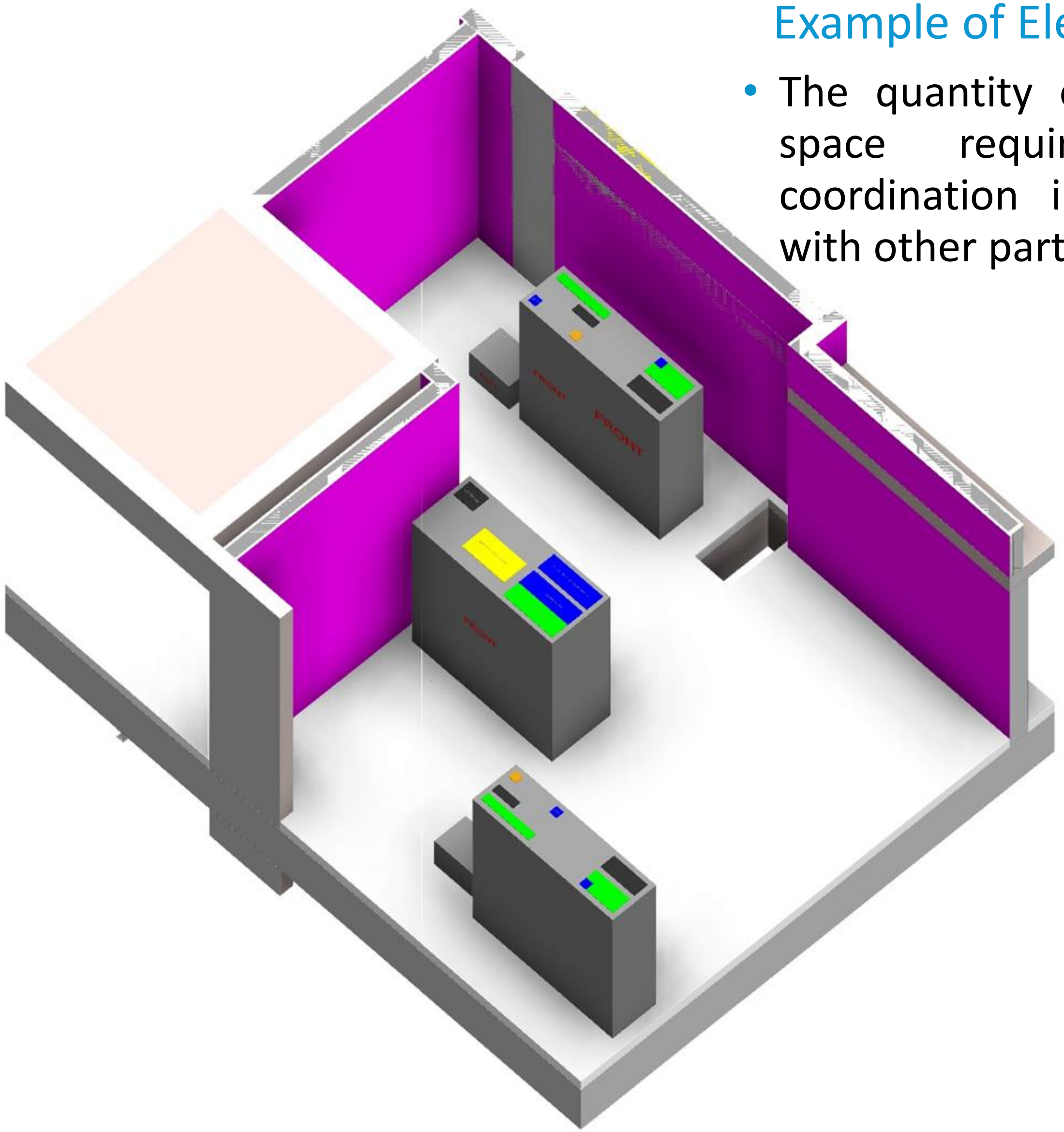


Example of Fan Room design

- The quantity of services & lack of space required a continuous coordination in terms of interface with other parties.

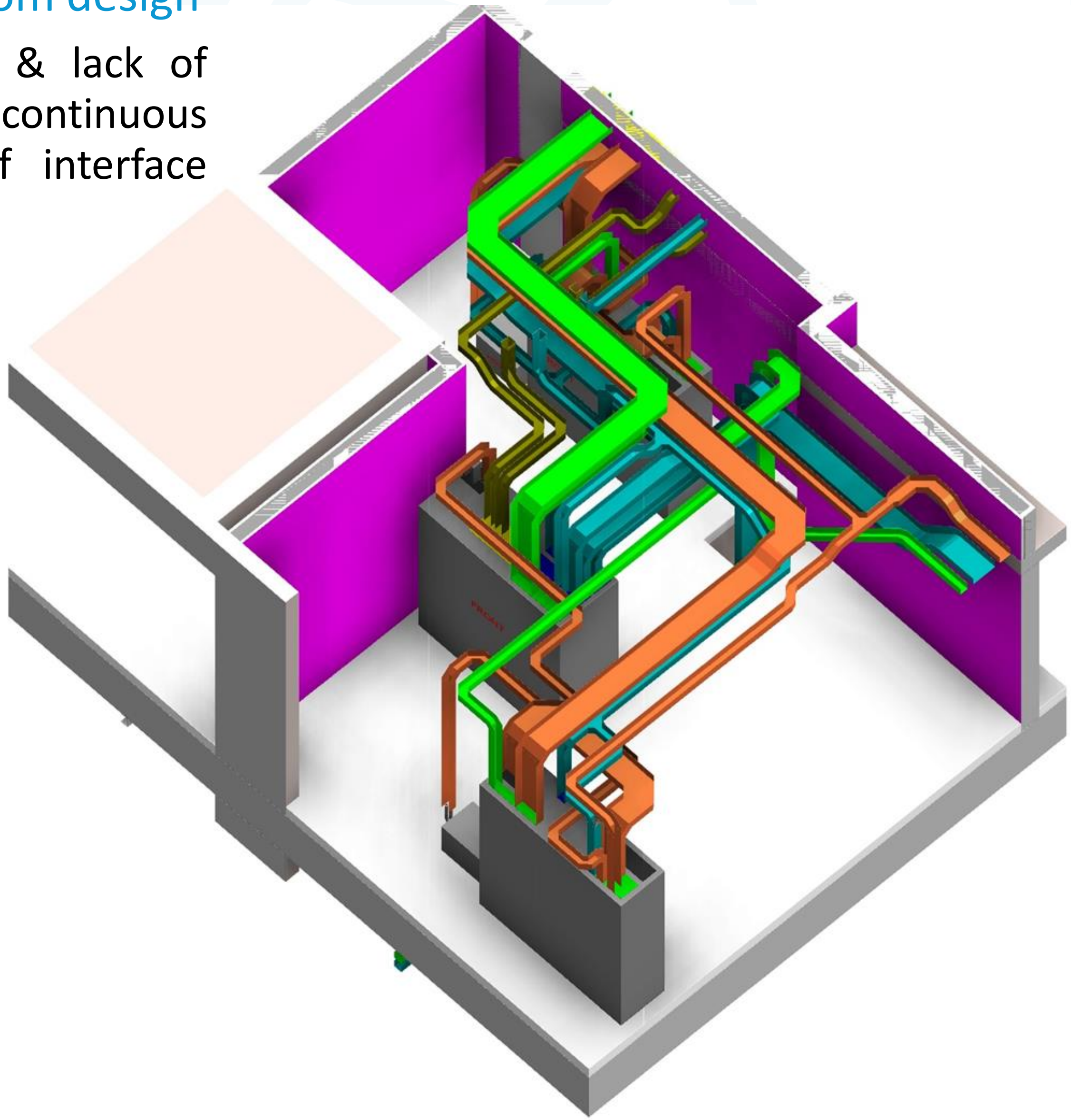


TVS interface management in Doha Metro Project



Example of Electrical Room design

- The quantity of services & lack of space required a continuous coordination in terms of interface with other parties



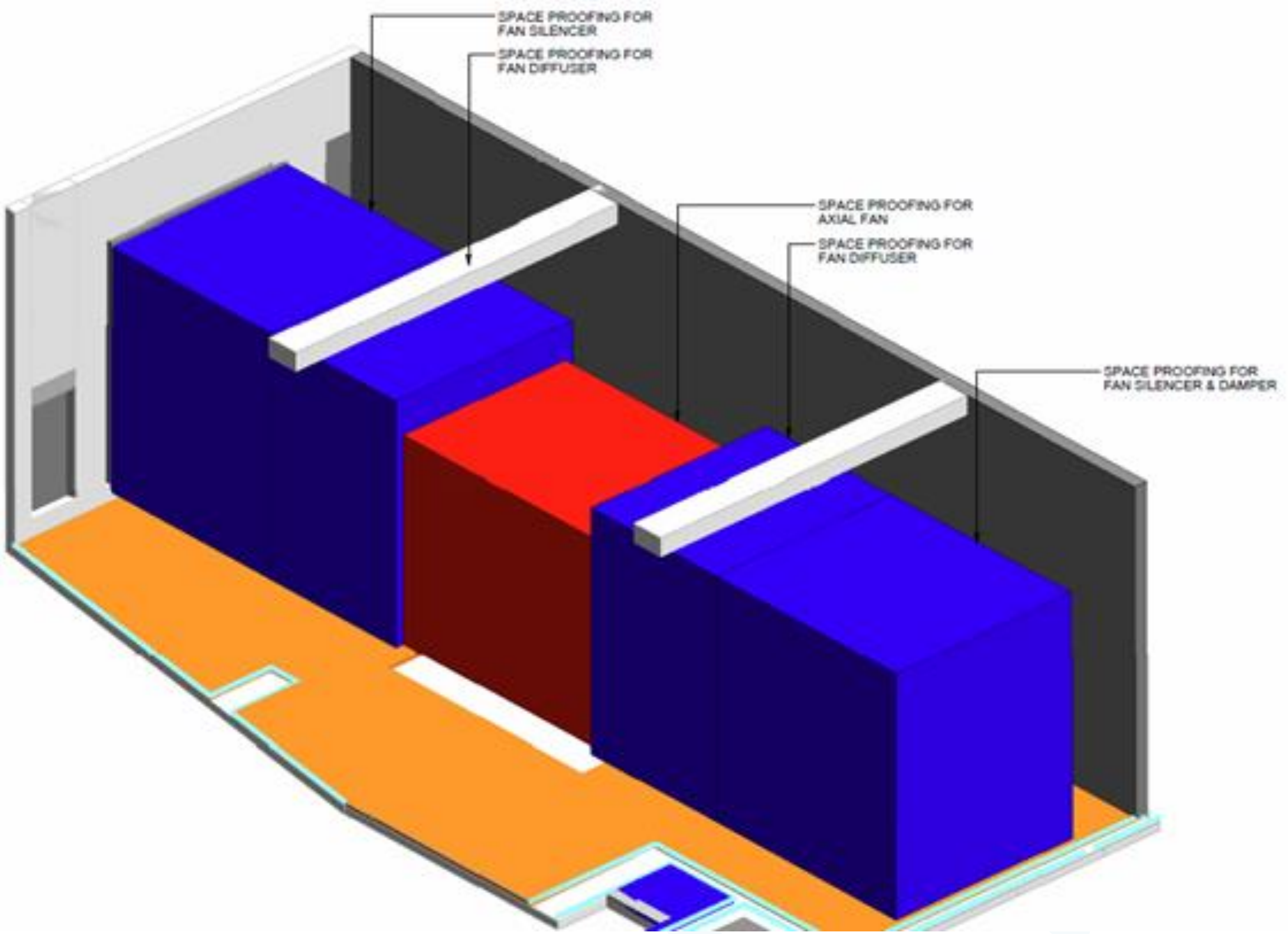
BIM IMPLEMENTATION THROUGHOUT THE DESIGN PHASES

3

BIM implementation throughout the design phases

Design Stage 1 (DS1)

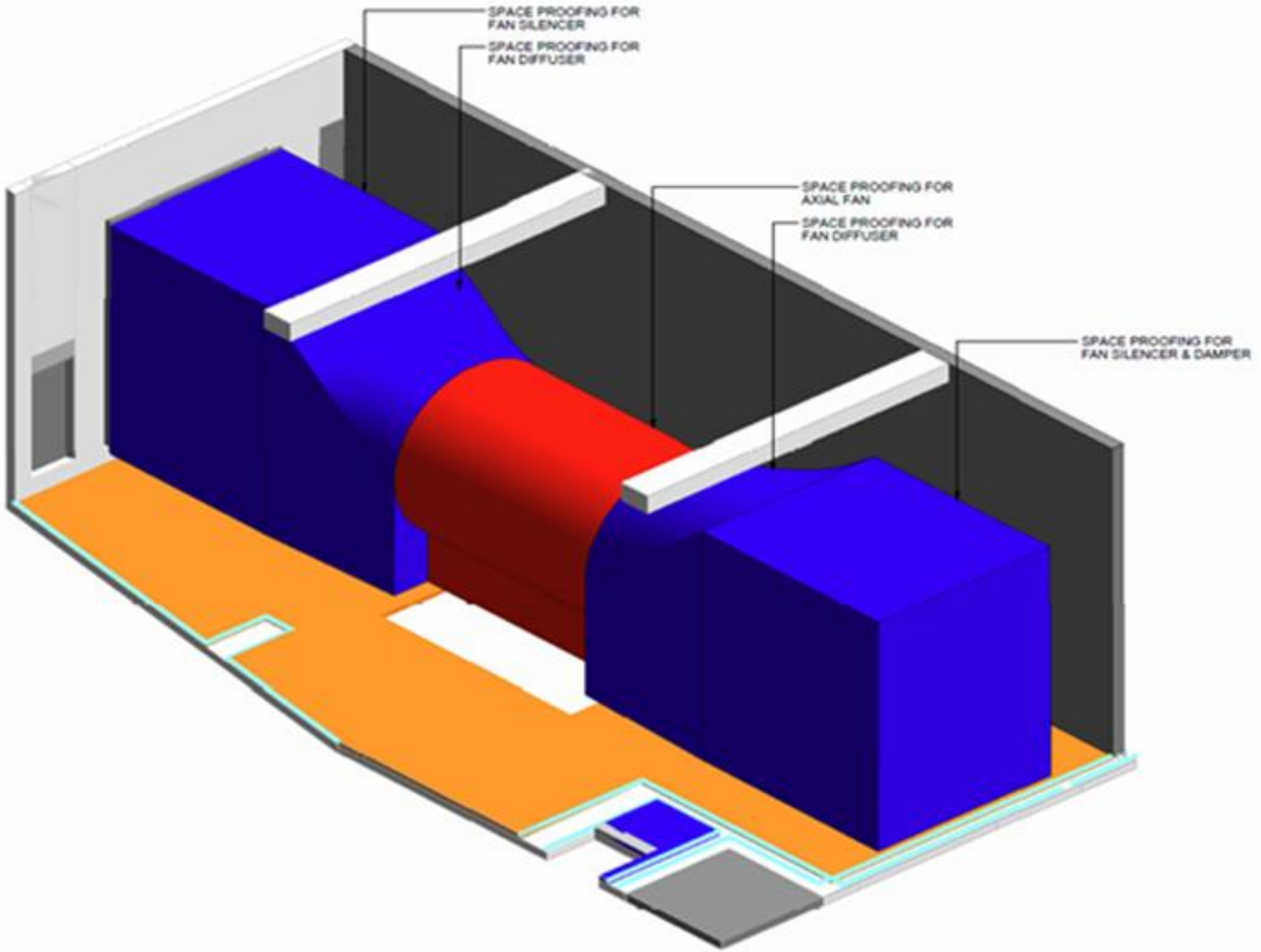
- Low level of detail (LOD100)
- Space proofing
- Final dimensions of equipment may not be defined yet: Booking the space is capital here
- Cable routing randomly for booking space purpose
- Agile and fast coordination through simple design



BIM implementation throughout the design phases

Design Stage 2 (DS2)

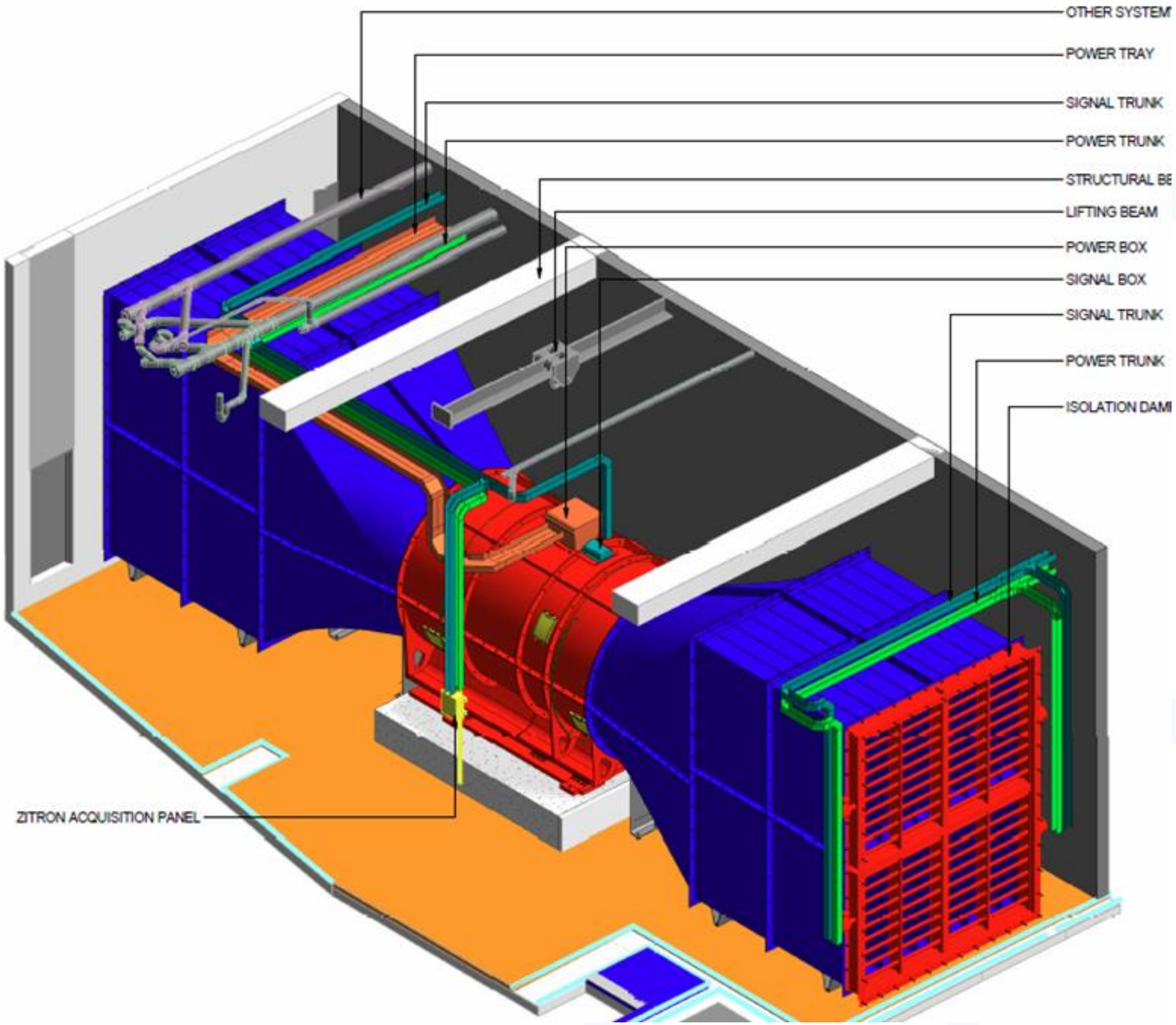
- Increased Level of Detail (LOD350)
- Geometry approach to definitive
- Improvement in the design facilitates the coordination and incorporation of other equipment in the proximities
- Incorporation of some MMS data



BIM implementation throughout the design phases

Design for installation purposes

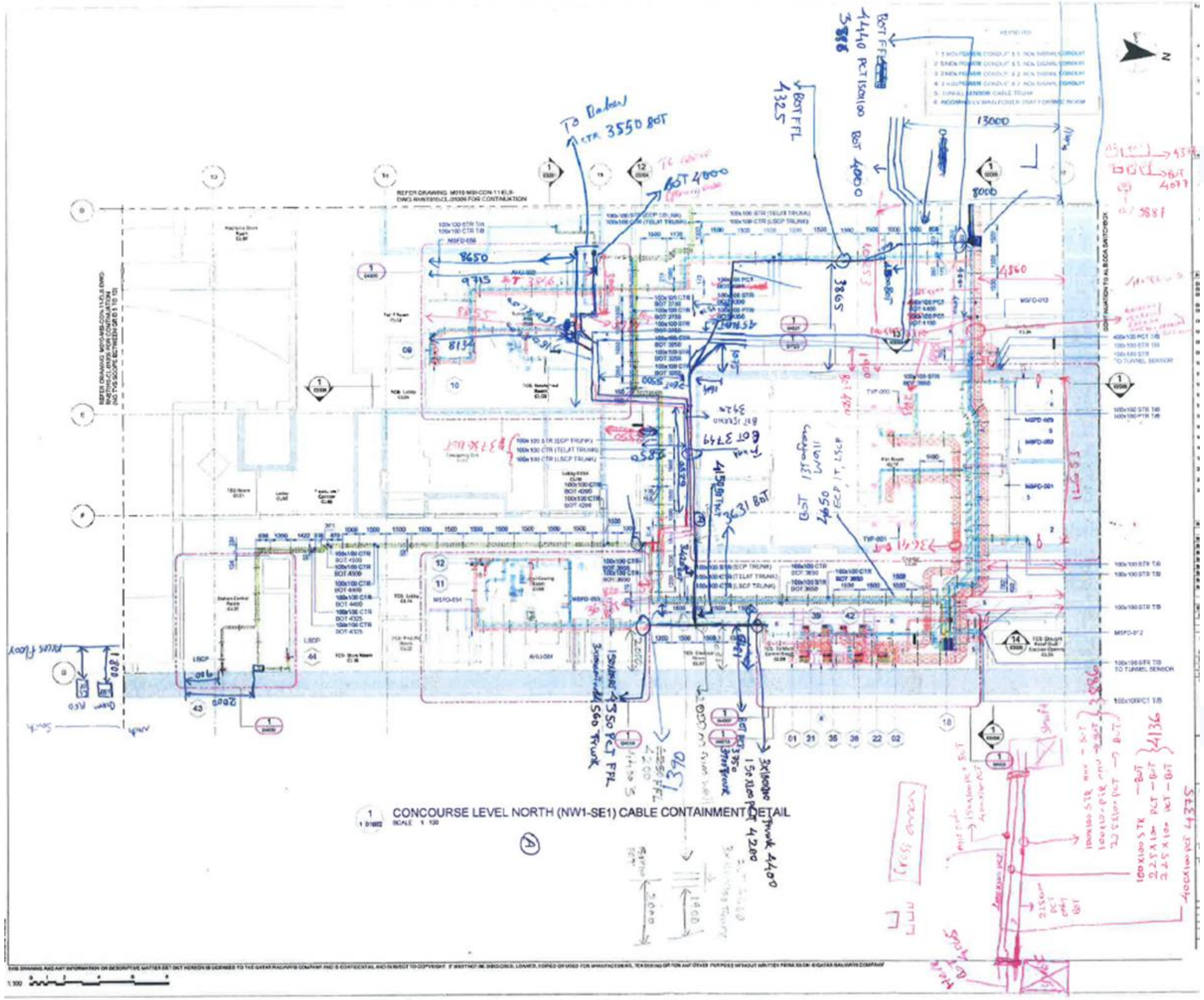
- Very High Level of Detail (LOD400)
- Geometry definitive
- Accurate Design
- Space proofing is fully defined as per real workshop dimensions to allow full coordination of other services at same location
- Incorporation of most of MMS data



BIM implementation throughout the design phases

As-Built Drawings

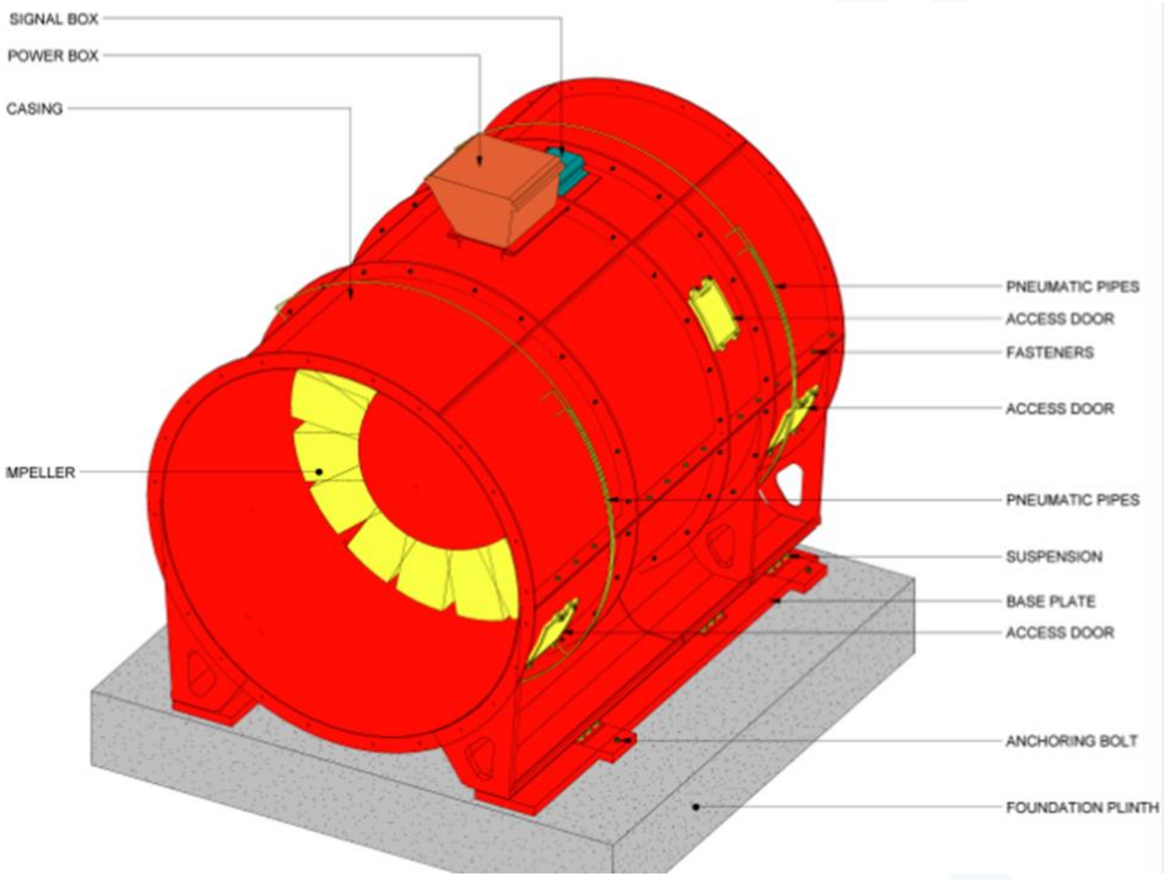
- Assess the site to contrast the design with the reality installed
- Register the deviations with the installation drawings
- Update the installation drawings to obtain the AS BUILT drawings

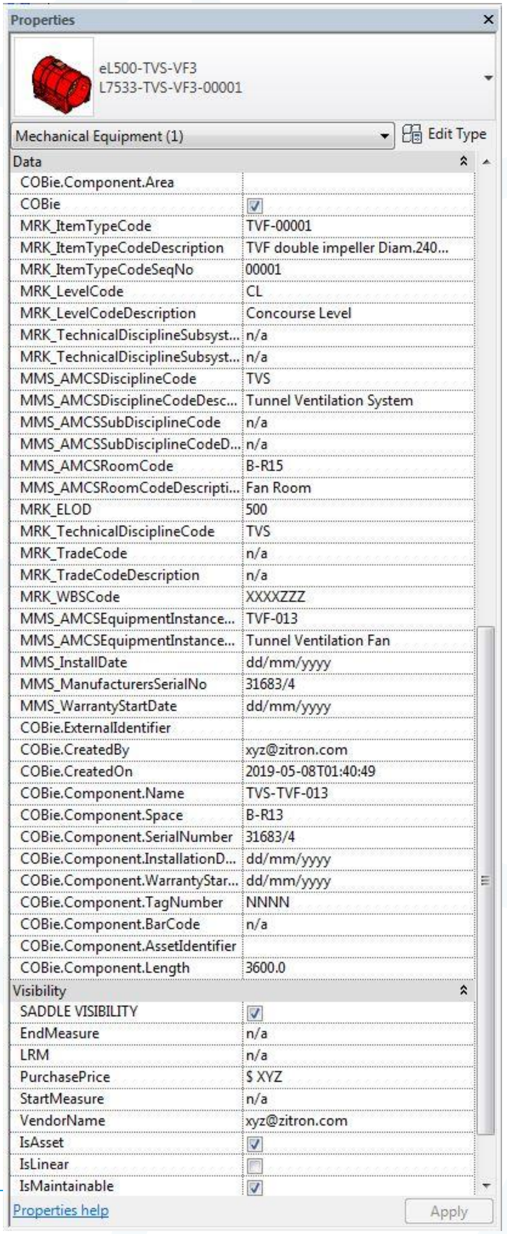


BIM implementation throughout the design phases

As-Built Drawings

- Include the upper level of detail (LOD500). The model is available for operational use and maintenance.




Properties

eL500-TVS-VF3
L7533-TVS-VF3-00001

Mechanical Equipment (1) — Edit Type

Data	
COBie.Component.Area	
COBie	☑
MRK_ItemTypeCode	TVF-00001
MRK_ItemTypeCodeDescription	TVF double impeller Diam.240...
MRK_ItemTypeCodeSeqNo	00001
MRK_LevelCode	CL
MRK_LevelCodeDescription	Concourse Level
MRK_TechnicalDisciplineSubsyst...	n/a
MRK_TechnicalDisciplineSubsyst...	n/a
MMS_AMCSDisciplineCode	TVS
MMS_AMCSDisciplineCodeDesc...	Tunnel Ventilation System
MMS_AMCSSubDisciplineCode	n/a
MMS_AMCSSubDisciplineCodeD...	n/a
MMS_AMCSRoomCode	B-R15
MMS_AMCSRoomCodeDescripti...	Fan Room
MRK_ELOD	500
MRK_TechnicalDisciplineCode	TVS
MRK_TradeCode	n/a
MRK_TradeCodeDescription	n/a
MRK_WBSCode	XXXXZZZ
MMS_AMCSEquipmentInstance...	TVF-013
MMS_AMCSEquipmentInstance...	Tunnel Ventilation Fan
MMS_InstallDate	dd/mm/yyyy
MMS_ManufacturersSerialNo	31683/4
MMS_WarrantyStartDate	dd/mm/yyyy
COBie.ExternalIdentifier	
COBie.CreatedBy	xyz@zitron.com
COBie.CreatedOn	2019-05-08T01:40:49
COBie.Component.Name	TVS-TVF-013
COBie.Component.Space	B-R13
COBie.Component.SerialNumber	31683/4
COBie.Component.InstallationD...	dd/mm/yyyy
COBie.Component.WarrantyStar...	dd/mm/yyyy
COBie.Component.TagNumber	NNNN
COBie.Component.BarCode	n/a
COBie.Component.AssetIdentifier	
COBie.Component.Length	3600.0
Visibility	
SADDLE VISIBILITY	☑
EndMeasure	n/a
LRM	n/a
PurchasePrice	$ XYZ
StartMeasure	n/a
VendorName	xyz@zitron.com
IsAsset	☑
IsLinear	☐
IsMaintainable	☑

Properties help — Apply

CLASH MANAGEMENT IN THE TVS DESIGN INTERFACE

4

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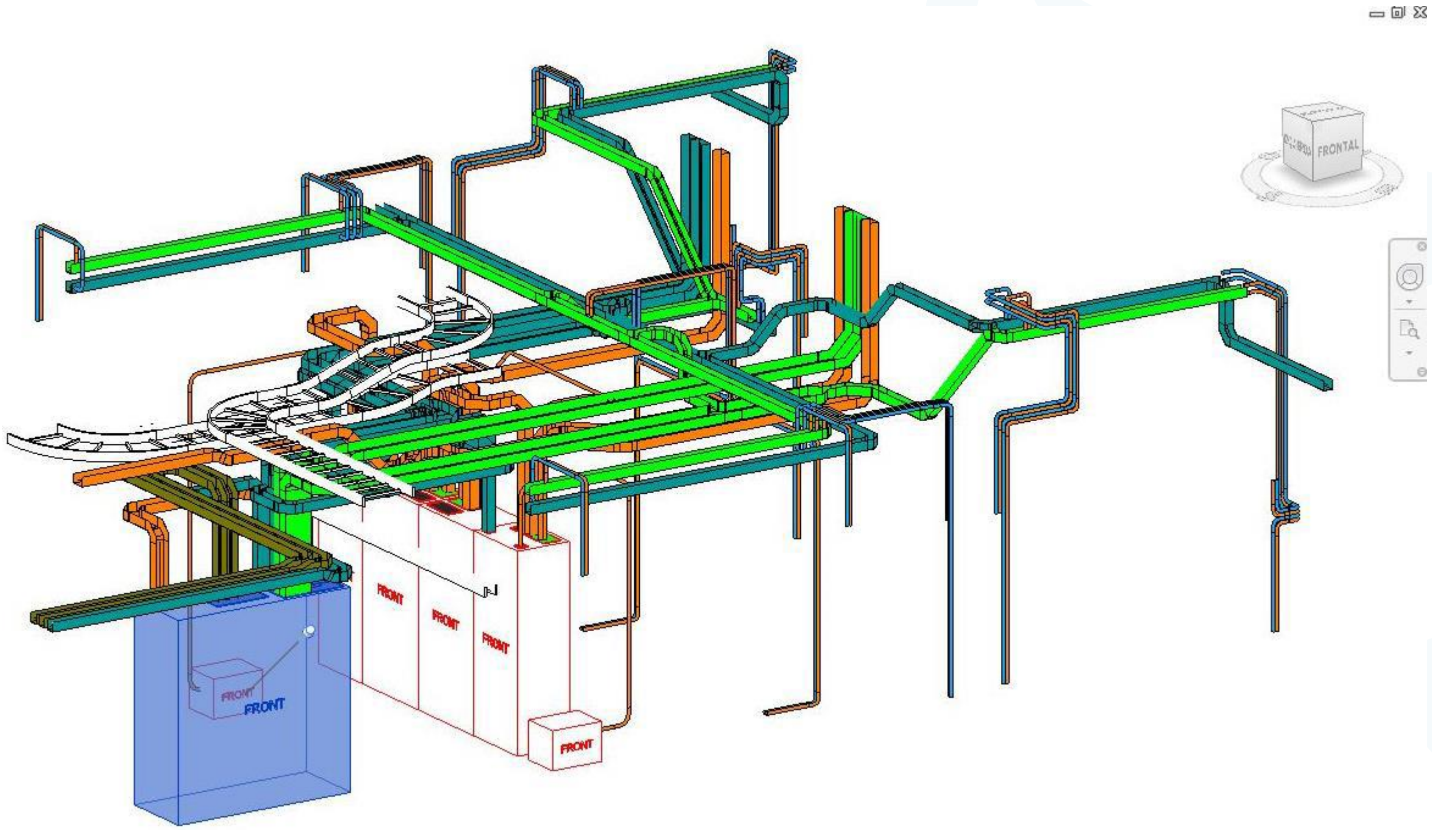
Clash management in the TVS design interface

Definition & clash types

A **clash** is defined as the interference between elements/equipment from different design parties are occupying in either way the same volumetric space within a combined multidisciplinary design model



Clash management in the TVS design interface

Definition & clash types

Regarding the **affection type** and **nature of the conflict** detected, the clashes were summarized in four types:

- **Hard clashes**
  The ones detected when two components are sharing the same space – Example: a fire pipe running through an Axial Fan lifting beam in a dedicated Tunnel Vent System room
- **Soft clashes**
  The ones detected when the buffer zone, space proofing or tolerance of an element has been breached by another element
- **Workflow or 4D clashes**
  The ones involving conflicts due to unaligned Contractors Work Scheduling or to different timelines of inter-disciplinary activities (main risk: potential cascade effect on others)
- **Other clashes**

Clash management in the TVS design interface

Examples of clash detection & solving with BIM

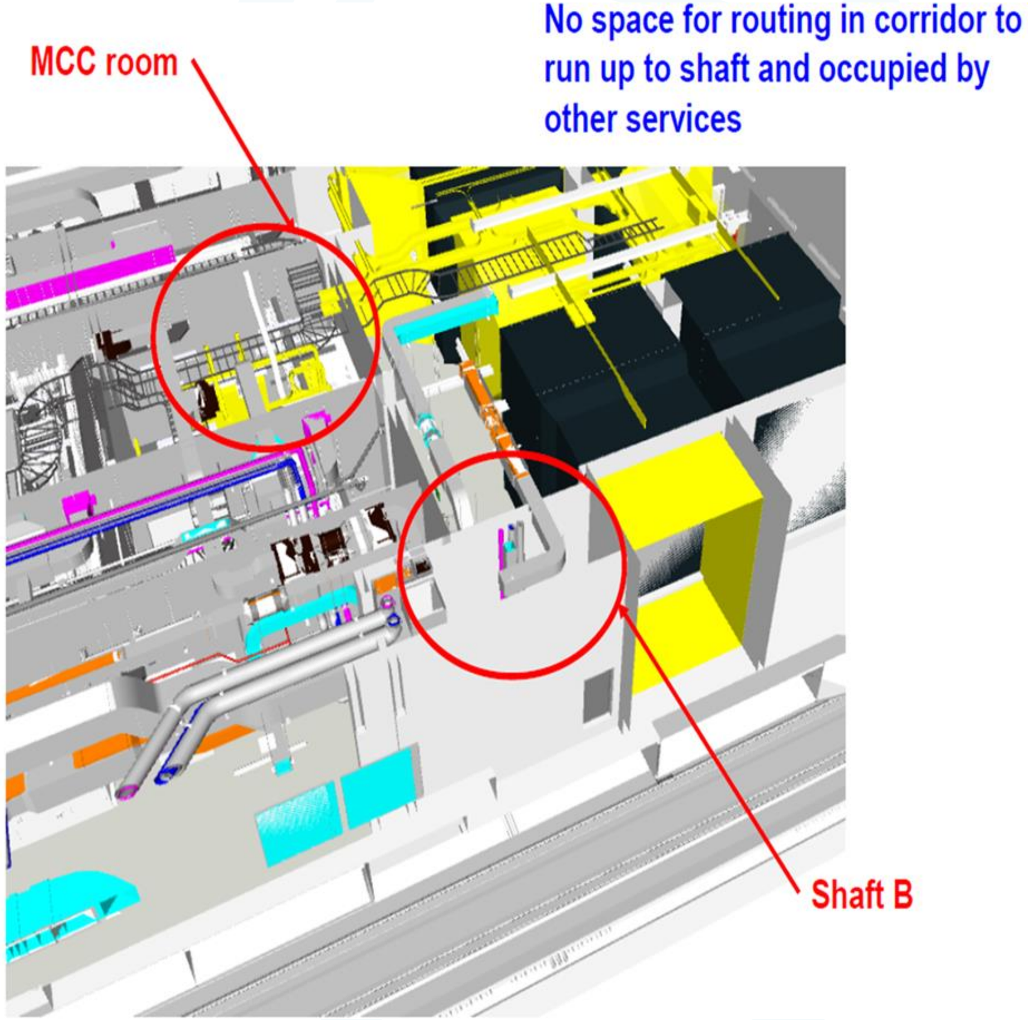
3D BIM Clash detector tool allows to ***automatically***:

- Detect
- Quantify
- Categorize

} DESIGN CLASHES

BIM Discipline key strenghts:

- Minimizes human errors
- Time and accuracy optimization
- Eases a multidisciplinary design progress
- Potential delay avoidance
- Further extra costs reduction



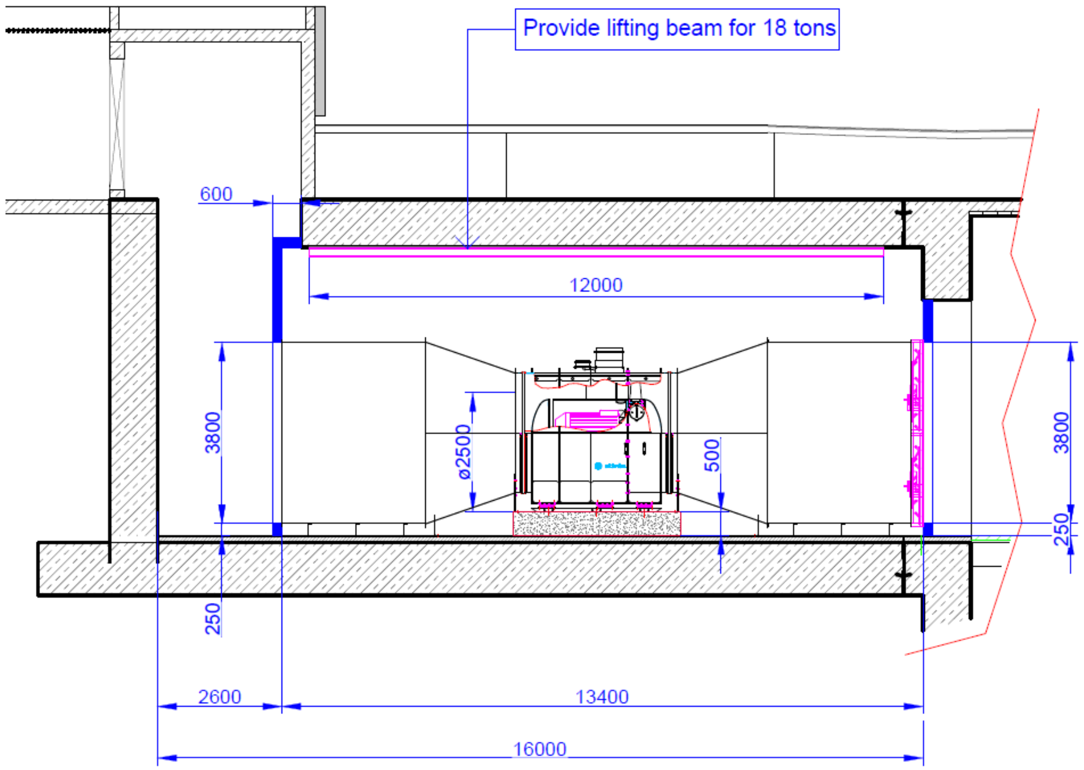
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

Case 1. Hard clash: fire fighting pipes / GA conduits with permanent TVF lifting beams

Background

- The axial fans and their accessories (diffusers, acoustic silencers, motorized smoke and fire dampers) were installed in dedicated rooms (TVF rooms)
- TVF room was allowed to be used by others to install their services (mainly fixed to the roof). However, the space proofing priority was given to TVS (not mandatorily and subject to interface coordination)
- 500mm concrete plinths required for fan installation
- Due to the weight and size of the fans the installation Method Statement (MES) considered the usage of hoist beams for fan delivery, installation and potential replacement



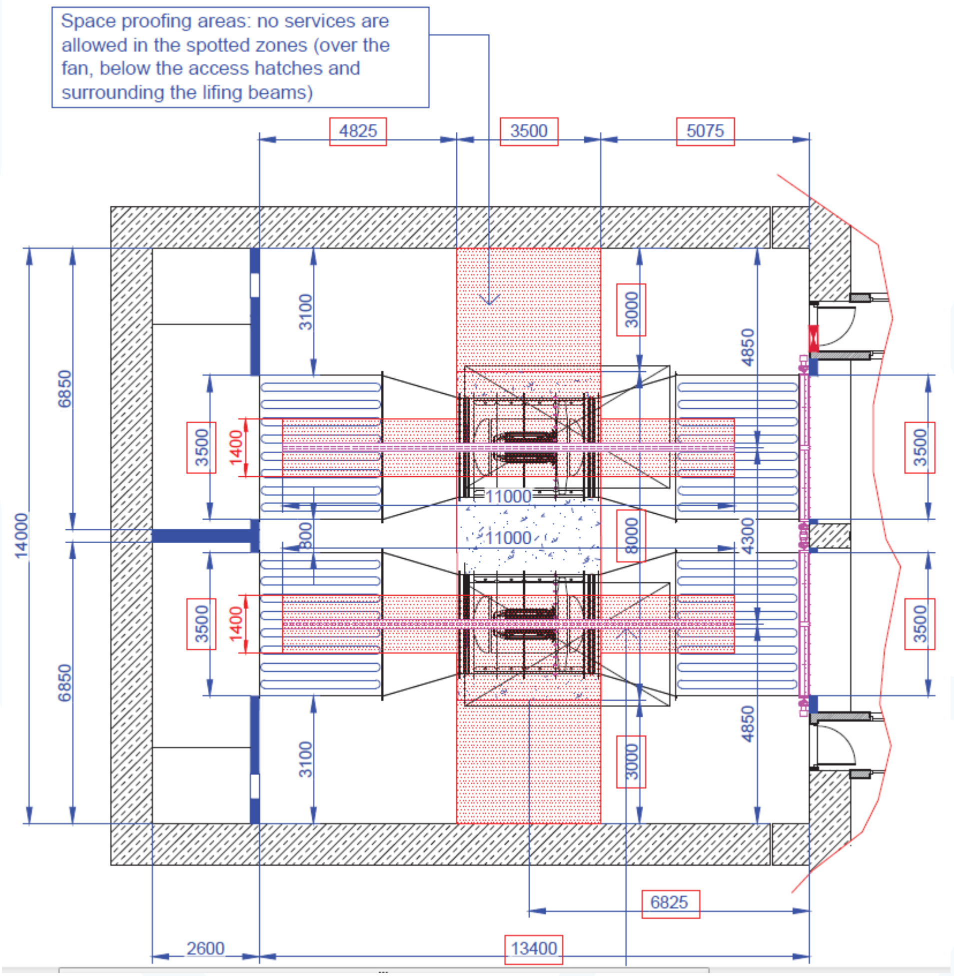
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

Case 1. Hard clash: fire fighting pipes / GA conduits with permanent TVF lifting beams

Background

- Interface Control Forms (ICFs) were developed, agreed and signed by the different parties involved in the TVF room service coordination
- TVF lifting beam space proofing requirements:
  - ✓ Ensure mínimum 700 mm clearance at both sides of the TVF lifting beam centerline
  - ✓ Such clearance shall apply along the full beam length
  - ✓ No services shall cross over the footprint of the TVF equipment in order to guarantee the delivery and potential replacement
  - ✓ No services shall cross the footprint of lifting beam space proofing



Clash management in the TVS design interface

Examples of clash detection & solving with BIM

<u>Case 1. Hard clash: fire fighting pipes / GA conduits with permanent TVF lifting beams</u>

<u>Interface headlines</u>

- In some TVF rooms, the signed ICFs were not followed by both the Civil fire-fighting system installer and the GA electrical conduit installer
- TVS BIM Design priority was also dismissed
- FF piping and GA conduits were installed in advance invading the TVF room exclusion area required for the TVF lifting beam installation
- The resulting impacts on TVS Design could not be absorbed

<u>Solution and impacts</u>

- Instruction to dismantle all the clashing piping (unpaid additional works)
- Requirement to extend the necessary permits to work for TVF room occupation
- Third parties construction schedule constrained due to the dismantling and reinstallation Works carried out by Civil installer (time & cost)

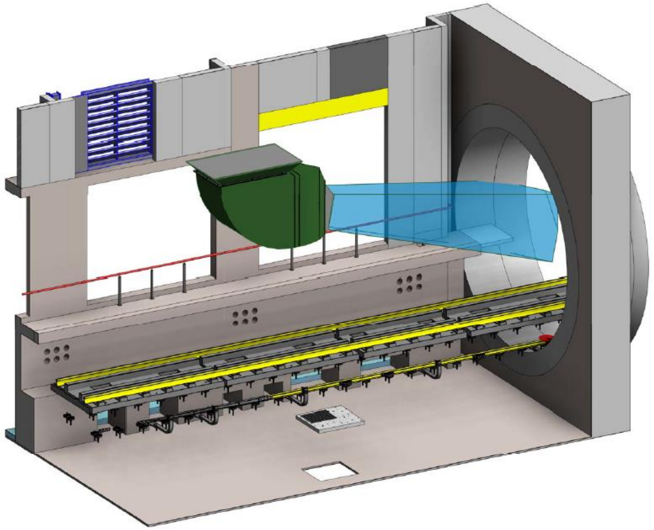
Clash management in the TVS design interface

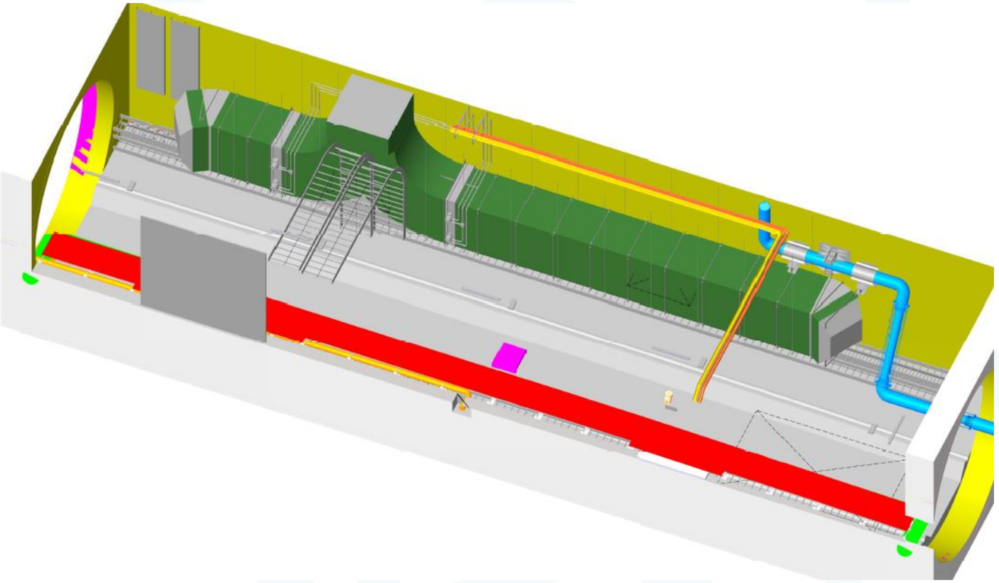
Examples of clash detection & solving with BIM

<u>Case 2. Soft Clash: TVS AHU Nozzle clash with other services and Rolling Stock</u>

<u>Background</u>

- The AHUs were required to be fitted with outlet nozzles in order to steer the air jet supplied towards the tunnel located downstream





- This requirement was detected and settled during the Design Interface Stage, so the nozzle implementation in BIM showed several clashes which required further coordination

Clash management in the TVS design interface

Examples of clash detection & solving with BIM

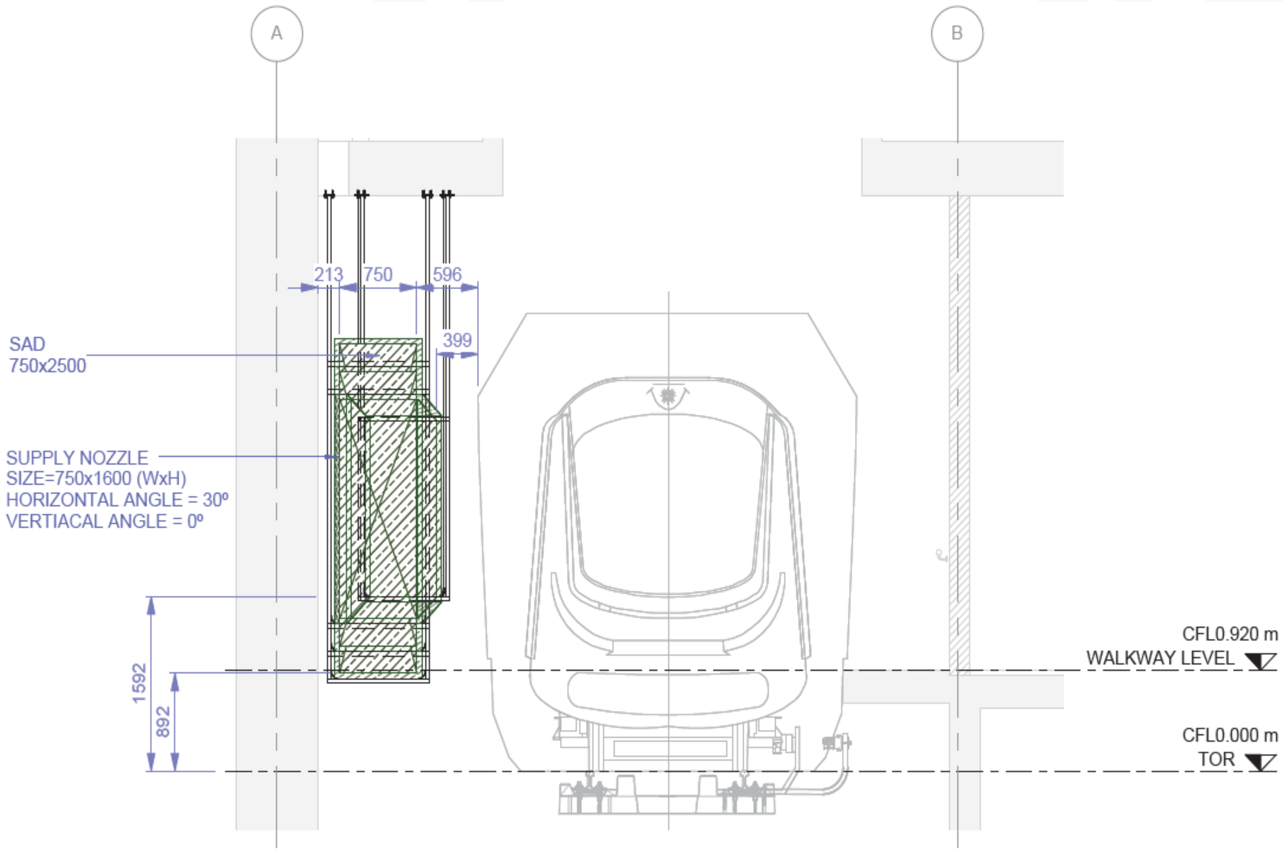
Case 2. Soft Clash: TVS AHU Nozzle clash with Rolling Stock

Interference headlines

- Nozzle dimensions
- Space constraints (congested areas)
- Train gauge space proofing
- Impossibility to place the nozzles above the track center line

Solutions achieved through BIM

- Resolve any clash by redesigning the nozzle while keeping the TVS technical specs and performance requirements (preferred option by the Client)
- Resolve any clash by relocating other services in cases where TVS performance could not be guaranteed



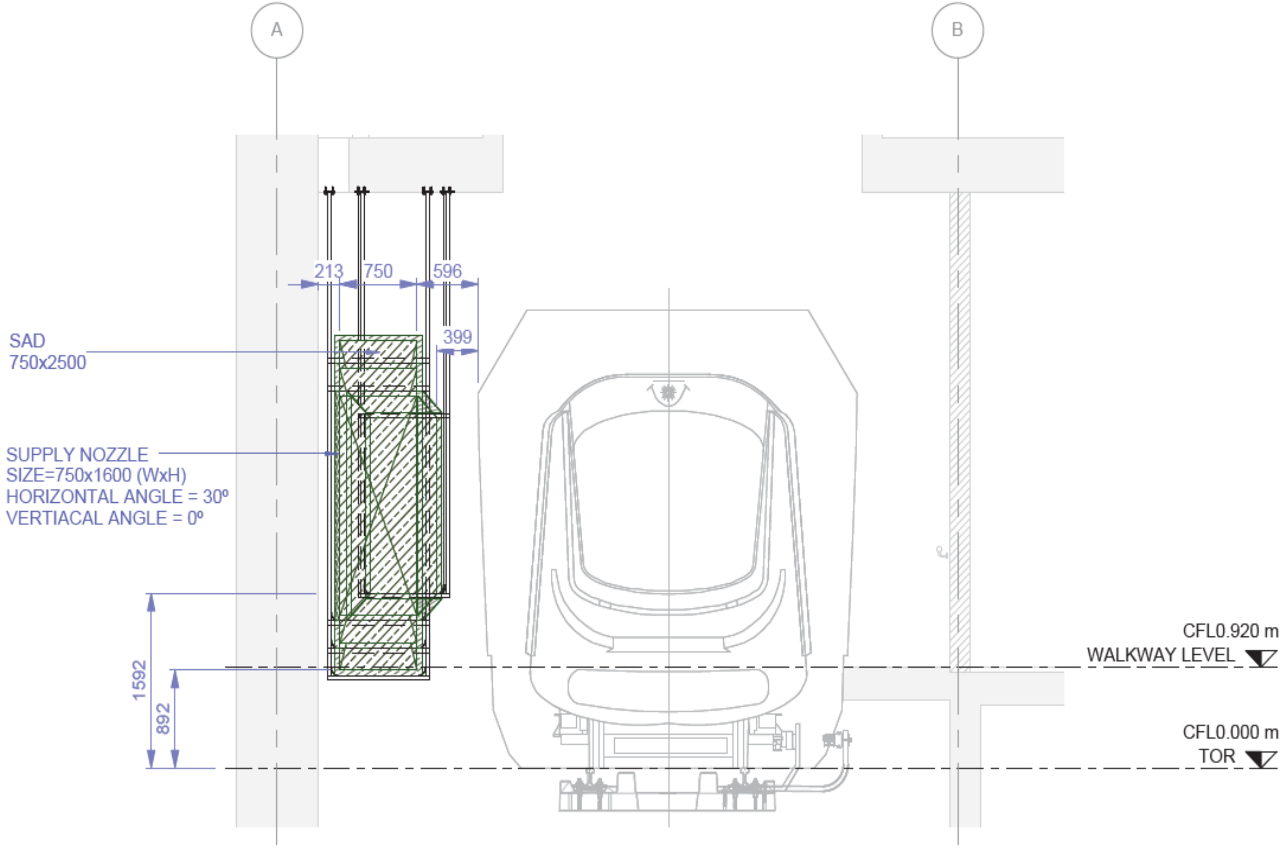
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

<u>Case 2. Soft Clash: TVS AHU Nozzle clash with Rolling Stock</u>

<u>Impacts</u>

- 100% of the problematic designs were amended accordingly
- Escalation to final Client was reduced to zero cases
- Reworks were limited at Design level, avoiding potential impacts involving TVS, Rolling Stock or any other third party at below levels:
  - ✓ Manufacturing
  - ✓ Site installation
  - ✓ Testing & commissioning
- TVS extra cost saving per nozzle was estimated in the range of 5,000 to 10,000 USD
- TVS potential impact estimation: 420,000 to 840,000 USD



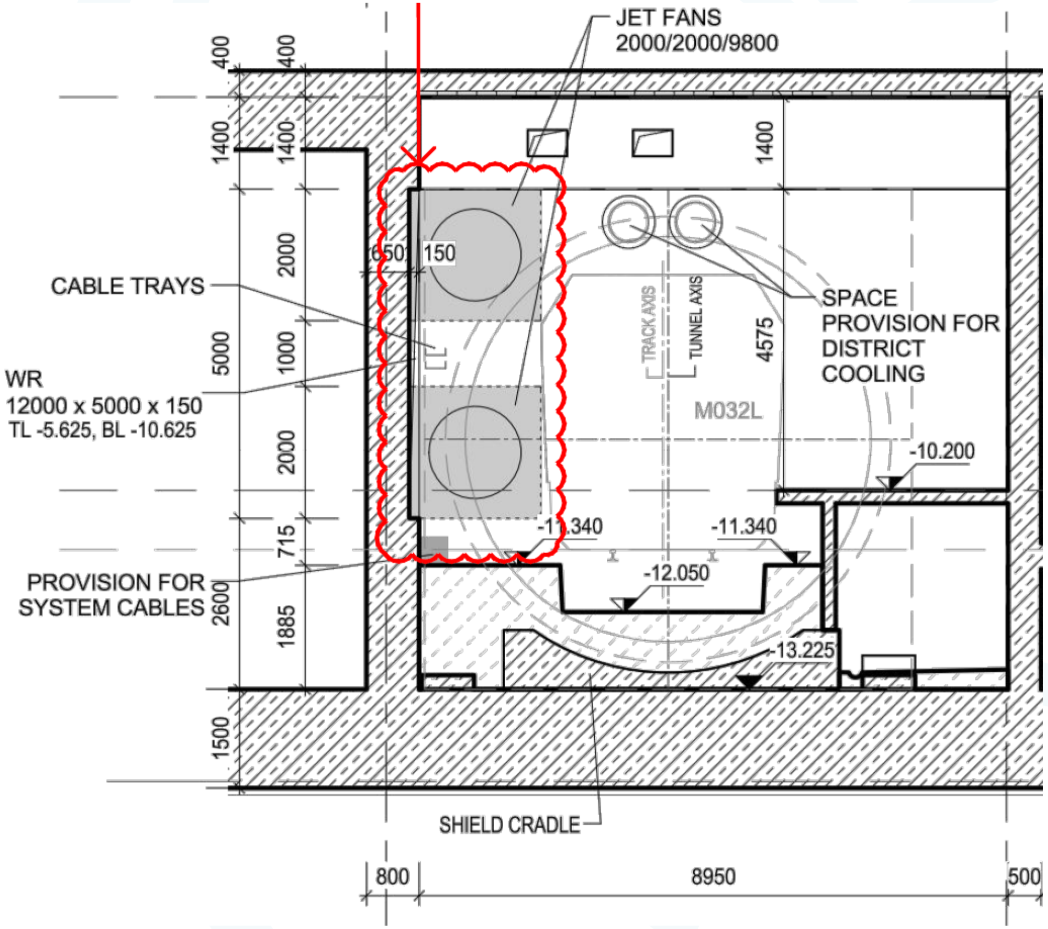
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

Case 3. Workflow clash: CIVIL district cooling pipe & TVS jet fans

Background

- CIV, ENR linear services along tunnels and switchboxes
- TVS Jet Fans to be installed at certain chainages in accordance to the TVS Design Document “SES cold flow análisis”
- Signed ICF (Interface Control Form), preliminarly guaranteed cohabitation without any adverse effect and without any performance impact:
    - ➢ CIV District Cooling Pipe to be located at the top
    - ➢ TVS Jet Fans to be installed at one of the side walls



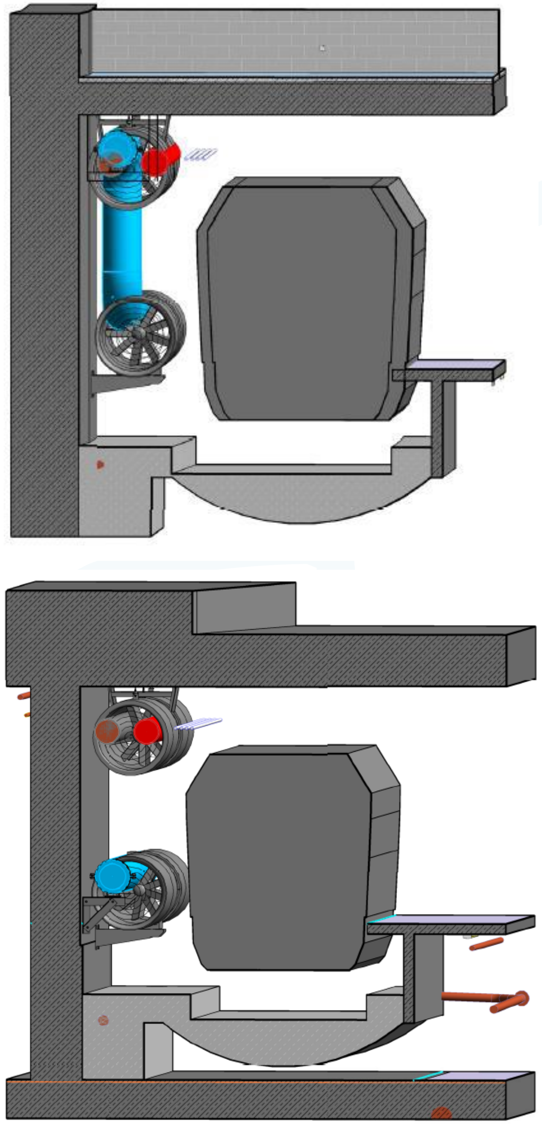
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

<u>Case 3. Workflow clash: CIVIL district cooling pipe & TVS jet fans</u>

<u>Interference headlines</u>

- Due to site constraints, CIV modified the agreed district cooling pipe routing
- The DCP was then relocated to the same space provision where the TVS Jet Fans should be placed
- No BIM coordination/interface was carried out to resolve the potential clashes due to different timelines between CIV and TVS
- When TVS arranged its BIM implementation, below obstructions appeared:
  - Hard clashes: DCP clashing with the JFs
  - Soft clashes: DCP obstructing the JF discharge area (affecting their performance)



Hamad Hospital Switchbox

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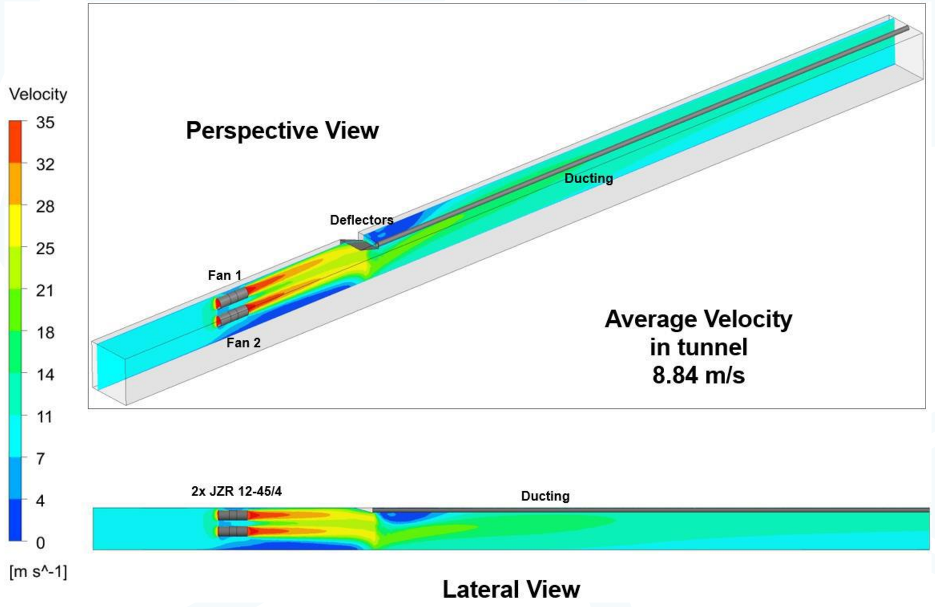
Clash management in the TVS design interface

Examples of clash detection & solving with BIM



<u>Case 3. Workflow clash: CIVIL district cooling pipe & TVS jet fans</u>

<u>Solutions & Impacts</u>

- Design interface re-coordination (time & cost impact):
  - ✓ Re-scheduling of a new interface process (meetings, ICFs, BIM coordination,…)
  - ✓ Engineering hours spent to find a suitable solution for each case
- Additional & unplanned engineering works to be arranged by TVS (time & cost impact):
  - ✓ CFD studies carried out to analyse the potential effects of the piping blockage
  - ✓ CFD studies carried out to analyse potential mitigation measures
- Punctual impossibility of agreement between parties (escalation to Client):
- Site reworks (time & cost impact):
  - ✓ Installation of additional deflector plates by CIV to minimize the air blockage as a mitigation measure (where possible)
  - ✓ Relocation of the DCP by CIV where the hard/soft clashes could not be mitigated

Clash management in the TVS design interface

Examples of clash detection & solving with BIM

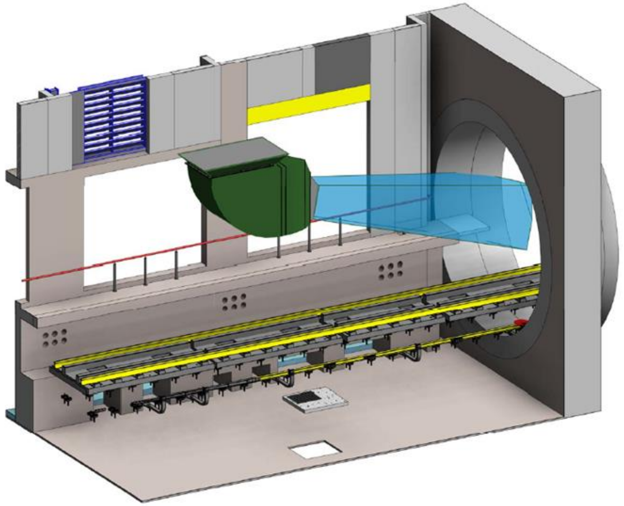
Case 4. Other clashes: clashes with potential safety consequences

Background

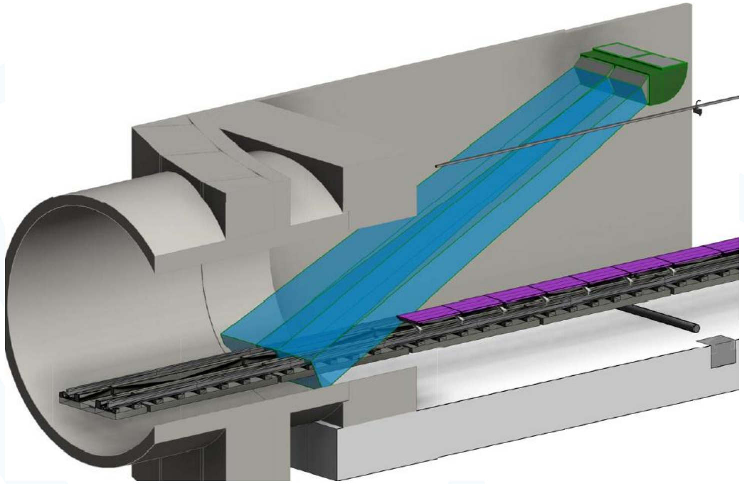
The safety-related clash explained hereafter was noticed after TVS design was completed, with the equipment already installed and during the testing and commissioning activities:

- AHU Nozzles as an additional TVS element to steer the air jet towards each station downstream tunnel
- Nozzles could not be located over the track centerline due to site constraints and rolling stock space proofing
- Nozzle design baselines:
  - ➢ Guarantee the train gauge and other services buffer restrictions
  - ➢ Keeping the minimum TVS performance parameters

Souq Waqif Station



Mid Tunnel Vent Shaft - 2



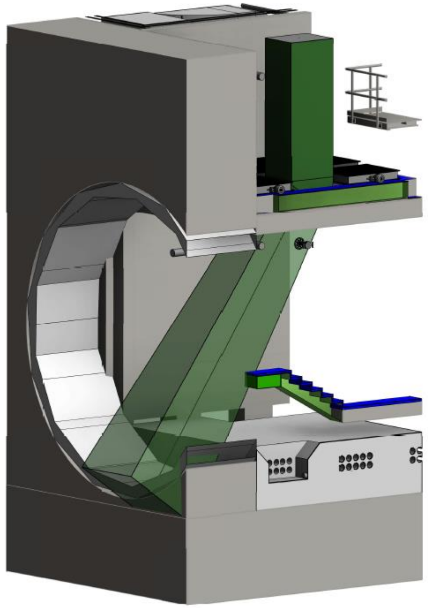
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

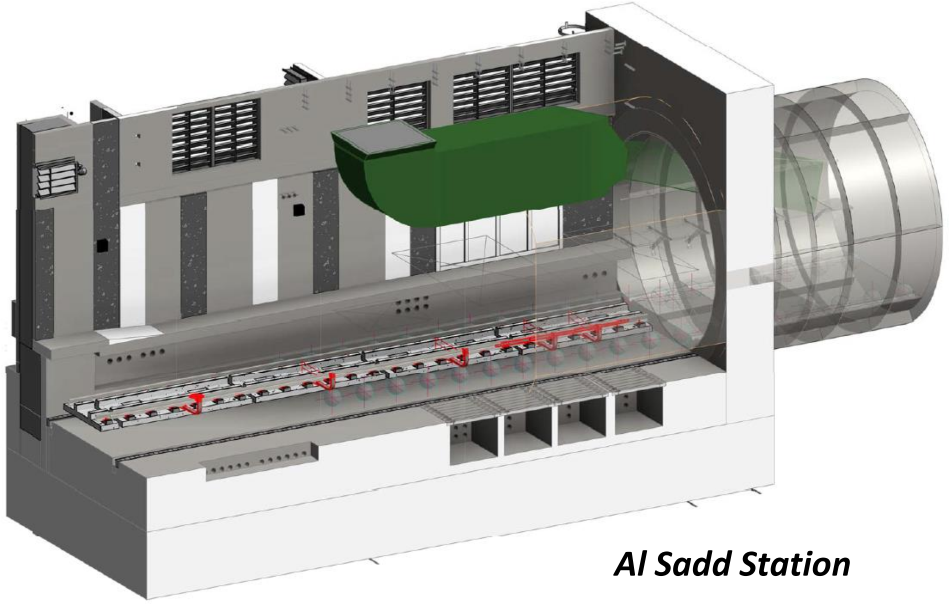
<u>Case 4. Other clashes: clashes with potential safety consequences</u>

<u>Interference headlines</u>

- Due to the mentioned restrictions, the nozzle air jet resulted obliquely pitched towards the intersection of the tunnel portal and the stations' boxes
- The air obliquely blown into the tunnels, was eventually blown over the egress walkways
- The applicable Standard NFPA-130 Annex B states that the maximum recommended air velocity in egress routes is 11 m/s
- During Tunnel Aerodynamic Testing, it was noticed that the air jet projected by 4 nozzles out of 84 was quite strong
- Further air velocity measurements shown that the air velocity in those cases exceeded the NFPA recommendations (the length affected varied from 3 to 7 meters in all cases)
- This was considered as a safety issue, so the Client required to take additional mitigation measures



Msheireb Station



Al Sadd Station

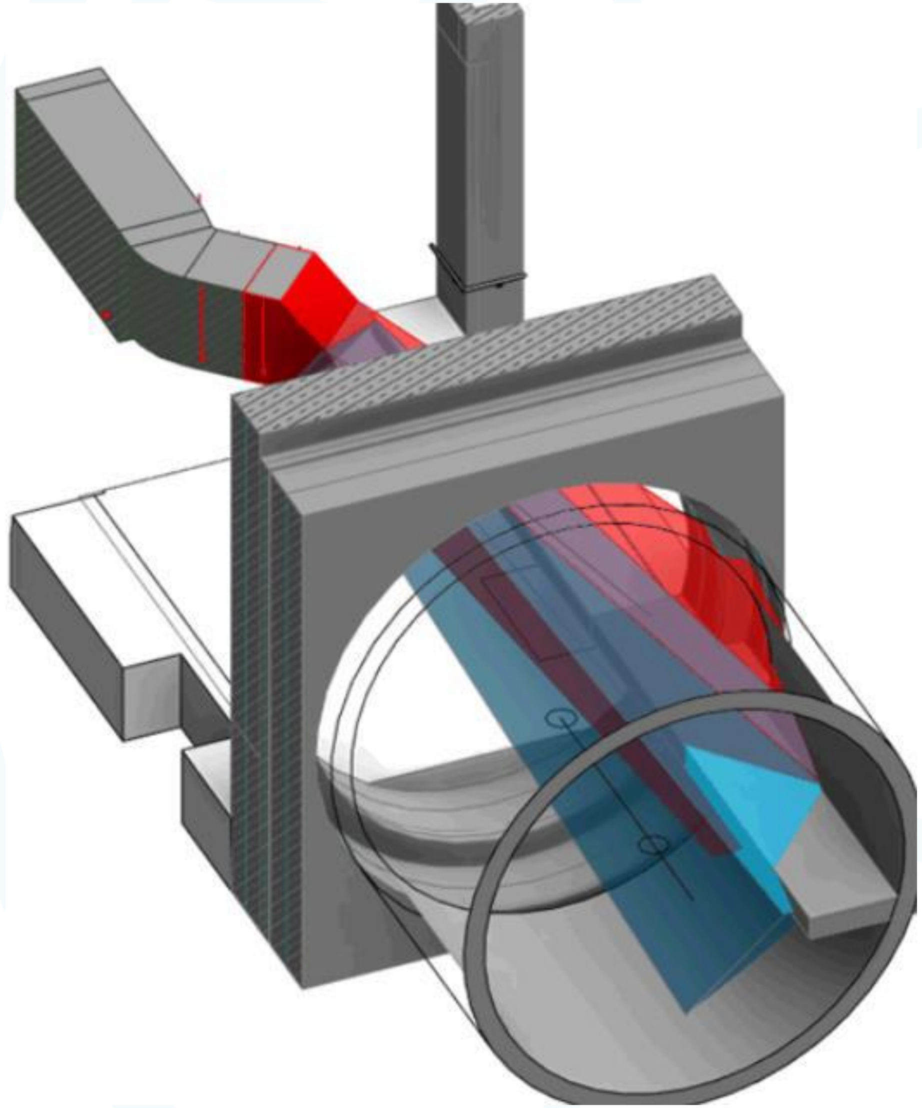
Clash management in the TVS design interface

Examples of clash detection & solving with BIM

Case 4. Other clashes: clashes with potential safety consequences

Solutions and impacts

- **Option 1** (dismissed): installation of protective screens at the walkway edge.
  - ✓ *Impacts: time & additional costs, train door potential blockage*
- **Option 2** (dismissed): train gauge space proofing relaxation.
  - ✓ *Impacts: reduction on the space proofing safety margins*
- **Option 3** (dismissed): consider the impacted zones as exceptions to the NFPA-130 recommendations.
  - ✓ *Impacts: potential safety issues during tunnel evacuation*
- **Option 4** (considered option): rearrange a detailed nozzle re-routing study in BIM avoiding any new clash. BIM Simulation of the theoretical air jet projection corrected according to different nozzle configurations.
  - ✓ *Impacts: redesign and engineering works, new interface process, accelerated day/night shifting for nozzle modification*



SUMMARY & CONCLUSIONS

5

Summary and conclusions

- Design Interface in a Metro Project is a discipline which involves a multidisciplinary workforce involving Civil, Mechanical and Electrical engineers
- BIM discipline was applied not only for design purposes but also for interfacing and clash solving
- Doha Metro Project required of a multilateral BIM coordination in order to share information in real time. Classic coordination methods would not have allowed to achieve the tight deadlines in time and manner
- TVS interface involved an estimated amount of 100,000 man-hours
- Cost saving estimation after Design Interface completion is up to 20,000 to 25,000 direct man-hours (without considering fabrication of additional components/materials, costs overrun due to own and others delay and potential penalties)
- Work quality has been improved
- Modern construction projects require "not to design in isolation"
- Main improvements summary:
  - ✓ Collaboration and communication with other parties
  - ✓ Design coordination and clash detection and solving
  - ✓ Productivity and prefabrication
  - ✓ Pre-construction Project visualization

ZITRÓN GROUP

For over 50 years ZITRÓN has been at the forefront of providing customers with cutting-edge, tailor-made solutions for their ventilation system requirements for underground infrastructures such as road, rail, metro tunnels and mining.

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