

CS226936

# Optimizing Fast-Paced Scan-to-BIM Projects Using ReCap, Revit, Navisworks

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## Learning Objectives

- Learn how to define and set standards for level of accuracy and level of development
- Learn how to select technology and equipment for reality capture
- Learn how to save time in handling and modeling from large-size point clouds
- Learn how to quickly manage the numerous clash results from the Clash Detective tool in Navisworks

## Description

This class will discuss the workflow of using Autodesk software like ReCap Pro software, Revit software, and Navisworks software in a project where 6 commercial buildings with 340,000 square feet of floor space were renovated for a Silicon Valley tech giant in Mountain View, California. The project involved reality capture and modeling from point clouds resulting from scans. This case study highlights some of the challenges the team faced when dealing with the aggressive 30-day timeline and suggests the means to overcome them in the scan-to-BIM process. We'll also talk about the efficient clash coordination process used to finalize the constructability of the project that included the as-built 3D models developed from the scan-to-BIM process used by each trade sub in developing new designs. The attendees will learn the best workflow and tips using Autodesk software in tandem to achieve the right accuracy, the desired time savings, and the achievement of the BIM coordination schedule in time to meet construction deadlines.

## **Speaker(s)**

Rehan Amin is a BIM specialist who works in the AEC industry to provide BIM and 3D technology solutions over the life cycle of buildings.

Rehan believes capturing, digitizing and organizing data involved during the life cycle of projects will become very beneficial and save a lot of time.

Rehan has worked at multiple Scan to BIM projects since the beginning of last year and is actively working to improve the schedule by 3-5 times from the industry norm.

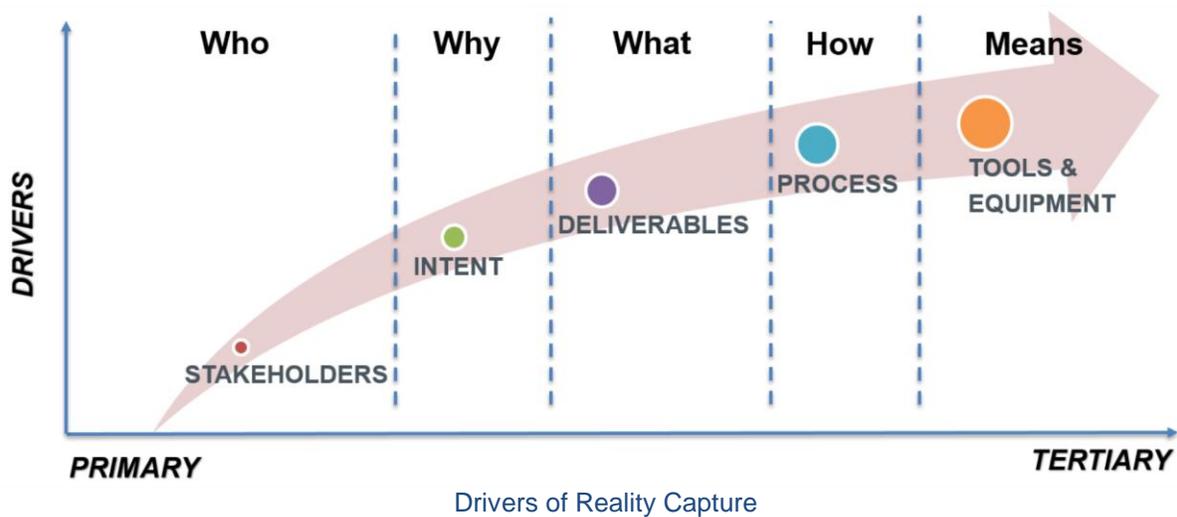
Rehan holds a master's in construction engineering from Purdue University

Vigny Mathew is a BIM Construction Engineer working in Sanveo to provide BIM and 3D technology solutions. Vigny has worked on multiple BIM coordination projects since the beginning of 2017 and is working to improve the workflow and streamline the BIM coordination process. Vigny believes that effective BIM coordination and use of technology to simplify the process can eliminate waste and increase value for everyone involved in a construction project. Vigny holds a master's in engineering and project management from UC Berkeley.

## What Drives Reality Capture

Reality Capture can help construction professionals in several different ways. Incorporating reality capture into current project workflows is proving to be a challenge because of how costly the process can be as well as the skillset required to deal with it. To get the best return on investment (ROI) in using this technology, we need to have the complete knowledge of the different equipment, tools and software available in the market. To achieve the same, firstly, we need to understand the basis of choosing the right type of technology, equipment, tools and software. Furthermore, we need to learn few tips and tricks in the software used to boost our productivity even further.

Before diving into the nitty-gritty, the importance of the following drivers, starting from primary to tertiary, are described. This is very critical in nailing down the best workflow.



### Who - Stakeholders

The first question which needs to be asked is- Who wants to execute the process of reality capture? This is important because depending on the stakeholders involved, who will eventually be the end users of the reality capture output, will help in understanding the next driver of reality capture. A stakeholder can be an owner, architect, design engineer, general contractor or the mechanical, electrical, plumbing and fire (MEPF) subcontractors.

### Why - Intent

The second question which needs to be asked is- Why do the stakeholders want to perform reality capture? Understanding the problem statement will help in establishing the intent of reality capture so that it can be proved that it will save time and money in comparison to the traditional methods used. This will help in finalizing the next driver of reality capture. The intent

of reality capture can be to visualize the existing situation, for design and coordination, 3D documentation of heritage buildings or for space and facility management.

### **What - Deliverables**

The third question which needs to be asked is- What are the deliverables of reality capture? Based on the deliverables required by the stakeholders, the right process of reality capture can be decided. We must make sure that we are not wasting time and money in preparing the deliverables which are of no/less benefit to the stakeholders. The deliverables of reality capture can be 2D photos, 360 3D photo walkthroughs, point clouds, 3D mesh models, data-rich BIM models or reports of comparison of signed-off BIM models with installed elements.

### **How - Process**

The fourth question which needs to be asked is- How will the process of reality capture be performed? This includes the finalization of technology of reality capture to be used. The process of reality capture can be infrared scanning, photogrammetry or 3D laser scanning. Depending on the technology, the next driver of reality capture can be decided.

### **Means – Tools & Equipment**

The fifth and the last question which needs to be asked is- Which tools and equipment need to be used to perform reality capture? This choice will govern the amount of time and money spent in the whole process. This process involves choosing the right equipment for reality capture, right software for processing the captured data, right software to create and qa/qc 3D BIM models.

## Introduction to Case Study

This case study is about a project involving the renovation of interiors of 6 commercial buildings having 2 floors each. The area involved was 340,000 sq. ft. The general contractor for the project was Novo Construction. The technology partner helping the general contractor was Sanveo. The general contractor was facing the following problem:

### Problem Statement

For the new design team to design and perform coordination, there was a need to capture the existing conditions of the space after demolition as there was no existing 3D BIM of the buildings. This was a very fast paced project and the owner was ready to spend money for aggressive schedule achievement. Sanveo suggested the GC to perform reality capture of the complete interiors of the buildings and then develop 3D BIM models from it which can be used for new design and coordination of models. The as-built model generated was used by architect, structural engineer, MEPF engineers and the general contractor.



Existing state of the commercial space after demolition

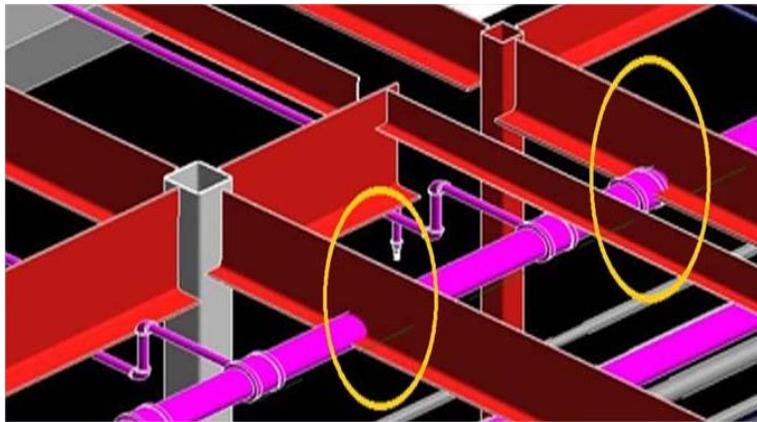
After identifying all the stakeholders involved, understanding the intent and need for the project, Sanveo was in a position to define the scope and project requirements.

## Scope and Project Requirements

Defining the scope and project requirements is a part of finalizing the deliverable of the reality capture process. This includes understanding the intent, desired level of accuracy (LOA), desired level of development (LOD), extent of data capture and the importance of pre-scan logistical planning. This process becomes critical as it will act as the reason for the choice of technology of reality capture.

### Intent

Understanding the right intent begins with defining the project scope. As stated earlier, the intent of the project was as-built model generation. So, the definition of the project scope should be in alignment with the correct purpose of as-built. In the building construction industry, reality capture is used mostly when there is a need for as-builts for clash coordination, pre-design visualization, facility management and heritage documentation.



Purpose 1: Clash Coordination

The purpose of as-builts for clash coordination arises when the as-built BIM models are used in the BIM coordination process by the architects, structural engineers and MEPF engineers to avoid the newly modeled elements clashing with the existing elements. This requires accurate measurements such as diameter of conduits, width of the duct, interstitial space available etc. as the model is used in the BIM coordination process.



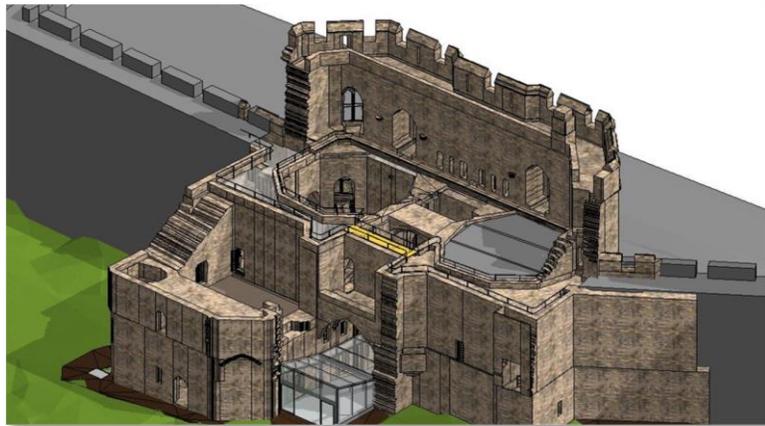
Purpose 2: Pre- Design Visualization

The purpose of as-builts for pre-design visualization arises when the as-built BIM models are needed by the architects, structural engineers and MEPF design engineers to perform rough measurements such as distance between columns, elevation of bottom of beam, conduits etc. in making preliminary design.



Purpose 3: Facility Management

The purpose of as-builts for facility management arises when the as-built BIM models are needed by the owners and facility managers to keep track of the information, location and maintenance schedule of the all the equipment present in their facilities.



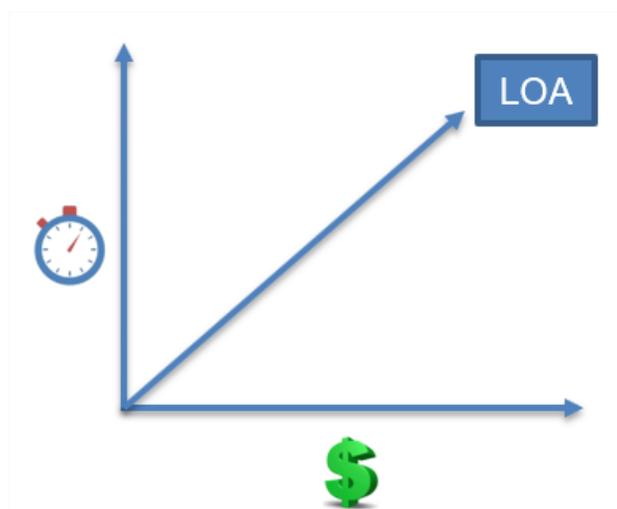
Purpose 4: Heritage Documentation

The purpose of as-builts for heritage documentation arises when the as-built BIM models are needed by the government owners, architects, structural engineers to capture digital data in the repository and to plan for new design or retrofit or repair work of the historical buildings. Since the requirement is to capture absolute digital data in the form of BIM model, the models need to be super accurate in comparison to the purposes of the as-built models.

For the project of this case study, the requirement of as-built models generated by performing reality capture, as specified by the general contractor, was for clash coordination and pre-design visualization.

### Level of Accuracy (“LOA”)

After defining the correct purpose of the as-built models, the next step is to finalize the level of accuracy required for output data of reality capture. This depends on the selected purpose of the as-built models.



Accuracy vs Time vs Cost

Finalizing the level of accuracy is very important because requiring higher accuracies than needed will lead to unnecessary time and cost spending. We should also note that requiring lower accuracies than needed will not solve the purpose and the final as-built models will not be utilized efficiently leading to delay and higher costs later in the construction cycle.

| Intent                               | LOA   | Acceptable Limit |
|--------------------------------------|-------|------------------|
| Heritage                             | 50    | 1/16"            |
| Coordination - Clash Detection       | 30-40 | 5/8"             |
| Pre-Design - Visualization           | 20    | 2"               |
| Facility, Asset and Space Management | 10    | >2"              |

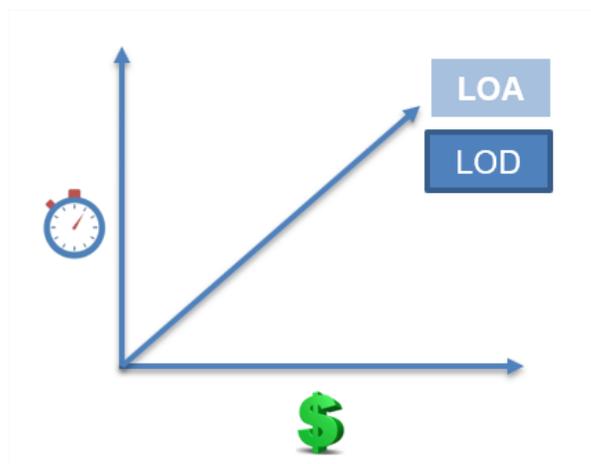
Acceptable Limit of LOA depending on the Intent (USIBD)

As per the United States Institute of Building Documentation (USIBD), the term Level of Accuracy (LOA) is defined based on the acceptable limits for the difference between the output data of reality capture with respect to actual reality.

For the project of this case study, based on intent of the as-builts, it was concluded that the LOA requirement will be 30-40 which meant that the output data of reality capture must be within 5/8" of actual reality.

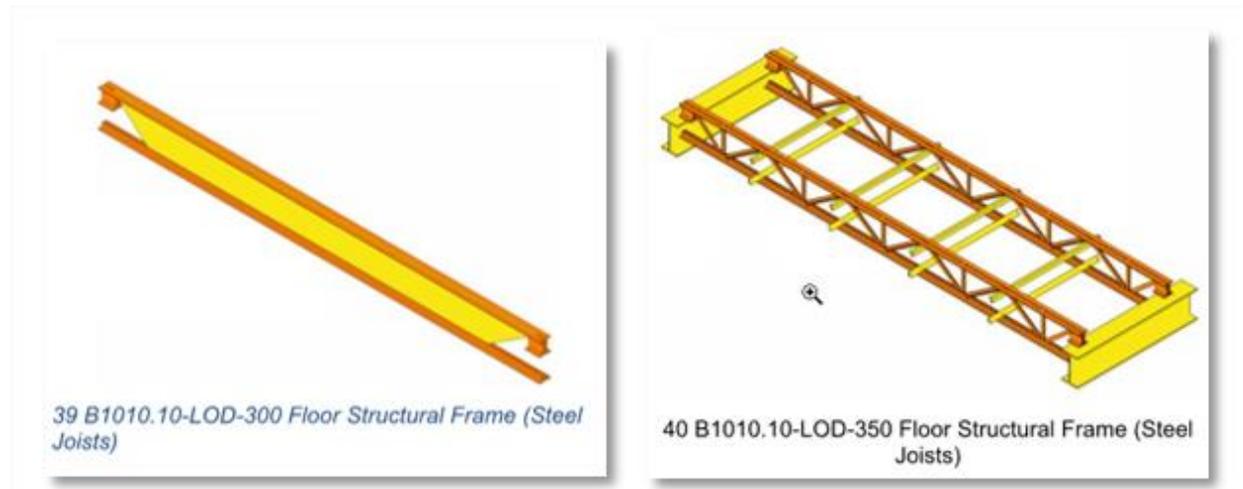
### Level of Development ("LOD")

After finalizing the level of accuracy for the project, the next step is to finalize the level of development of the BIM model. Choosing the correct level of development also depends on the purpose of the as-builts.



LOD vs Time vs Cost

Like the level of accuracy, finalizing the level of development is also important because requiring higher LOD than needed will lead to unnecessary time and cost spending. We should also note that requiring lower LOD than needed will not solve the purpose and the final as-built models will not be utilized efficiently leading to delay and higher costs later in the construction cycle.



LOD 300 vs LOD 350 for steel joists

As you can see in the figure above, modeling a LOD 300 model will take less time than modeling an LOD 350 model. For the project of our case study, based on the intent of the as-builts, modeling to the detail of LOD 400 model would have been an overshoot. So, it was concluded that the LOD requirement will be 300-350 depending on the importance of the elements.

| Intent                               | LOA   | Acceptable Limit | LOD     |
|--------------------------------------|-------|------------------|---------|
| Heritage                             | 50    | 1/16"            | 400-500 |
| Coordination - Clash Detection       | 30-40 | 5/8"             | 300-350 |
| Pre-Design - Visualization           | 20    | 2"               | 200     |
| Facility, Asset and Space Management | 10    | >2"              | 200     |

LOD selection depending on the intent

## Extent of Data Capture

After deciding upon the level of development for the project, the next step is to finalize the extent of data capture required for the BIM model. This essentially is a step in which a checklist of all the elements which were required to be present in the BIM model are listed out by the modeling team for the end users. The end users confirm the required elements. This process removes the time wasted on modeling unwanted elements and removes the chance of missing any elements in modeling from point cloud which ultimately causes delay in the overall timeline of the project.

| Architectural   | Y/N |
|---|-----|
| Exposed Metal Studs   | Y   |
| In-wall Modelling (inside boundary)   | N   |
| Vermiculite on elements   | Y   |
| Penetrations  | Y   |
| Exact Risers and Treads   | Y   |
| Exact Railings  | N   |
| Generic Railings  | Y   |
| Exact Wall Thickness (includes veneer, insulation, interior skin, airspace) | Y   |
| Window frames & Mullions  | Y   |
| Actual exterior wall texture  | N   |
| Flooring Material variation   | N   |
| Smooth wall trims   | Y   |
| Furniture   | N   |
| Ceiling and Wall Elements   | N   |
| Casework  | N   |
| Signage   | N   |
| Open gaps in wall surface/joinings  | Y   |

Architectural Elements Checklist

| Electrical                           | Y/N |
|--------------------------------------|-----|
| J Hooks                              | Y   |
| Custom Supports                      | N   |
| Hanger Struts                        | Y   |
| Seismic support                      | Y   |
| Wall Elements (receptacles, lights)  | N   |
| Minimum diameter of conduit to model | 2"  |
| Wires and Cables                     | N   |
| Flexible conduit                     | N   |
| Equipment supports pads              | Y   |
| Generic lighting fixtures            | N   |
| Exact lighting fixtures              | N   |

Electrical Elements Checklist

| Plumbing/Fire                 | Y/N |                                     | Y/N |
|-------------------------------|-----|-------------------------------------|-----|
| J Hooks                       | Y   |                                     |     |
| Custom Supports               | N   | <b>Mechanical</b>                   |     |
| Hanger Struts                 | Y   | J Hooks                             | Y   |
| Seismic support               | Y   | Custom Supports                     | N   |
| Minimum diameter of pipes     | 1"  | Hanger Struts                       | Y   |
| Insulation(cover point cloud) | Y   | Seismic support                     | Y   |
| Flanges/Valves                | N   | Insulation(cover point cloud)       | Y   |
| Flexible Pipes                | N   | Exact Mechanical Piping Connections | Y   |

Mechanical/Plumbing/Fire Elements Checklist

For the project of our case study, the above tables give an example of the elements which were required to be present in the model. This process removed any confusion and made sure that the modeling team and the contractors are on the same page.

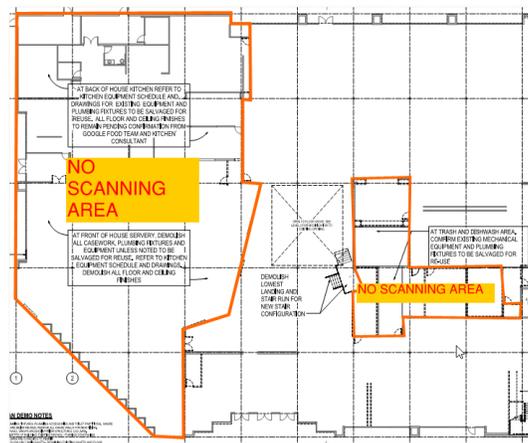
### Pre-Scan Logistical Planning

After deciding the extent of data capture in the form of checklist for the project, the next step is to perform pre-scan logistical planning. This process is important because it helps in preparing better for any contingency which may exist while doing the field work of reality capture, thereby saving time.



Site walk-through

Site Walk-through is a must as it prepares us for the conditions of the site. It helps in planning out the path of scanning and makes us prepared for the hazards such as tight areas, dark and reflective surfaces etc. For this project, this process helped us in not missing any areas which required scanning as some of the special electrical rooms in the buildings had access from the exterior. If a complete site walk-through was not performed, then it would have been very easy to miss those rooms. This would have led to rescanning of the areas and delay in the overall process.



Exceptions

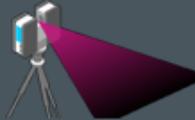
It is very important to mark the exceptions of no scanning areas on floor plans and should be provided to the scanning team as this will prevent unnecessary time spent in scanning the unwanted areas.

After finalizing the deliverables, the next step was to decide how the process of reality capture will be performed and then choose the correct tools, equipment and software required to do the process of reality capture which provided the best value for the right application.

## Field Execution

Based on survey and research of the technologies, tools and equipment present in the market, a matrix of comparison of all the technologies and equipment, which can be used for reality capture for tenant improvement jobs, was built. This was done to finalize the technology process and the respective equipment to be used for reality capture.

### Technologies and Equipment - Survey

|            |    | <b>3D LASER SCANNING</b>  |
|------------|---|---|
| Stationery |   | PROS Most Accurate; Best Quality<br>CONS Slow; Expensive                  |
| Handheld   |  | PROS Fast<br>CONS Lower Accuracy; Noisy Quality                           |
| Mobile     |  | PROS Fastest; Good Accuracy<br>CONS Lower Resolution                      |
| Aerial     |  | PROS Fastest; Good Accuracy; Good Quality<br>CONS Expensive for Interiors |

3D Laser Scanning Options Comparison

We divided the 3D laser scanning equipment available among the stationery, handheld and mobile and aerial classifications. After that, we noted the pros and cons of each classification.

Firstly, the stationery laser scanner has the advantage of producing the most accurate point clouds. In addition to the accuracy, the relative quality of point cloud in terms of noise is the best among other types of reality capture equipment. The trade-off of using stationery laser scanner is that it is slower and is on the expensive side in comparison to the other options whether used as a service or if the equipment is purchased.

Next, the hand-held laser scanner options available in the market have the advantage of being faster than the stationery laser scanners. The trade-off here is that the hand-held laser scanners have lower accuracy than the stationery ones. In addition to this, the quality of the point cloud is on the noisier side as the lidar is in dynamic motion and is handheld.

Next, the mobile trolley-based laser scanners have the advantage of being the fastest available ground-based method of reality capture. The accuracy and range are lower than the stationery method but still useful for interior scanning of buildings. The trade-off here is that the resolution of the output point cloud is not good enough for capturing elements <2-3" in diameter at standard open ceiling heights of commercial buildings. However, the point clouds generated are less noisy than the hand-held scanners.

Lastly, the aerial laser scanning options consists of lidar mounted on unmanned aerial vehicles (UAVs) like drones, aircrafts etc. These have an advantage of being the fastest method of exterior reality capture with good accuracy and point cloud quality. The trade-off here is that it is very risky and expensive if used for interior capture of buildings. The cost of the equipment or using it as a service is quite expensive.

|  <h2 style="text-align: center;">PHOTOGRAMMETRY</h2> |   |
|--|---|
| Stationery   |  <p>PROS Fast; Good Quality; Affordable<br/>CONS Lower Accuracy</p>    |
| Handheld   |  <p>PROS Faster; Affordable<br/>CONS Not Accurate</p>                  |
| Mobile   | N/A   |
| Aerial   |  <p>PROS Fastest; Good Quality; Affordable<br/>CONS Lower Accuracy</p> |

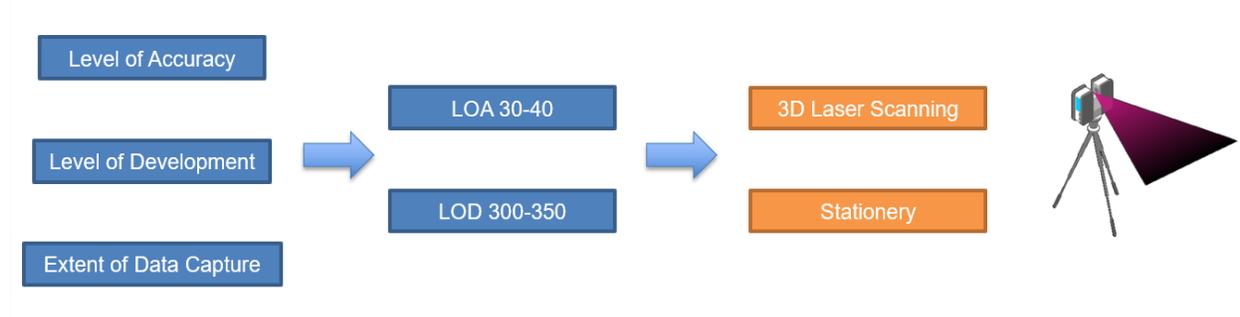
Photogrammetry Scanning Options Comparison

In addition to the 3D laser scanning equipment available in the market, we also surveyed the photogrammetry scanning options available. The equipment functioning based on photogrammetry technology were also divided among the stationery, handheld and aerial classifications and then the pros and cons of each classification was noted.

Firstly, the stationery method of photogrammetry has the advantage of being faster than stationery laser scanning and being more affordable. The point cloud quality is good for developing architectural models. The cost of the equipment is affordable. The trade-off here is that the accuracy is on the lower side when compared to the laser scanning methods.

Next, the hand-held method of photogrammetry involves using an off the shelf 360-degree camera like Insta360 One and then using a photogrammetry stitching software like Cupix. This method has an advantage of being faster and affordable method of reality capture than the stationery photogrammetry equipment. However, the trade-off here is that it is not at all accurate and should only for used for pre-design visualization.

Lastly, the aerial photogrammetry options consist of cameras mounted on drones. These have an advantage of being the fastest method of photogrammetry capture and very affordable both in terms of purchase of the equipment or used as a service. The point cloud generated is of fairly good quality and having less noise. The trade-off here is that the accuracy is on the lower side and being a risky method if used for interiors.



Choice of technology and equipment

Finally, based on the finalized LOA, LOD and extent of data capture, it was decided to go ahead with the stationery 3D laser scanning method for performing reality capture for this project to provide the best value for the desired application. The next sub-section discusses a few tips and tricks which can be used to save time in the scanning process at field.

### Scanning Tips

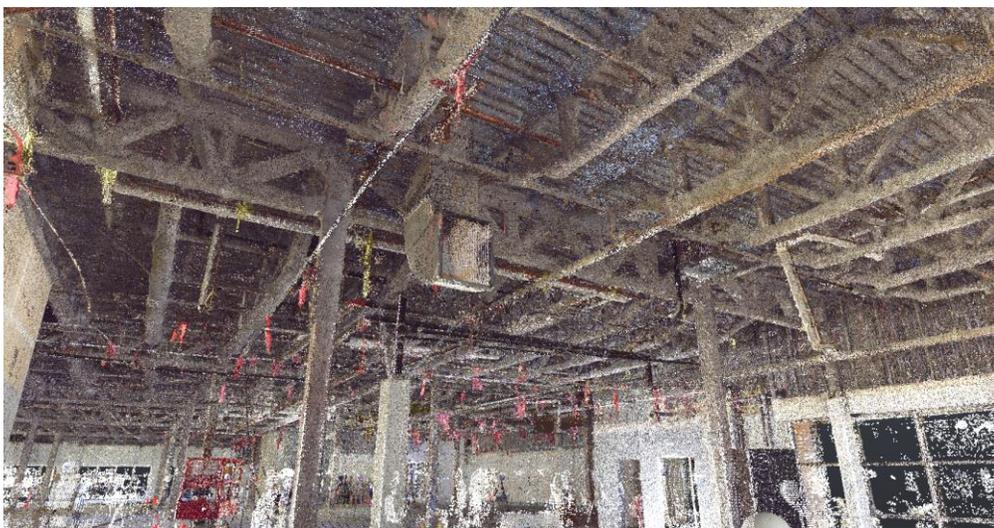
At the beginning of the project, for the first 2 buildings, we scanned using color mode on. We noticed that based on the resolution selected and with the color mode on, it was taking us 6 minutes per scan. To save time, we experimented by scanning with switching off the color mode. This reduced the scanning time to 3 minutes per scan. The color of the point cloud comes from the photographs captured by the scanner. When the color mode is off, the point clouds are generated in grayscale. The modeling team needs to view the real colored 360

photographs to visualize and recognize the MEP utilities for modeling to supplement the grayscale point cloud. To capture the photos, we used the off the shelf 360 camera like Insta360 One and created a 3D walkthrough using a technology software called Cupix. This saved time of scanning. The size of the grayscale point cloud is less than the colored point cloud. Since the size of scans decreased, time was also saved in the file transfer process. This resulted in time savings of up to 40% of time.

The method of scanning with color mode off can be useful in saving time in projects like tenant improvement of commercial spaces where the density of the MEP is not too dense after demolition.

### Processing Point Cloud

After performing laser scanning on field, the next step is to process and register the scans to produce a point cloud which will be used as a source to create as-built 3D BIM model. For registering the point cloud, we used Autodesk's ReCap Pro. ReCap Pro was selected to be used because of its easy user interface. Sanveo's team was able to self-learn the process of registering using ReCap Pro through the instructional videos in the internet. The software was on the affordable side of the market. There is also a feature of overlaying the model developed with respect to the Real View (360 photo view) in ReCap Pro. This feature helped greatly in the process of QA/QC of the developed model. Since the software was easy to learn and required minimal training, it saved 4 days of time required for training the software in this project. The other solutions present in the market to register point cloud such as FARO Scene, Leica Cyclone and Trimble Real Works can handle large point clouds (>100 scans) in a better manner but for a project of this size, Recap worked perfectly.



Point Cloud registered in ReCap

The next sub-section discusses a few tips and tricks which can be used to save time in handling large point cloud files in ReCap Pro.

## Point Cloud Handling - Tips

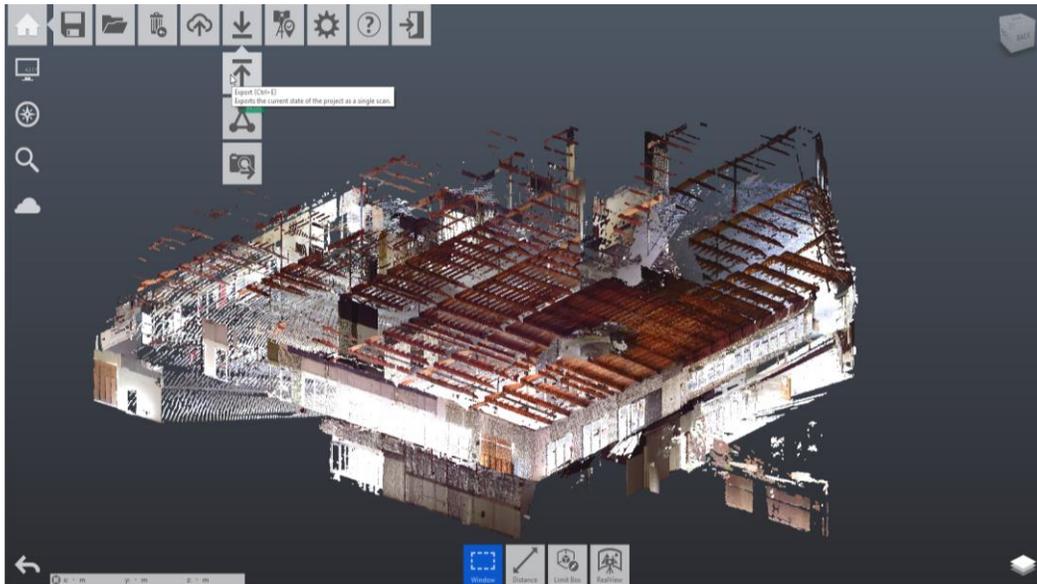
Handling the large size of point clouds is one of the biggest challenges in Scan-to-BIM projects. Based on Sanveo's experience, some helpful workflows were discovered which can be used in saving time in the overall process.

For this project, Sanveo limited the project file size by dividing the project into various zones and kept the ReCap project files to 50 -75 scans. There was a trade-off here. This increased the field time as more time had to be spent on field in getting the coordinates for more target control points for geo-registration of each project file. However, in the end, it saved 25% of time in modeling because of the smaller sized point cloud file. The modeling software Autodesk Revit worked very smoothly, and no money was spent in upgrading the system configuration. So, the trade-off was in the favor of limiting the size of ReCap project files.



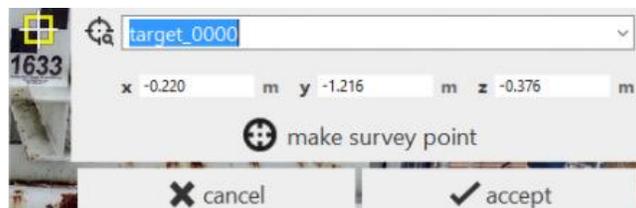
Limiting ReCap file size by dividing project into zones

Another method which can save time in later process of modeling, is by exporting the heavy ReCap project files (RCPs) to RCS. Large ReCap files make modeling in Revit slower as it is a heavy file. The system takes a lot of time while navigating the point cloud. By performing this method, the catch here is losing the geo-referencing done in the RCP file as RCS point cloud does not contain scan location. To tackle this, only for the first time, the RCS point cloud was required to move to the exact location of RCP in Revit and then modeling was started using the RCS point cloud after removing the RCP point cloud.



RCS export from RCP

For this project where the purpose of the as-built model was to be used for clash coordination, geo-referencing the point cloud is crucial. Geo-referencing the point cloud will save time in aligning the point clouds with each other, if the project was divided into multiple RCP files. It also makes sure that the developed 3D BIM models of different trades from the point cloud are always aligned with each other and the new design trade models when appending in Navisworks for BIM coordination process. This ultimately improves productivity and eliminates issue of time wasted in manually aligning the models.



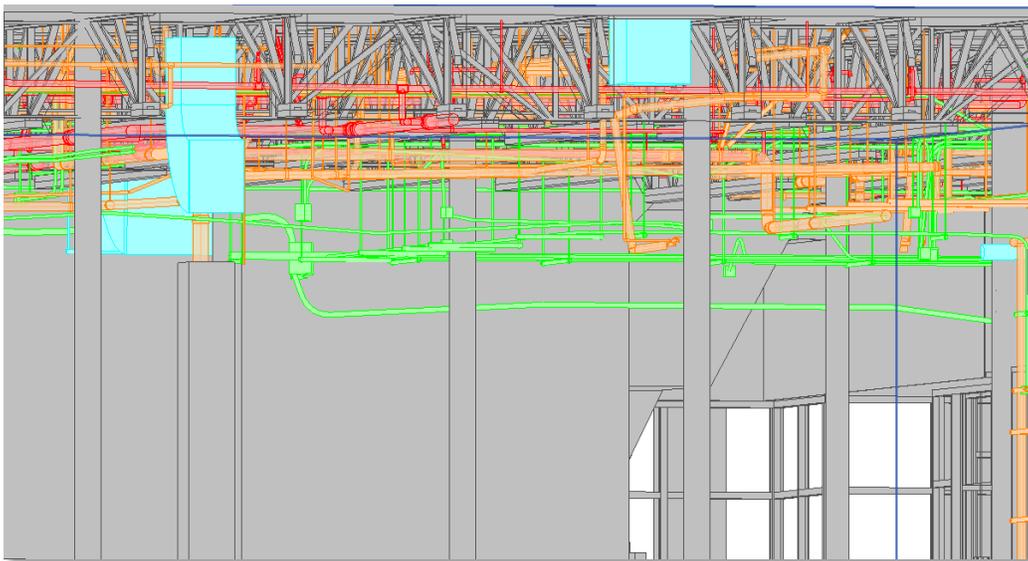
Geo-Referencing

## Modeling

After the scanning process and registration of the point cloud, the next step was to develop BIM 3D models from the point clouds. In the modeling process, the registered point cloud is imported in the modeling software and then the modelers trace over the point cloud to produce the 3D elements resulting in the 3D BIM model.

### Software Selection

For developing 3D models from point cloud, Sanveo used Autodesk Revit. Revit was selected to be used because of prior experience in using the software. It offers easy collaboration for working and the most important thing was that it was the stakeholders' requirement.



3D model developed in Revit from point cloud

The next sub-section discusses a few standards followed during the model creation process in Revit which leads to better collaboration and avoids confusion in using the developed 3D models by the end users.

### Pre-Model Planning & Workset Handling

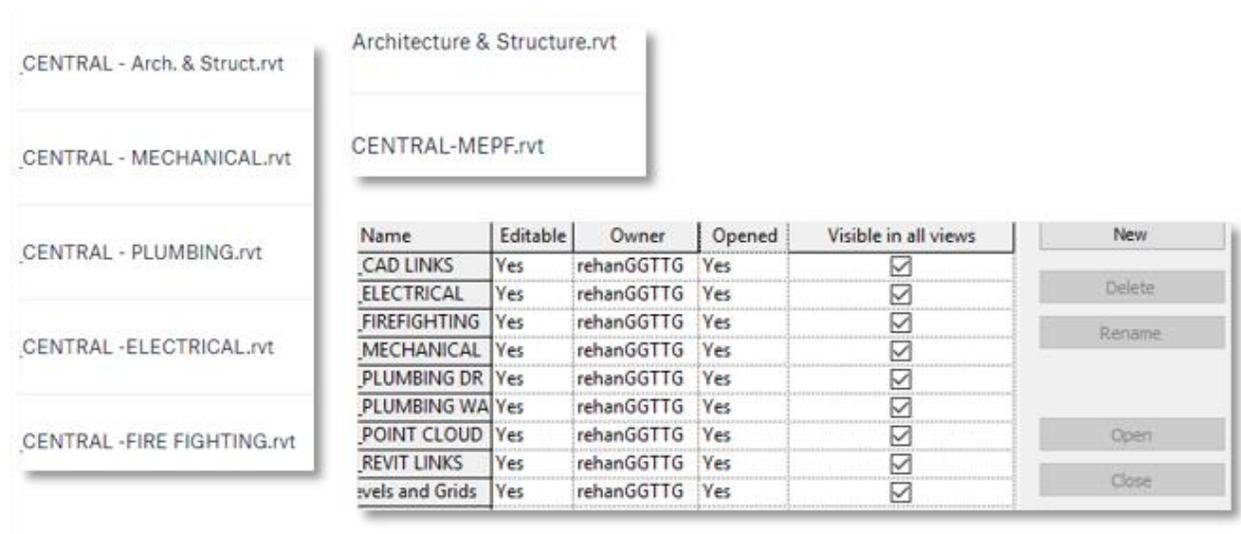
To save time in modeling and benefit the end users in utilizing the deliverables more efficiently, some modeling standards were enforced while modeling in Revit.

If the purpose of the model is to be used by each MEPF trade engineer for building the new design, then organizing the Revit model trade wise will make each Revit file light, containing only the respective trade elements. This will eliminate the other trade elements from the model whose presence may cause confusion in new design modeling. The other way of organizing the

Revit model is by having core & shell in one file and other interior trades on separate file. This should be used when the only intent of using the models is in clash coordination. This will save time in removing too many links in the Revit model and time spent in appending each trade file will be eliminated.

One more useful modeling style is the inclusion of column grids and setting project north while modeling from point cloud. This helps modelers to visualize the point clouds in a better way and makes it easier to trace upon the elements as the elements can be clearly visualized if they are straight/orthogonal.

Lastly, the practice of using work sets either by trade, by level or by area helps in efficient collaboration. This feature in Revit enables the multiple modelers to divide the work among themselves and model their part simultaneously real-time. This leads to 50% of time during the modeling phase.



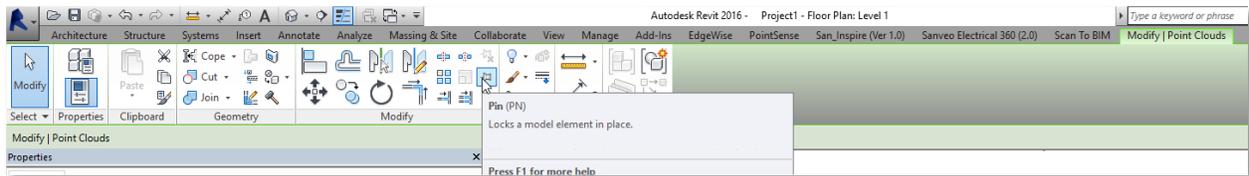
Organization of Revit Model and use of work sets

The next sub-section discusses a few tips and tricks which can be used to save time during the modeling phase in Revit.

### Modeling - Tips

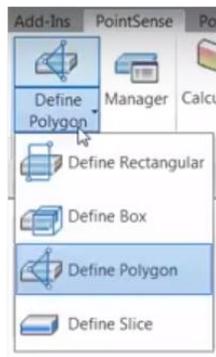
In the overall scan-to-BIM project, the most time-consuming phase is modeling. Saving time in this phase is very crucial if the overall project is fast-paced like this case-study. Based on Sanveo's experience, some helpful workflows were discovered which can be used in saving time in the overall process.

First tip will be always pinning the point clouds when modeling in Revit. If not pinned, random clicking and dragging can change the position of point cloud while the modeler will be unaware of this. Therefore, pinning the point cloud is very important as it will remove any sources of error in modeling caused by random clicking and dragging.



Pinning the point cloud

Another tip to save more time is by using one of the plug-ins available in the market which has better clipping and sectioning tools. For this project, Sanveo used standard section views, scope boxes and callouts while modeling. However, after testing few of these plug-ins like FARO Point-Sense and it was found out that it offers efficient clipping and sectioning methods in comparison to the traditional way in Revit saving 25% of time in the modeling process.



Clipping and Sectioning using Plug-Ins

## Beyond Manual Modeling – Survey of Tools

The process of manual modeling and QA/QC can be slow. Since it is the most time-consuming phase in the scan-to-BIM projects, more time can be saved by using one of the automation tools which are available in the market. Sanveo performed a survey and testing of these tools available in the market and noted their capabilities.

The Scan to BIM tool by Imaginit technologies is a plug-in in Revit itself. On testing, Sanveo found out that it was good in automatic extraction of straight as well as curved walls. Automatic extraction of columns and floors was also possible.

The Edgewise tool by ClearEdge 3D is a desktop-based application where point clouds can be uploaded for automatic extraction. This application gave very good results in extraction of MEPF elements like pipes and fittings. Automatic extraction of architectural and structural elements was also possible.

Other Plug-ins in Revit like PointSense from FARO and Cloudworx from Leica have good slicing and sectioning tools which also helps in saving time in the modeling process.

| Name        | Developer   | Type                 | Pros   |
|-------------|-------------|----------------------|--|
| Scan to BIM | Imaginit    | Plug-In              | Good for Walls and Columns   |
| Edgewise    | ClearEdge3D | Separate Application | Comprehensive auto-extraction for Arch, Struct, Pipes                        |
| PointSense  | FARO        | Plug-In              | Good for Walls/Columns/Windows/Doors, Pipes; Awesome sectioning/slicing tool |
| Cloudworx   | Leica       | Plug-In              | Good Slicing/Sectioning tool   |

Automatic extraction from point cloud tools

After testing these tools, Sanveo found out that we cannot rely completely on automation yet. For this project, in one of the situations, during the automatic extraction of MEPF pipes, the grooves in the pan deck were also extracted as pipes which were false positive. A lot of time was wasted in removing these pipes which compensated for the time saved because of the automatic extraction. This led to spending more time in the modeling process. This helped to make a conclusion that there is still manual human intervention required. These tools should be used intelligently only on those areas which can reap good results, until these tools become more intelligent in future.

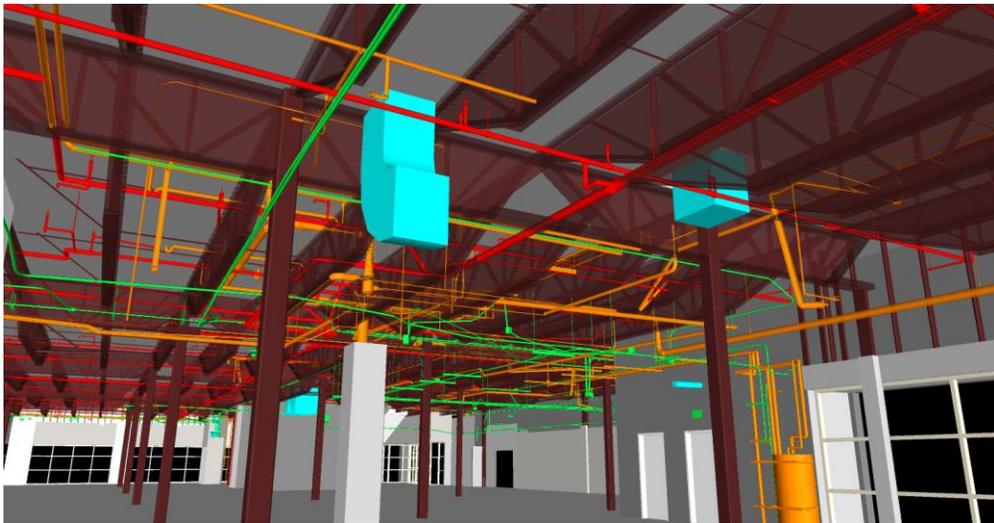
## QA/QC

After developing the 3D BIM model from the point cloud, the next step was to QA/QC the 3D model with respect to the point cloud. In the QA/QC process, the registered point cloud and the developed 3D model are imported in the point cloud visualization software and then a visual as well as measured comparison is done to ensure the quality of model developed in Revit is accurate with respect to the point cloud. In case of any discrepancy, the model is corrected in Revit and checked again in the point cloud visualization software.

### Software Selection

Initially in the project, Sanveo was visually comparing the point cloud with model manually. This did not prove to be one of the most efficient ways to produce the highest quality. The scope of error was too high as it was found by doing random field measurements and verified in the model. Using this method, a potential of causing huge liability was getting developed.

To solve the issue, Sanveo discovered a more accurate way of verifying the developed model. For performing QA/QC of the developed model with respect to point cloud, Autodesk Navisworks was used. Navisworks was selected to be used because of prior experience of using the software in BIM coordination projects. It provided faster and accurate method to QA/QC the model.



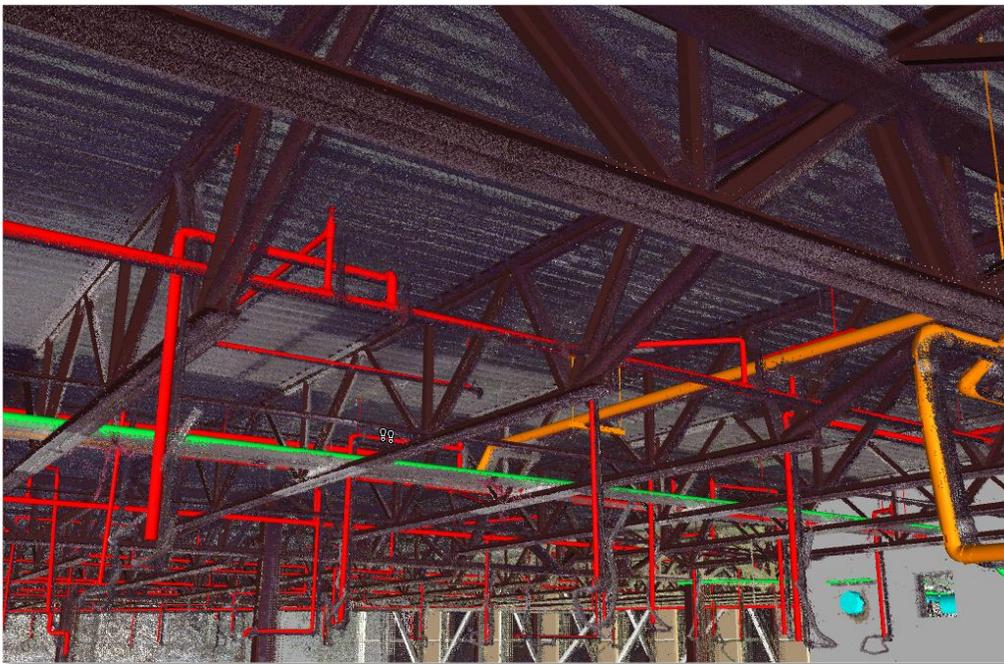
3D model visualized in Navisworks

The next sub-section discusses a few tips and tricks which can be used to save time during the QA/QC phase in Navisworks.

## QA/QC – Tips

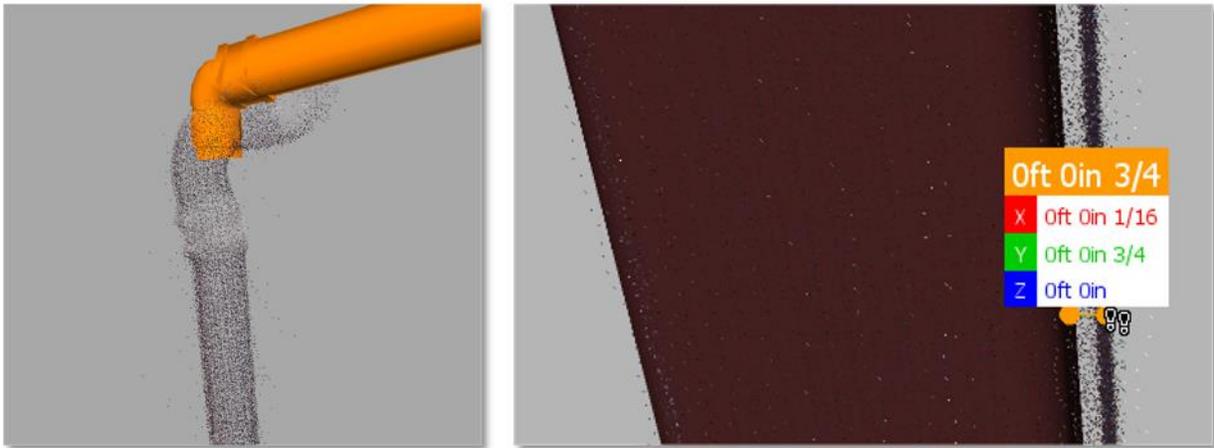
In the QA/QC phase, dealing with large models and point clouds may become overwhelming. This process is important because accuracy of the model depends on it. Based on Sanveo's experience, some helpful workflows were discovered which can be used in saving time in the overall process.

Since the point cloud file and the 3D model can be appended together in a single view, Navisworks works as an ideal platform to fly through the model and check for any discrepancies. This can be done by appending the RCS point cloud file with the NWC extracted from Revit model. This provided better visualization between point cloud and model in comparison to Revit. Flying through the model also became a lot easier in comparison to Revit.



Visualization of Point Cloud and Model in Navisworks

Using the fly/walk mode in Navisworks, it was very easy to walk through the model to find missing modeled elements by visually comparing with the point cloud. It also gave the ability to actually measure deviation between the point cloud and model. If the deviation was found out to be greater than the decided tolerance, then the model was corrected in Revit.



Finding missing modeled elements and measuring deviation with respect to point cloud

Another feature which can be utilized was if the color mode was not switched off during the field scanning, ReCap can also be used to find out missing modeled elements. ReCap Pro has a feature available in which the NWD from Navisworks can be overlaid on the RealView in ReCap. This enabled visual comparison of the NWD model with respect to real 360 photo views in ReCap which provided better visualized and saved 20% of time in the overall process.

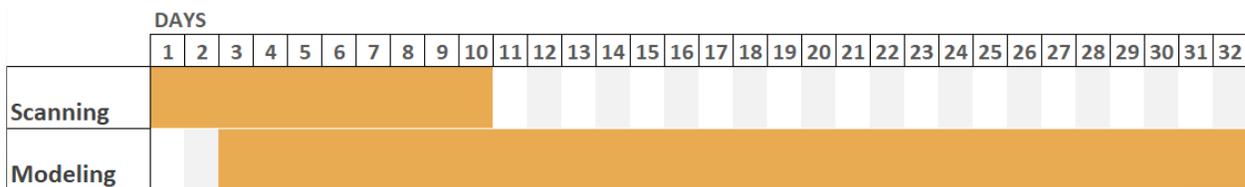


NWD in RealView of ReCap

## Summary

Using all the information, experience, research and the capability of Autodesk software, this project which comprised of 6 commercial buildings having 2 floors each with an overall area of 340,000 sq.ft. was executed successfully by meeting the aggressive schedule requirement of 30 days.

The result achieved in this project included 2 weeks of on-field scanning and point cloud generation time. It also included 30 days of time spent in model generation. By managing the tasks in simultaneous overlapping manner, the overall project time of 32 days was achieved.

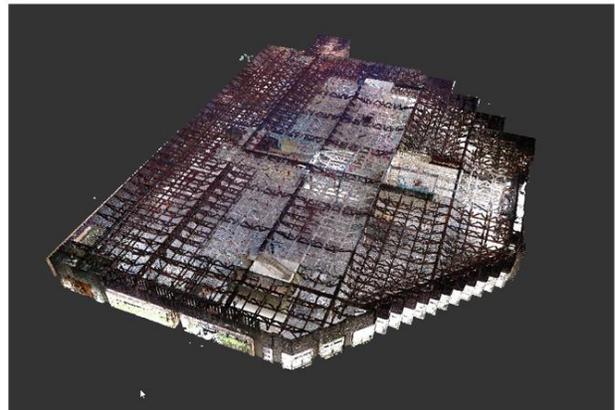
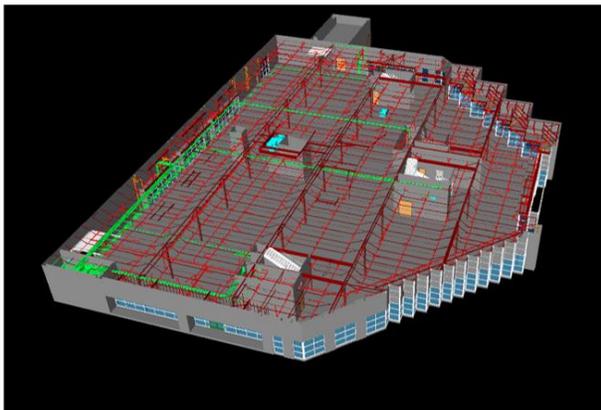


Schedule overview

## Best Practices

With the help of this project as a case study, the following best practices for scan to BIM projects which require aggressive timeline are established.

- Choosing the right technology and equipment which brings value for the right application is very important in avoiding unnecessary time wastage.
- Switching off photo mode during scanning can save time during on field scanning, registration and file transfer.
- Using the best suited auto extraction tool during modeling can save a lot of time as modeling is the most time-consuming process in scan to bim projects.
- The use of Navisworks can also save time as a faster QA/QC process can be achieved.



Model with Point Cloud Overview

The next section discusses how to efficiently manage the BIM coordination process which follows the scan to BIM phase in the overall construction project.

## **Tips and Tricks to manage the clash results from Clash Detective Tool in Autodesk Navisworks**

Sanveo was the BIM Coordination Lead on this project, working alongside the General Contractor. This section describes the BIM Coordination process that Sanveo's team laid out for this project and includes some lessons learnt.

The output from the scan to BIM process was distributed to the Architect and the MEPF design teams to use it as a foundation and develop their design. The existing architectural and structural elements were included in the Architectural model for BIM coordination.

### **Must Haves in the BIM Execution Plan**

- Project Information: Information on project type, square feet, location, number of floors
- Coordination Team Roles & Responsibilities: Names of each trade contractor involved in BIM coordination and their role
- BIM Project Contacts: Email list of representatives from each trade contractor involved in the BIM coordination process
- BIM Coordination Schedule: This schedule should tie in with the construction schedule, and is a living document which needs to be updated regularly – based on coordination meeting updates/ changes in construction schedule. The document should include the information below for each level/ area:
  - model upload deadlines (allow at-least one day between model upload deadline and coordination meeting for better quality in meeting preparation and reporting)
  - coordination meeting dates
  - release dates for mechanical duct mains
  - sign-off date
  - shop drawing submission dates
- LOD: Level of Development required for the models
- BIM Process Maps: Export settings from Revit/ Autodesk CAD to be followed for nwc exports
- Navisworks Color Coding Guide: Colors to be assigned to each trade for the federated model
- Data Exchange Platform
- File Naming Guideline
- File Sharing Checklist: List of files expected to be uploaded by trades in their periodic uploads
- Viewpoint Naming: Information on how the viewpoints will be structured and how the naming will indicate which trade a viewpoint is assigned to
- Coordination Tolerances: The tolerances that are recommended for the project
- Coordination Priority: A typical coordination priority that decides which trade moves in a conflict

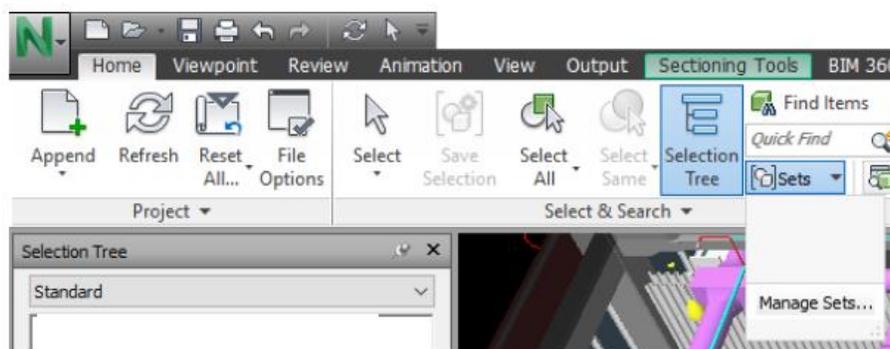
## Use of Search sets and Clash test templates

### Selection sets vs Search sets:

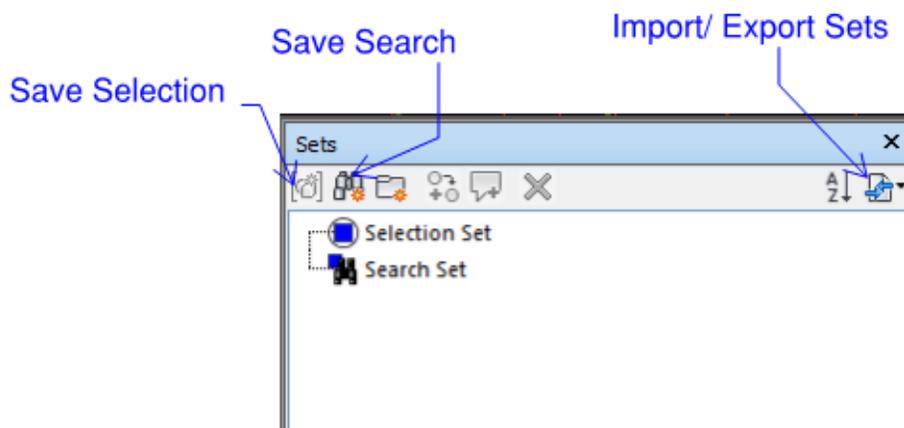
Selection sets are static and created by selecting items in the Scene view or Selection tree and then saving the selection using Save Selection in the Sets window, or by dragging the selected items into the Sets window. Search sets are dynamic and are defined by setting rules or search criteria using Find Items.

Selection sets cannot be exported and re-used unlike search sets. Selection sets are generally useful for changing the appearance (color/ transparency) or to hide the selected items.

To open the Sets window, click Home tab > Select and Search Panel > Sets Dropdown and click Manage Sets

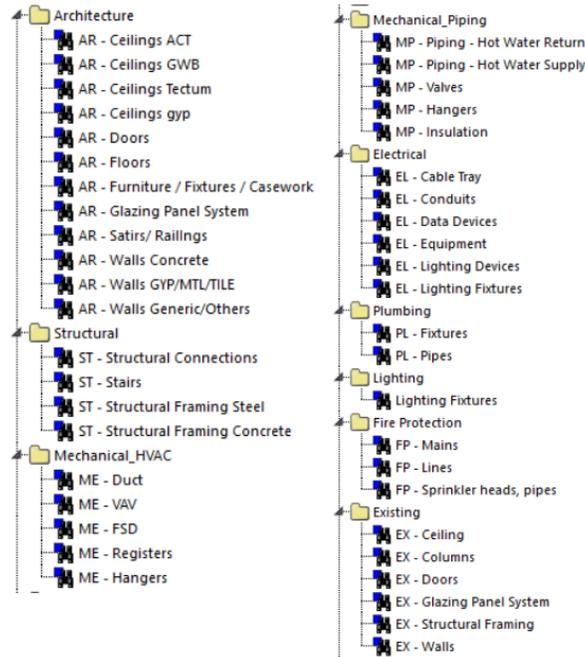


Manage sets location



Manage sets window

It is good practice to define search sets for each trade in the model. This helps the BIM coordinator understand how the models are set up by each trade.



Search Sets sample

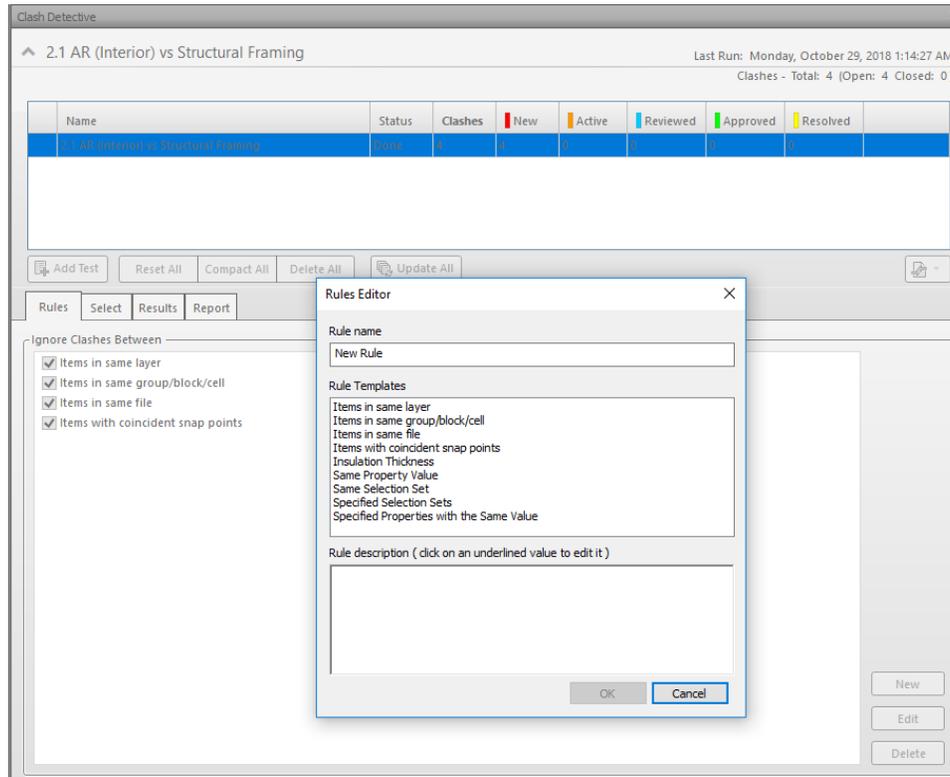
After a basic search set template is set-up, it can be exported as an xml file and used as a template for future projects.

Clash Tests:

Once the search sets are set-up, clash tests can be defined using these sets. While it is possible to clash every trade model against every other trade model, this would result in numerous clashes and wasted time and effort in reviewing false clashes.

Setting up clash tests with project specific rules at the beginning can save time later when running the same tests on updated models.

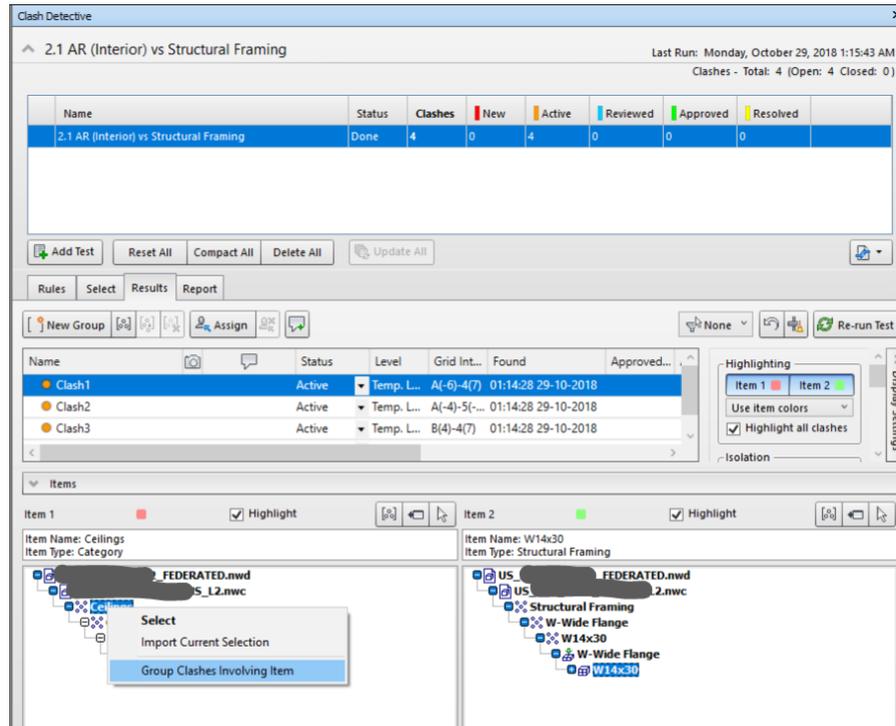
In addition to the default rules, new rules can be set in Clash Detective using the Rules Editor (In the Rules tab, click on New to open the Rules Editor window)



Rules Editor in Clash Detective

### Grouping and filtering clashes

One way to group clashes is to select the item in the results tab, right click and choose “Group Clashes Involving Item”. This will group all clashes involving that item in the clash test under one group.

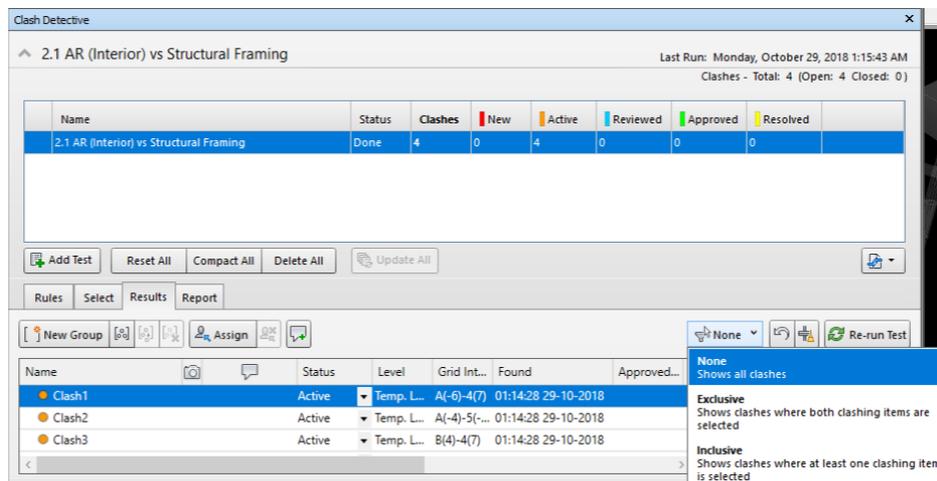


Grouping clashes

There are apps available with more grouping options.

Sanveo developed a custom add-in to group clash results from all tests/ selected tests by the either the first item or second item in the clash test. This helped us save almost 50% of time that we would have spent in clash review.

Clash results can be filtered by selected items using the Filter By Selection option in the Results tab.

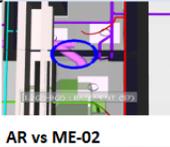
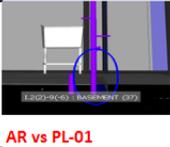


Filter By Selection

## Reports

At the beginning, we used the HTML report option in Navisworks to report the clash viewpoints. However, it wasn't easy to derive information quickly on the number of clash viewpoints, number of clashes assigned to a trade from the HTML report.

Sanveo developed a custom add-in, using which Excel reports could be extracted from the saved viewpoints. A snapshot of a sample report is shown below.

| Project Name                    |             |          |  |           |          |        |             | Sign Off: DD/MM/YYYY |
|---------------------------------|-------------|----------|--|-----------|----------|--------|-------------|----------------------|
| Sample Clash Report: DD/MM/YYYY |             |          |  |           |          |        |             | Updated: DD/MM/YYYY  |
| S.No.                           | Date Raised | Trade    | Viewpoint  | Action By | Priority | Status | Date Closed | Notes                |
| 1                               | 10/15/2018  | AR vs ME | <br>AR vs ME-01   | CCC       | Normal   | Open   |             |                      |
| 2                               | 10/15/2018  | AR vs ME | <br>AR vs ME-02  | CCC       | Normal   | Open   |             |                      |
| 3                               | 10/22/2018  | AR vs ME | <br>AR vs ME-03 | CCC       | Normal   | Open   |             |                      |
| 4                               | 10/8/2018   | AR vs PL | <br>AR vs PL-01 | AAA       | High     | Open   |             |                      |

Coordination log

Developing on this report, a dashboard view of the available data was built into the add-in which gave a snapshot view of the current status of the BIM coordination process. Sample shown in picture.



## Lessons Learnt

- Meeting Durations: Our meetings initially lasted more than an hour where we tried to discuss every clash. Through feedback from trade partners, we learnt that shorter meetings were preferable. Use meetings to discuss clashes that need input from architect or where more than two trades need to move. Lesser priority clashes can be resolved by the trades when they review the viewpoints in the model shared after meetings.
- Clash Assignment: Assignment of clashes needs to be complete in the federated models shared after each meeting, to avoid multiple trades working on the same clash when only one may need to move. The viewpoint naming and assignment is to be discussed at the BIM Kickoff meetings
- Action Item Tracking: Though we had meeting minutes shared with the team after every coordination meeting, action items sometimes got lost and were not followed up on. To solve this, we started using a simple Excel based Action Items tracker where action items from every meeting could to be tracked continuously through the coordination process in one location.

