

CI123061

BIM Evolution for Wet Infrastructure: What If We Started Panama Canal Expansion Today?

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Learning Objectives

- Learn how to apply BIM to any unique project types with some strategic planning
- Learn how to optimize the integrated design, engineering, and visualization workflows
- Discover best practices of design collaboration and coordination methods
- Explore the latest technologies for large, complex infrastructure projects

Description

This class will provide an overview of BIM implementation on one of the world's largest projects, the Panama Canal Third Set of Locks project which includes two massive lock facilities - one on the Atlantic side and another on the Pacific - each with three chambers and complex mechanical and electrical systems for locking Neo-Panamax vessels. BIM technology was used to manage the design and construction of this complex project. What if we started the Panama Canal Expansion today, with the dramatic advances in BIM that have occurred in only the last few years? With InfraWorks – which was not available during the planning phase - we can propose site design and road layout with GIS information. With Revit Parts – which was not available during the design phase - we can slice a model easily with sketch lines to produce the lift models for the concrete pouring sequence. With BIM 360 cloud services – also newly available - we can work better across regions and continents for design collaboration. Integrating these BIM tools with Augmented Reality and Virtual Reality technologies, we can now visualize our design better during the construction process. This class will present a “what if” scenario, to study how the design of this mega-project would proceed today, and to propose a new design template for the future.

Speakers

Joseph Chuen-huei Huang is Principal Architect / BIM Practice Leader at MWH, now part of Stantec. He has more than 20 years of professional experience in the AEC industry and has served as the BIM Manager for numerous large scale projects including the Panama Canal Third Set of Locks. His project experience ranges from vertical construction to large-scale infrastructure, where he has successfully integrated BIM into project design and construction phases. Besides that, he is the author of Participatory Design for Prefab House: Using Internet



and Query Approach of Customizing Prefabricated Houses, and presents BIM-related topics regularly to universities and global industry groups at international conferences like AU, SAME, ACADIA, eCAADe, and CADDRIA. He is a licensed architect registered in Illinois, an AIA professional member, and holds a PhD degree in Architecture from the Illinois Institute of Technology.

Raghavendra Bhat is a Building Information Modeling (BIM) leader at MWH now part of Stantec, providing integrated project delivery expertise utilizing Autodesk, Inc., software. Bhat has over 12 years of professional experience working in the architecture, engineering, and construction (AEC) industry using BIM technology on a wide variety of international and local projects (for example, federal government, public works, wet infrastructure, and skyscrapers). Bhat has also mentored, trained, developed standard guidelines and project standard templates.

Contents

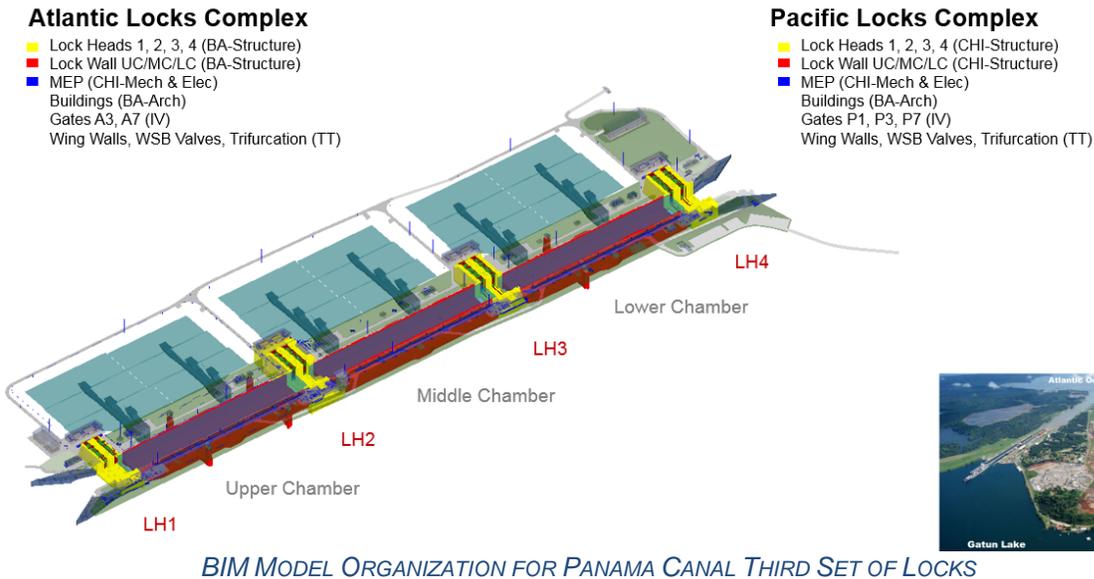
Overview of Panama Canal Expansion	4
BIM Integration.....	4
Lessons Learned	5
New Workflows for Wet Infrastructure (what if we started it today?)	6
Workflow #1: BIM Execution Plan & Contract Agreement	7
Workflow #2: BIM Integration Maps	7
Workflow #3: Site Information Modeling by InfraWorks (+ InfraWorks to BIM 360)	8
Workflow #4: Reality Capture (Point Cloud & Photogrammetry)	11
Workflow #5: Use Revit Parts for Lift Modeling	12
Workflow #6: Use Cloud for Design Collaboration (BIM 360 & C4R)	14
Workflow #7: Design Coordination & Clash Management.....	19
Workflow #8: Engineering Analysis Integration.....	20
Workflow #9: 4D Modeling / Construction Sequencing	21
Workflow #10: Quantification (5D) from Revit and Navisworks	22
Workflow #11: Facility and Asset Management in CMMS	24
Workflow #12: Advanced Visualization / Real-time Rendering.....	25
Workflow #13: Use Point Layout to Improve Office-to-Field Efficiency and QA/QC.....	27
Workflow #14: Interoperability between InfraWorks, Civil 3D, Revit & Navisworks	29
Moving Forward	31
Technology #1: Augmented Reality	31
Technology #2: Virtual Reality	31
Technology #3: Mixed Reality	32

Overview of Panama Canal Expansion

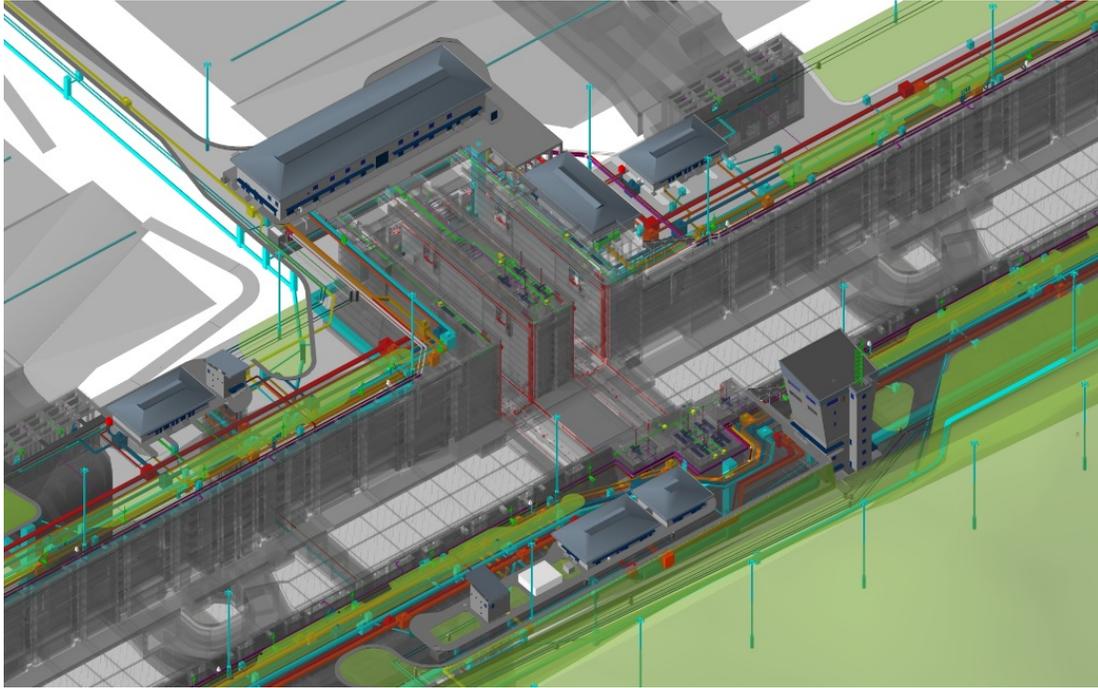
Completed in 1914, the Panama Canal currently handles approximately five percent of the global shipping trade. The purpose of the expansion project, including the Third Set of Locks, is to make it possible for the canal to accommodate today's larger ships, referred to as "Post-Panamax" ships. The Third Set of Locks project includes two massive lock facilities - one on the Atlantic side and the other on the Pacific side - each with three chambers. Innovative design elements include water basins that save and reuse 60 percent of the fresh water used in the lock system and state-of-the-art seismic analysis. MWH, now part of Stantec has worked on this project for more than 17 years, as it evolved from a concept to execution, begun in 1999 and completed in 2016.

BIM Integration

This project is one of the first large-scale civil works projects to deploy building information modeling, done at the request of Panama Canal Authority. The BIM process, together with the right people and technology, has supported the design team's efforts to advance the state-of-practice on many components on the project. The BIM process allows for improved quality of design, increases productivity by efficiently managing design changes and helps facilitate communication with clients and builders through visualizations.



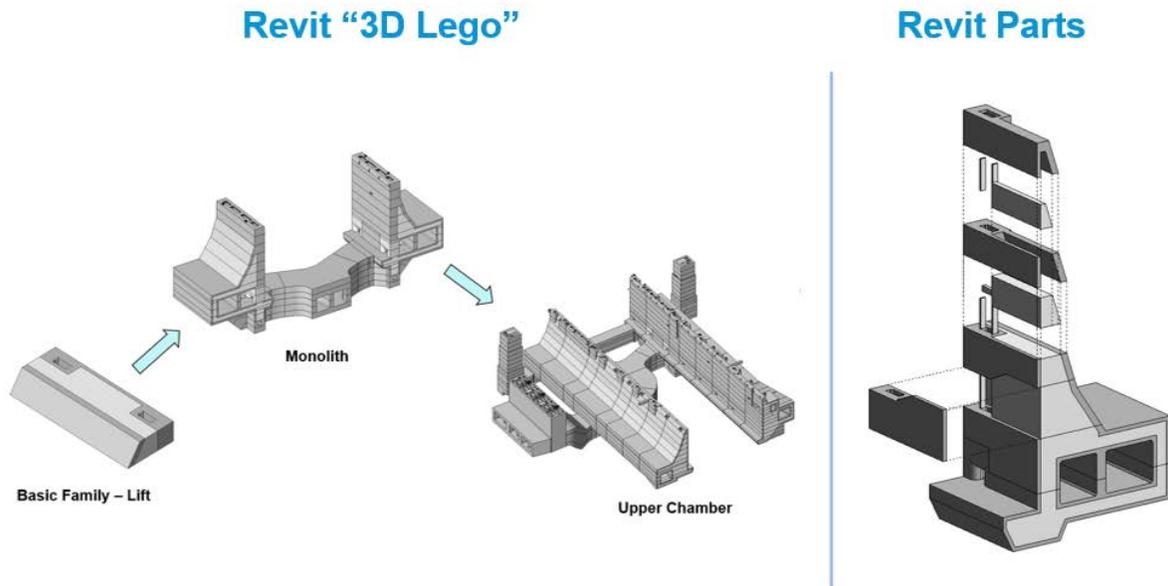
BIM modeling is being used in several ways on this project, including: building intelligent databases of key project components and systems, overlay of electrical, mechanical, architectural and civil/structural elements to identify and eliminate conflicts, and production of civil/structural backgrounds for use by electrical and mechanical designers to lay out their systems. Virtual clash detection eliminates field construction changes that can be costly and challenging to project schedules. Also, the BIM integrated project delivery has allowed this diverse project team around the world to collaborate efficiently, helping us to resolve design conflicts prior to construction, allowing for better coordination and ultimately saving time and money.



USING AUTODESK NAVISWORKS FOR DESIGN REVIEW AND CLASH MANAGEMENT

Lessons Learned

As one of the first BIM pilot projects with this magnitude, we learned the software interoperability is a challenge along with the learning curve of adopting new BIM tools. The design-build team did not start right away within the BIM environment because of the fast-paced project schedule with the conventional project planning and budgeting. Also, the software's limitation back to 2010 caused us to spend extra time for lock wall/lock head modeling. Revit Parts was not available until 2013 version and became more mature in later versions. We learned the hard way from Panama Canal Third Set of Locks project by creating "3D Legos" custom families to show the different types and stages of concrete with the construction joints. By using Revit Parts, we can "slice" a Revit model easily with a sketch line by a reference plane in both horizontal and vertical directions. It represents the construction joints lines with the division profile options provided. We use it to produce the lift model/drawing for the concrete pouring sequence (see the figure on next page). While the software tool is a key component of BIM, embracing the integrated design process that it enables will allow project teams to achieve the full benefits available.



COMPARISON BETWEEN WITHOUT AND WITH REVIT PARTS AS TOOL IMPROVEMENT

By involving the design-build delivery of Panama Canal Third Set of Locks, the design team has achieved many advanced design, with BIM providing the mechanism to integrate design changes as necessary to keep the project on track. Having made the investment to adopt the BIM process on this world-class project, we now have a template for applying BIM to similarly complex projects worldwide.

New Workflows for Wet Infrastructure (what if we started it today?)

BIM technology was used to implement the world-class Panama Canal Third Set of Locks project which includes massive lock complexes on the Atlantic and Pacific ends of the Canal capable of transiting Neo-Panamax vessels. Now, more than one year after opening of the completed project in June 2016, it is timely to review how BIM has changed and the lessons learned from this world-class project.

What if we started the Panama Canal Expansion today, with the dramatic advances in BIM that have occurred in only the last few years?

With InfraWorks – not available during the planning phase - we can propose site design and road layout with GIS information. With Revit Parts – not available during the design phase - we can slice a model easily with sketch lines to produce the lift models for the concrete pouring sequence. With BIM 360 cloud services – also newly available - we can work better across regions and continents for design collaboration. Integrating these BIM tools with Augmented Reality and Virtual Reality technologies, we can now better visualize our design during the construction phase as well.

The following steps of new workflows for wet infrastructure are recommended for any new large-scale complex projects, with the latest technologies and lessons learned from Panama Canal Expansion project.

Workflow #1: BIM Execution Plan & Contract Agreement

Most successful projects start with a well-thought strategic planning. The diagram below highlights the BIM usages and offering options during the different project delivery stages and lifecycle. It is important to communicate with all decision makers internally and externally with the same expectation even though the “BIM” acronym is not addressed in the contract. Nowadays, we do BIM as “business as usual” to a certain degree depending on the project, regardless if this is a contractual requirement or not.



However, it is important to start with a draft BIM Execution Plan during the proposal phase and incorporate any agreed BIM requirements into the scope of work in the contract with budget allocation. Because BIM Execution Plans are not legally recognized as strong documents, this is becoming the first step to the slippery slope of a legal black hole.

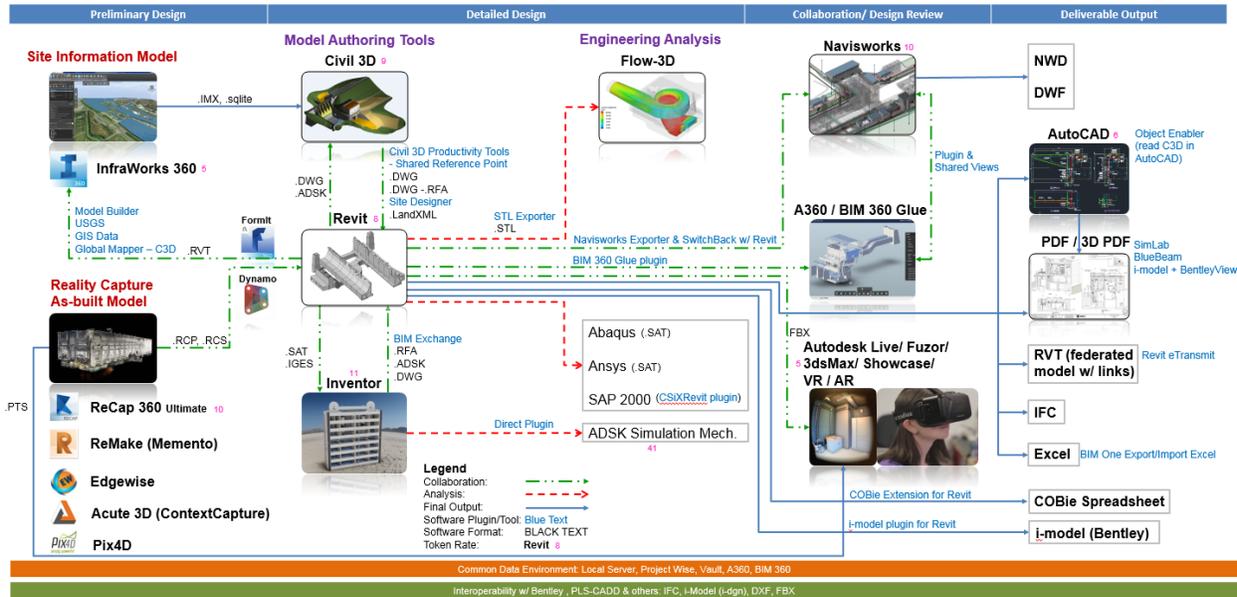
I have seen people created “BIM Addendum” after the project has been awarded (signed contract). BIM addendum is a contract document that globally addresses legal and administration issues associated with using BIM, it is intended to be used as an identical contract addendum for all project participants inputting information into a BIM Model. It also includes a BIM Execution Plan, which allows the parties to determine the level of reliance for the BIM model.

BIM is not new but new to some lawyers. Please get your legal team and company attorneys involved as early as possible.

Workflow #2: BIM Integration Maps

The beauty of BIM is not only about 3D geometry but also about the information contained along with the models. Every software application has its own strength to perform some specific

tasks, and most of the time we use more than one during a project delivery phase. An efficient workflow with resolved interoperability issue is the key to success. The diagram below illustrates an example of BIM integration map during the typical design phase of a hydropower project. It helps IT people to prepare all the software deployments and plug-ins before the project starts. In addition, it defines the specific output formats to translate the model from A to B platform with a purpose (i.e. CFD analysis or visualization).



EXAMPLE OF BIM INTEGRATION MAP (DESIGN PHASE)

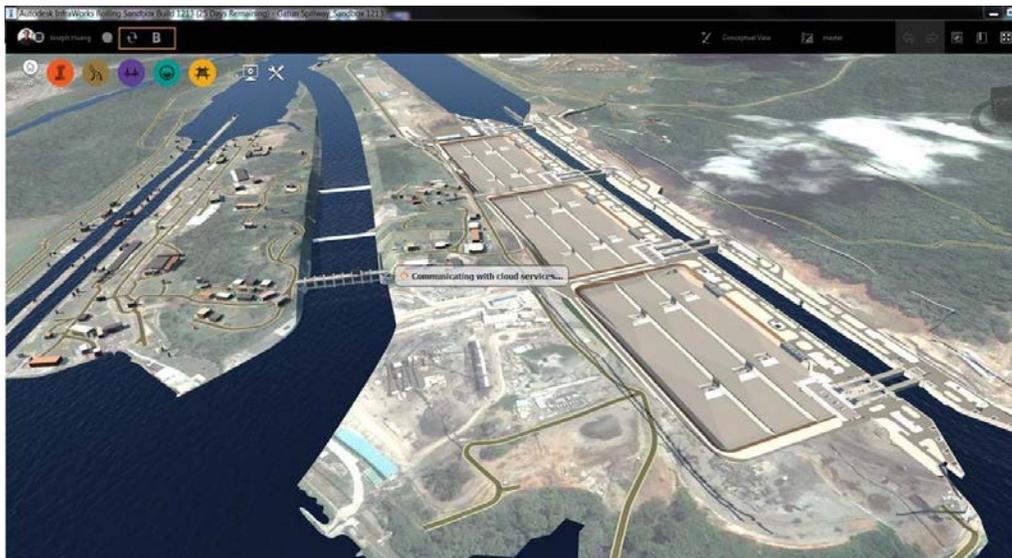
Workflow #3: Site Information Modeling by InfraWorks (+ InfraWorks to BIM 360)

Data gathering is an important step after the BIM planning/ BIM Execution Plan drafting. By using Autodesk InfraWorks, we build the site model for study and simulate our design virtually, and present the alternative design options with analysis results to our stakeholders. Autodesk InfraWorks has the capability to incorporate GIS data for planning and feasibility study during the early phase of design. It integrates traditional silo'd data into a visually oriented, easy-to-use 3D intelligent site model to improve project visualization and enable broader decision making. InfraWorks also allows us to publish the model to the cloud for design collaboration and it can be viewed from a web browser and mobile device. With embedded hyperlinks in any design elements, we can connect and view the detailed design models and drawings, which are stored in a different data management system like SharePoint, BIM 360, or private cloud server.

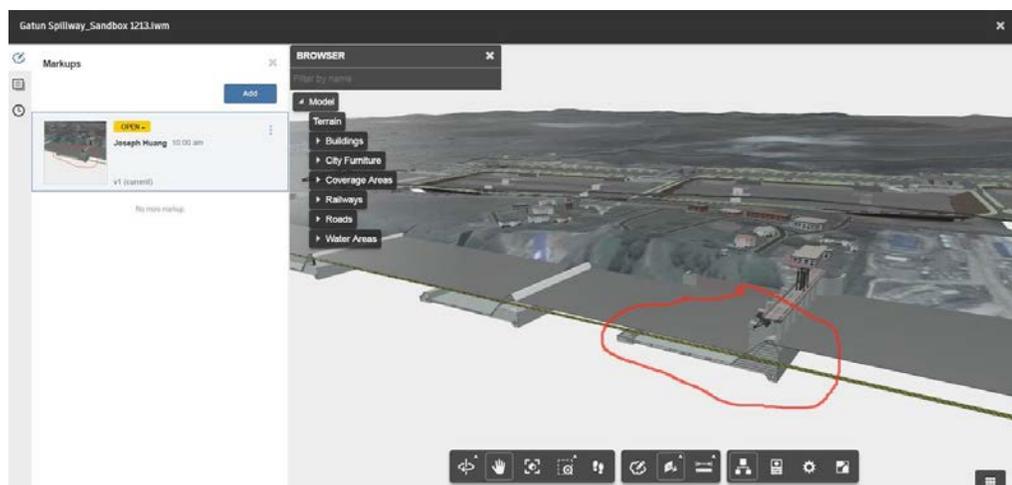
InfraWorks is the software that was not available during the Panama Third Set of Locks planning phase (2009-2010). Now, we use InfraWorks on almost every project and proposal, and consistently test any new features from the Rolling Sandbox and the latest release versions to see how to incorporate them into our design workflows. Some improvement highlights like InfraWorks and Civil 3D interoperability and "Points to Models" – converting the reality capture (drone-captured images, point cloud) data into 3D models like terrain, trees, traffic lights, site furniture, etc.

Some interesting new features we have evaluated recently:

- BIM 360 collaboration workflows within InfraWorks (Sandbox), which we can view models anytime, anywhere, and any way with Autodesk Viewer (aka. A360 Viewer). Also, we can manage access to our models along with other files in the project on BIM 360 Docs.
- Add Model-based Issues, Markups, RFIs, and review file update history on BIM 360 Docs.
- To publish a model from InfraWorks to BIM 360:
 1. Create a copy of your model (Settings & Utilities > Duplicate);
 2. Publish Model to the project on BIM 360 Docs; sync the model if any changes;
 3. An .iwm file represents an InfraWorks model for BIM360 collaboration is created. It points to the appropriate collaboration model in the model storage on the cloud. This file is also used to generate the content for the web viewer, so that you can explore your model in a browser.

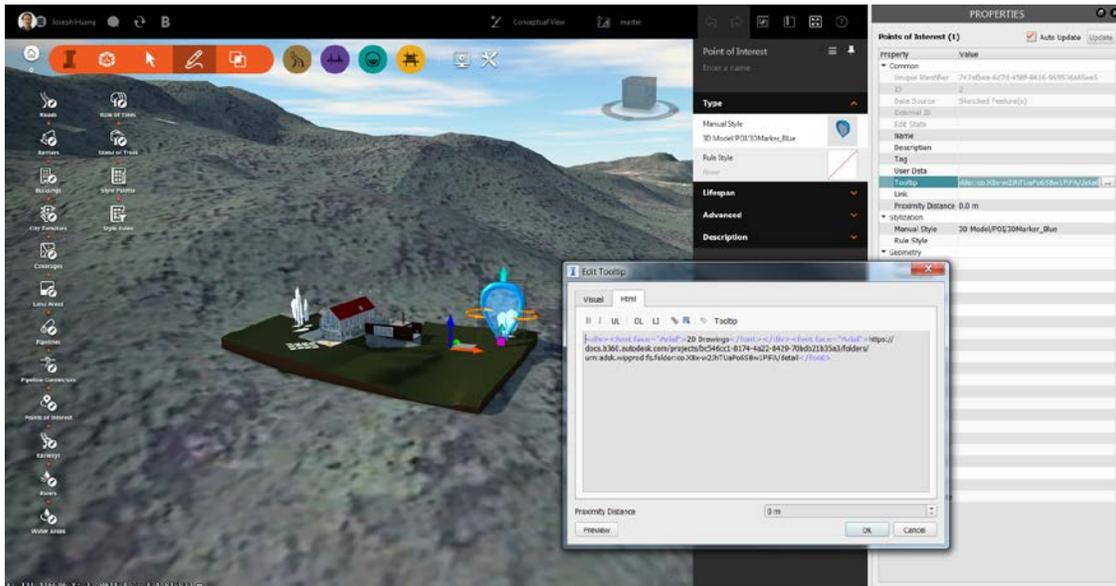


PANAMA CANAL THIRD SET OF LOCKS AND GATUN SPILLWAY (PROPOSED) INFRAWORKS MODEL

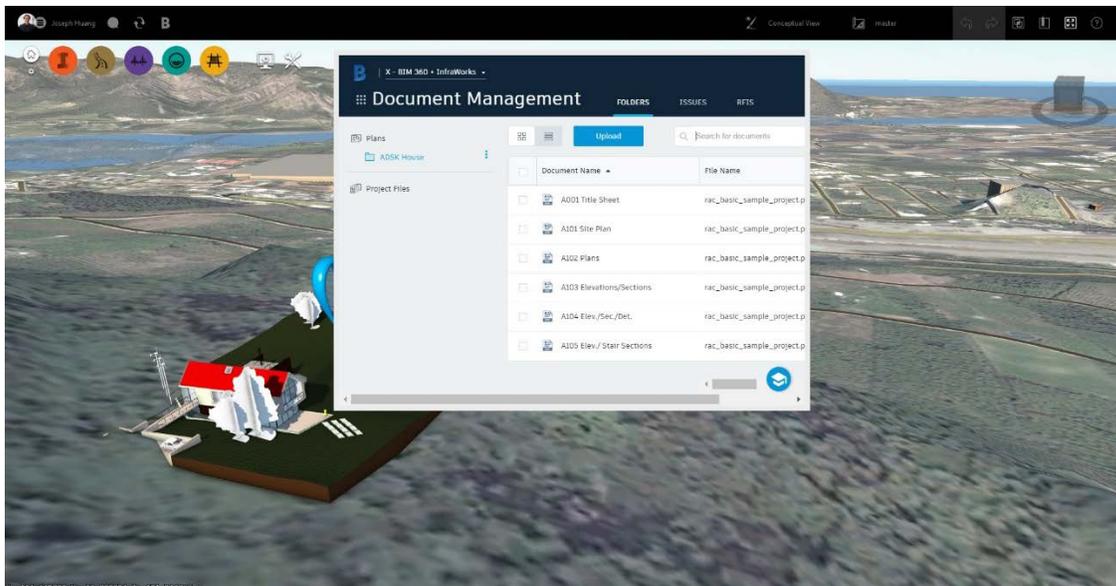


INFRAWORKS MODEL SYNCHRONIZED TO BIM 360 DOCS FOR MARKUPS

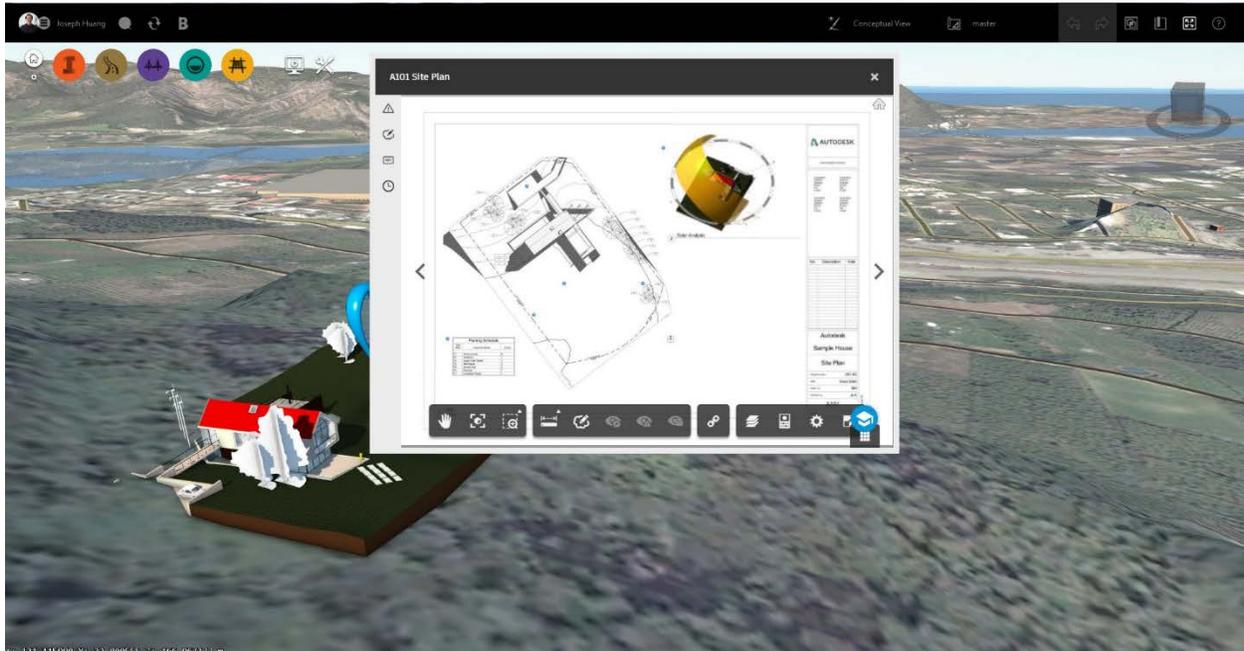
- Use Points of Interest (POIs) and Tooltip's HTML editor in InfraWorks to embed the URL hyperlink of drawing documents on BIM 360 Docs. In this way, we create a site model with all information and linked documents available for reviewers.



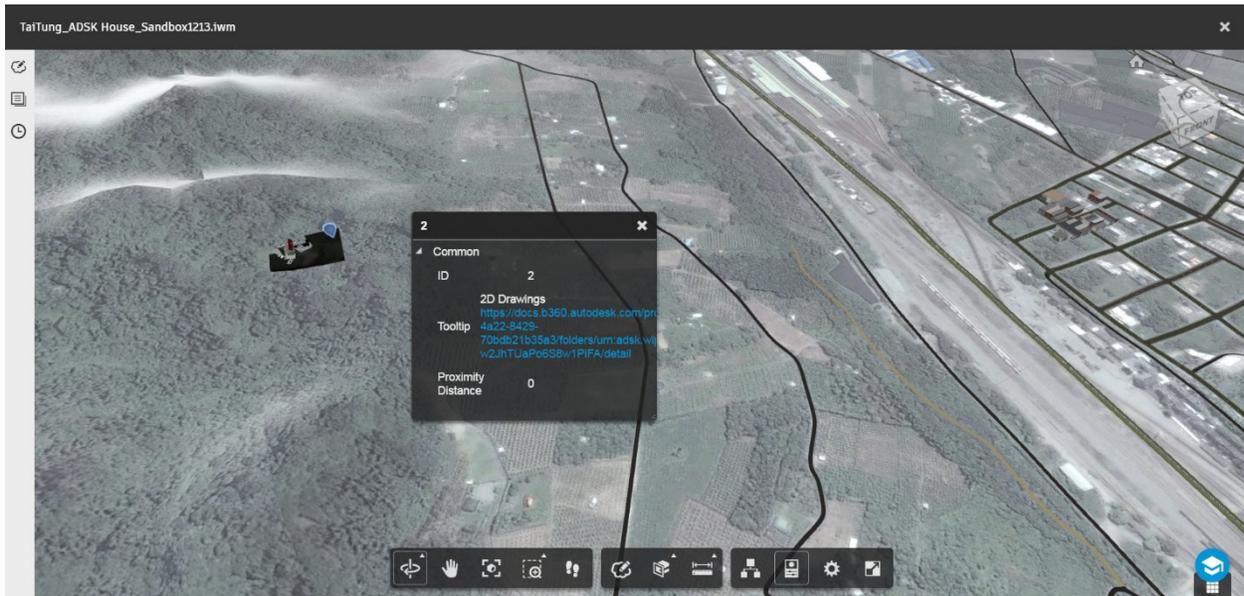
EMBEDDED BIM 360 DOCS URL IN INFRAWORKS MODEL



MOUSE-OVER THE POINTS OF INTEREST IN INFRAWORKS MODEL TO PREVIEW BIM 360 DOCS



MOUSE-OVER THE POINTS OF INTEREST IN INFRAWORKS MODEL TO PREVIEW THE DRAWINGS



POINTS OF INTEREST'S TOOLTIP PROPERTIES VIEW IN BIM 360 DOCS/ AUTODESK VIEWER

Workflow #4: Reality Capture (Point Cloud & Photogrammetry)

There are various tools and technology available to capture As-built information. We have been using the laser scanning and photogrammetry on a variety of projects after Panama Canal Third Set of Locks project (at that time, the technology was not matured). The concepts between Reality Capture and Reality Computing are very different as the definition and diagram explained on the next page.

Reality Capture: Reality capture can be achieved by using techniques such as LiDAR, where lasers take detailed scans of an area or by photogrammetry, which is an alternate method by which reality capture is achieved using photographs to reconstruct an accurate scale 3D representation of the area to be worked on.

Reality Computing: Reality computing is used by engineers/designers with help from many applications like ReCap, Revit, Infracworks to reduce time and increase accuracy in many types of proposed expansion works of existing facilities/plants etc.



REALITY CAPTURE BIM INTEGRATION MAP

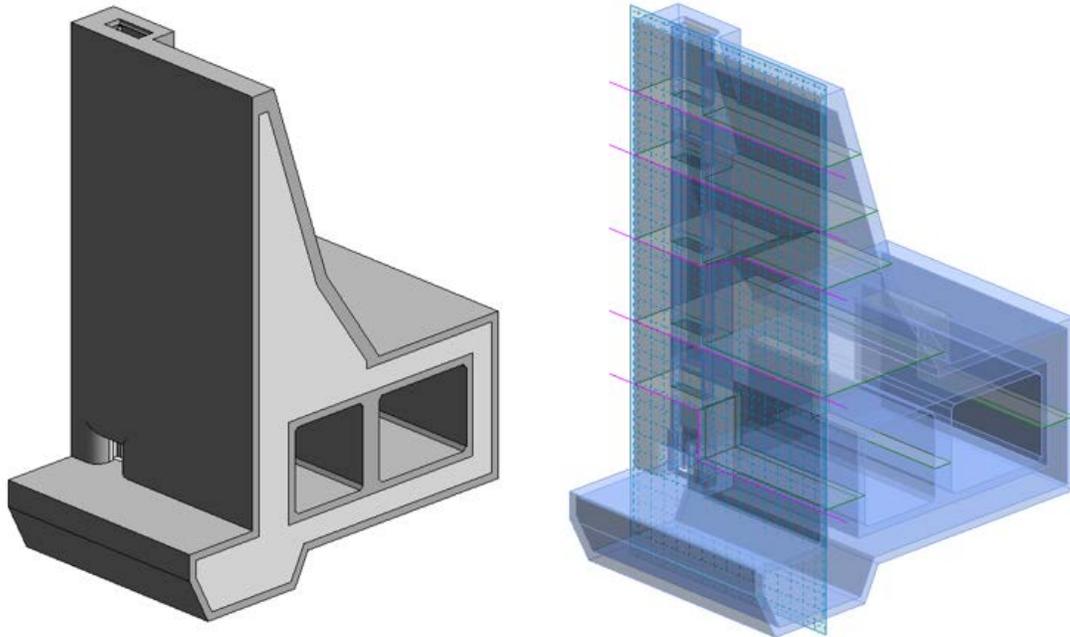
We need to create specs for the surveyor and put some disclaimer for internal budgeting purpose regarding (1) accuracy; (2) time; (3) hardware requirement; (4) software limitation; (5) RGB values (color preferred) & the coordinates registered from the raw scan formats (.FLS/.E57).

Generally, laser scanning is your tool/method if you need a high level of accuracy over a large space. Photogrammetry is a better tool/method if you are documenting smaller spaces and are looking for less accuracy but more visual photo realism with a quick result.

Workflow #5: Use Revit Parts for Lift Modeling

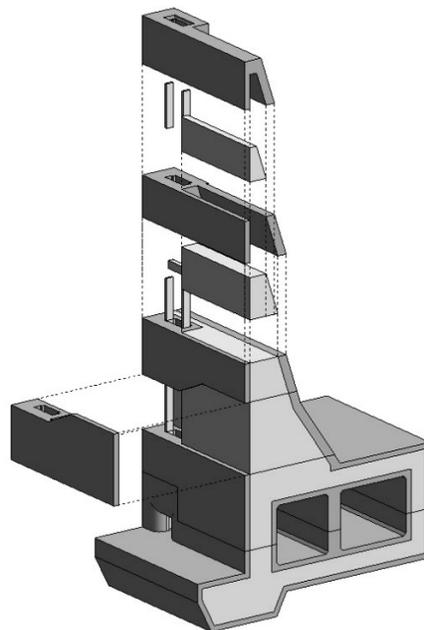
By using Revit Parts, we can slice a Revit model easily with a sketch line by a reference plane in both horizontal and vertical directions. It represents the construction joints lines with the division profile options provided. We use it to produce the lift model/drawing as the concrete pouring sequence. In addition, we use it to define the second stage concrete because most of the time we do not know the size of the turbine until engineers finish some analysis during the middle of the design process.

Revit Parts was not available until 2013 version and became more mature in 2014 version. We learned the hard way from Panama Canal Expansion project by creating "3D Legos" custom families to show the different types and stages of concrete with the construction joints.



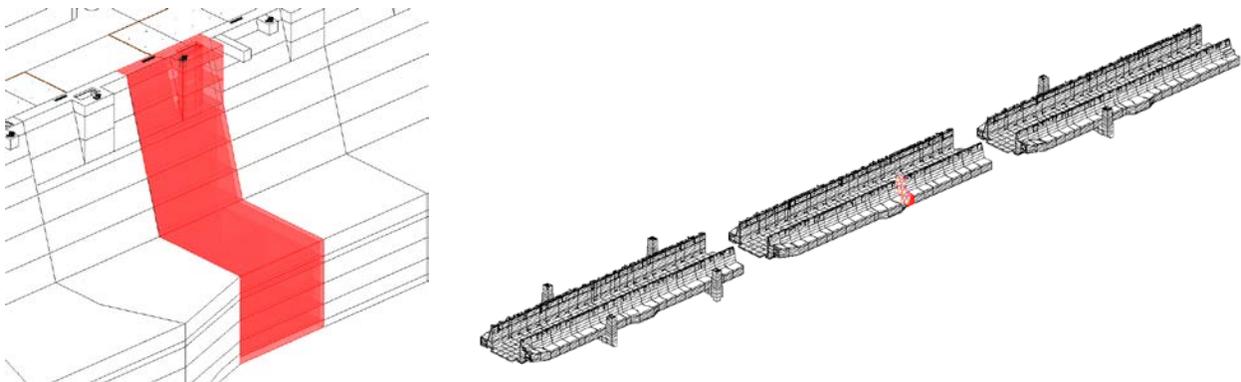
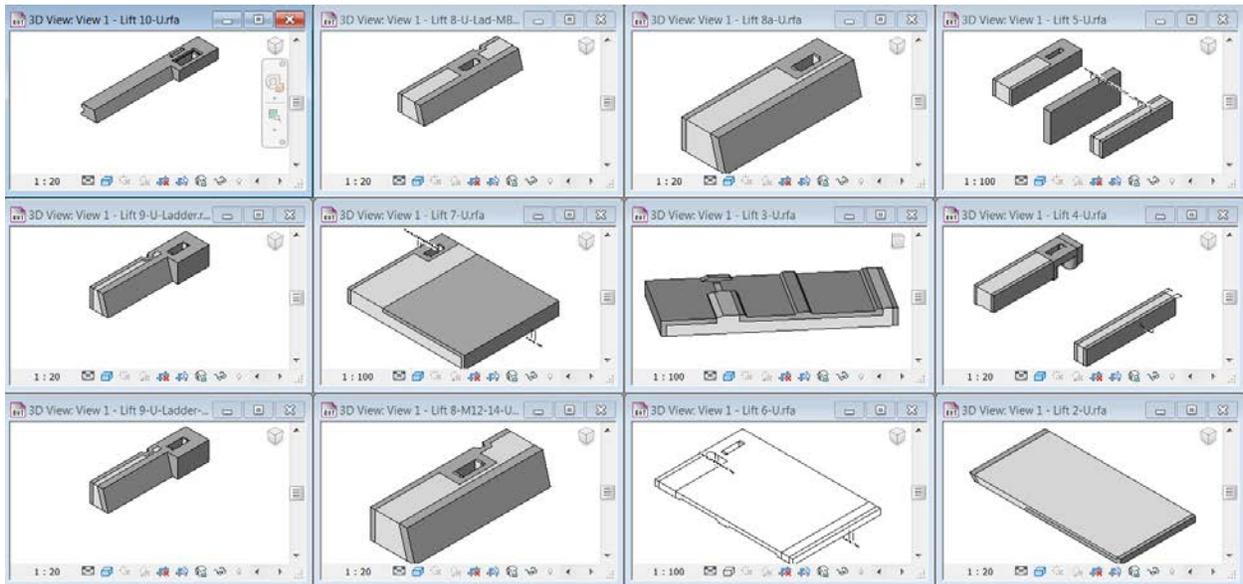
USING REVIT PARTS TO SPLIT THE MODEL AFTER

The Displace Elements feature in Revit allows us to create a custom view that pulls apart the model, and show graphically how everything fits together. It is very much like one of those exploded 3D views we often see in assembly instructions for IKEA furniture, or for some other product that we have to put together by ourselves. Displace offers a way to give a very clear presentation to some parts of our Revit projects.



DISPLACEMENT VIEW BY REVIT

Here are some screenshot images to show the Panama Revit Lock Wall model as a comparison. Without Revit Parts or any “slicing tool” in Revit, it required twelve lift families to compose one monolith wall module, and about 50 monoliths at one chamber. On each side of canal (the expansion project has both Atlantic and Pacific complexes), there are three chambers with hundreds of monoliths for lock walls, lock heads, and “cross under” (connected the lock walls from the lake and continent sides). Every time we had some design changes, it was a nightmare to edit tons of families to get the job done. I would say Revit Parts is a big Revit software evolution for wet infrastructure like waterways and hydropower & dams, though Autodesk might not design the tool for that purpose.



REVIT FAMILIES AND MODELS FOR LIFTS, MONOLITHS, LOCK WALLS ON PANAMA CANAL TSL PROJECT

Workflow #6: Use Cloud for Design Collaboration (BIM 360 & C4R)

Panama Cana Third Set of Locks project used Globalscape for model sharing/file exchange and Aconex for document management. We have experienced some challenges due to the constraint of the regional network infrastructure and long distance for “real-time” design collaboration. The workaround is to publish a detached but daily-based model to the shared server (Globalscape).

Autodesk Collaboration for Revit (C4R) combined with BIM 360 Team can become a better collaboration with BIM project management software to get centralized access to BIM data in the cloud for the whole team. C4R is a cloud service that works with Revit to enable multi-user co-authoring of BIM models without costly and complicated IT workarounds to share models. With the BIM collaboration software platform, there's no need to co-locate your Revit project teams and allows multiple offices, different companies around the world to centralized access the Revit models.

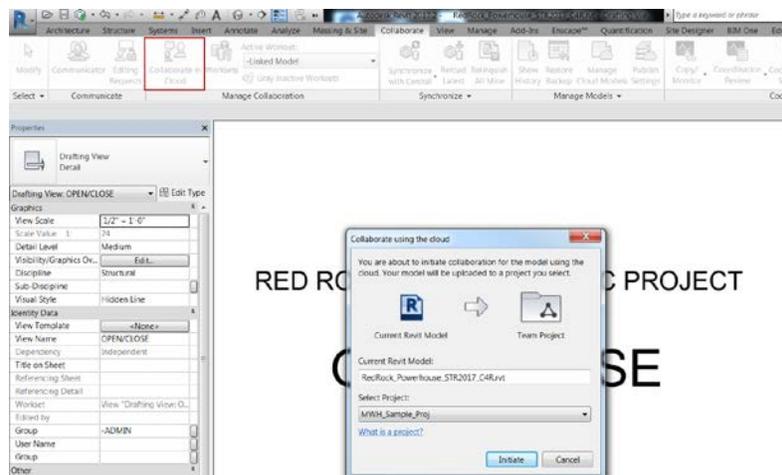
To initiate a C4R model (after C4R service has been enabled and “Editor” permission access has been granted in BIM 360 Team, a specific project):

- Sign in with your Autodesk ID and password.
- Open the project model (doesn't matter workshared or non-workshared) and SAVE AS a new project name on the local machine first.
- Click Collaborate tab > Manage Collaboration panel > Collaborate.
- In the Collaborate dialog, select “Collaborate using the cloud” option and click OK.



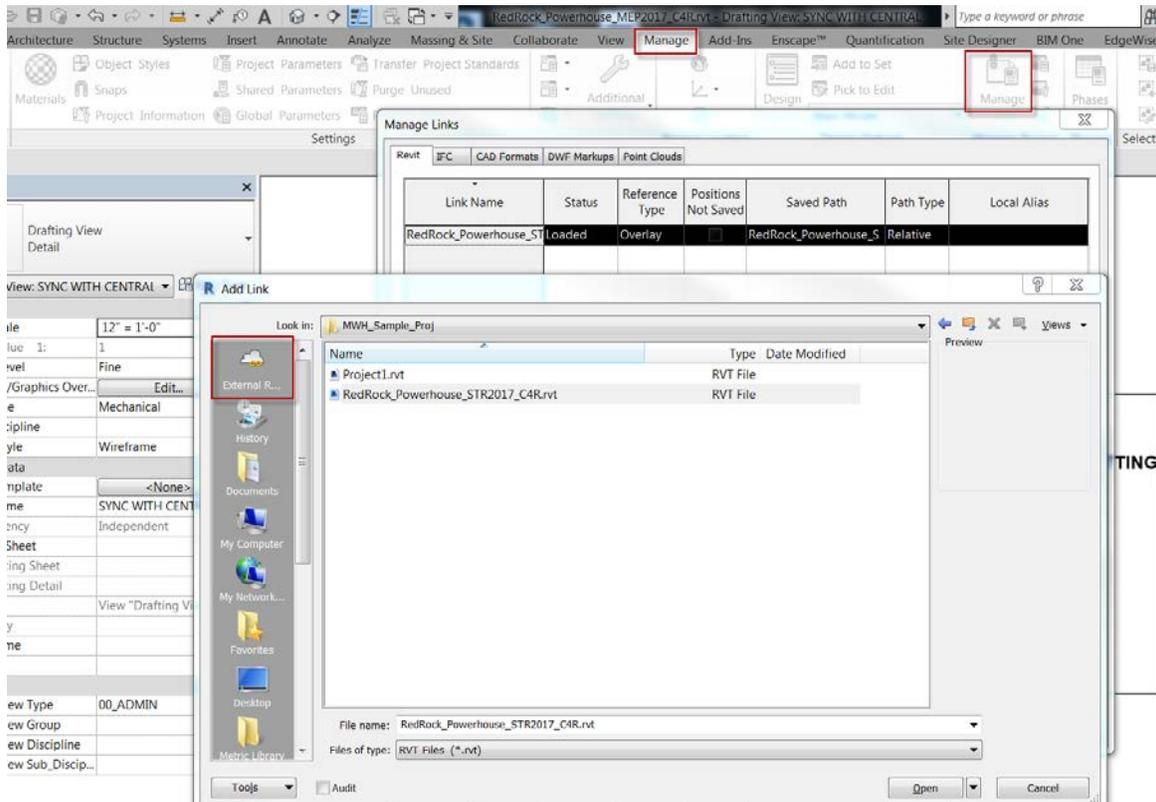
COLLABORATE OPTIONS

- Select a cloud project in which to store your Revit model and click OK.



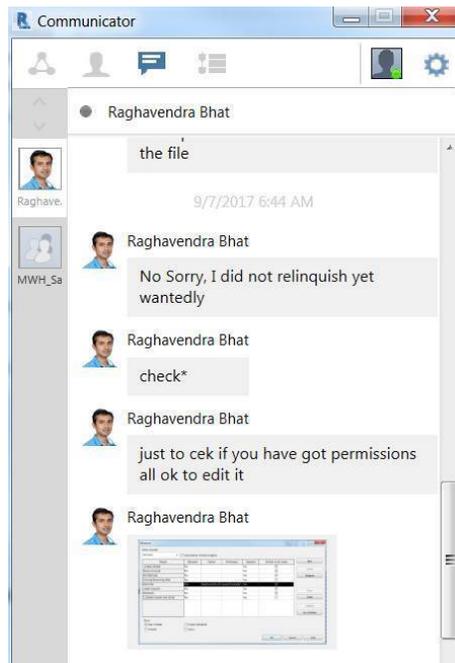
COLLABORATE USING THE CLOUD – CREATING A CENTRAL MODEL ON BIM 360 TEAM

- In the Collaboration in Cloud dialog, click Initiate. Revit displays information about the status of the initiation process.
- From Manage > Reload From > External Resource > BIM 360 > project folder... to re-associate the missing linked models



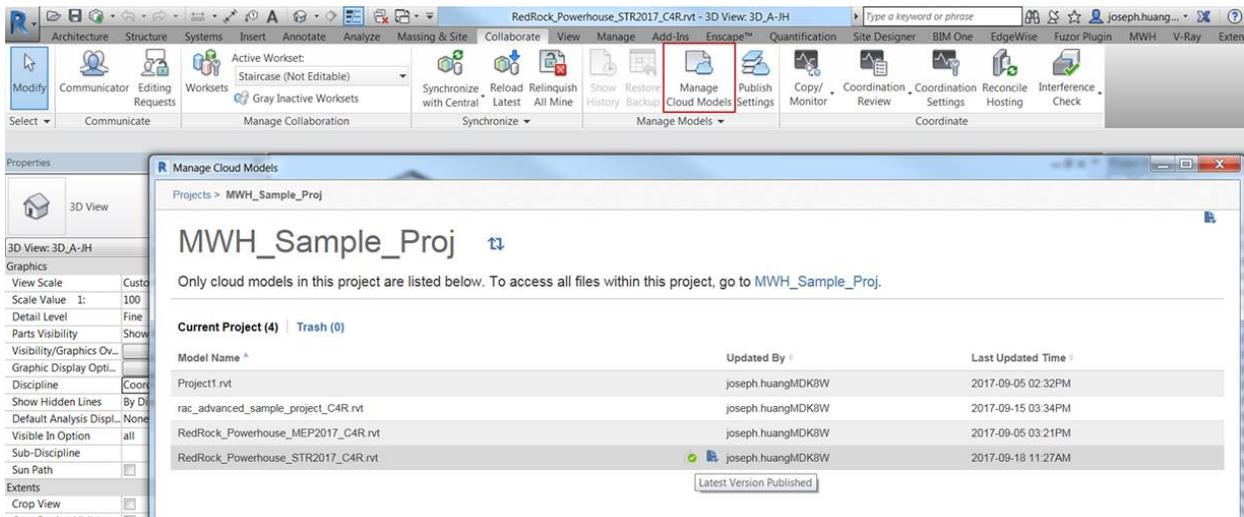
LINKING OTHER CENTRAL MODELS FROM BIM 360 TEAM

- Communicator is installed with Collaboration for Revit, and the interface on ribbon is part of Revit since 2017 version. It works with BIM 360 Team single sign on to provide contextual communication and collaboration tools for teams working on design and construction projects. We can chat with contact list, capture screens, store conversations, and send an email message to a contact or to all members of the project.



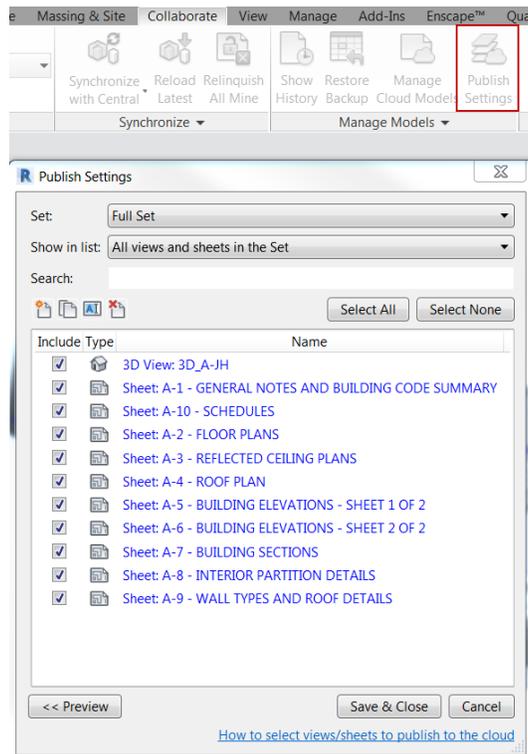
C4R COMMUNICATOR INTERFACE

- NOTE:** We must manually publish the latest version of Revit model to BIM 360 Team site from “Manage Cloud Models” in Revit. In this way, we can manage the internal collaboration (via Revit Synchronize with Central) and external collaboration (publish & update the models on BIM 360 Team).



PUBLISH THE SYNCHRONIZED CENTRAL MODEL FROM THE CLOUD TO BIM 360 TEAM

- Click Collaborate tab > Manage Models panel > Publish Settings to select & customize the publishing views (2D & 3D). Then, Sync with Central before publishing to BIM 360 Team.



PUBLISH SETTINGS – SELECT 2D/3D VIEWS AND SHEETS

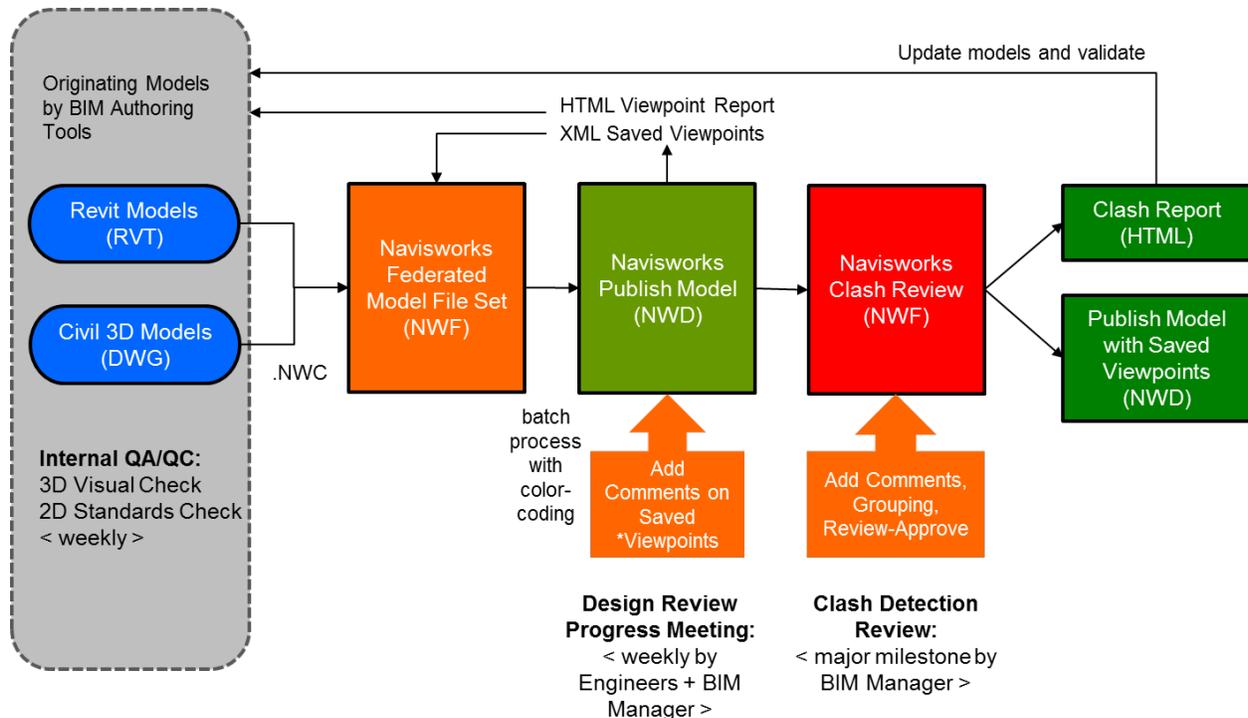
- The result of 3D model and drawing sheets can be reviewed from BIM 360 Team (with Autodesk Viewer). We can do the digital markup, version comparison, first person walk-through... model-based design review. Besides BIM 360 Team, Autodesk also has many cloud-based solutions for AEC industry like BIM 360 Glue, BIM 360 Field, BIM 360 Plan, BIM 360 Docs, etc.



BIM 360 TEAM – VIEWER INTERFACE

Workflow #7: Design Coordination & Clash Management

Here is the recommendation of Design Coordination Review workflow by Navisworks. The first part is weekly (or daily) “Design Review” led by the Project Engineer/Architect with BIM Manager’s help. The intent is to visually check the design in a big picture (sometimes Revit is too slow to navigate with all linked models turned on). The second part is running clash review during major milestones (30%-60%-90% or weekly/bi-weekly depends on the project). We saved all the grouped clash items as Viewpoints in Navisworks and provide the published format, NWD file to the team to be easily viewed in Navisworks Freedom (viewer). We also published the clash report in HTML (Tabular) format and converted that as a PDF (single document with all images embedded). We uploaded all the clash review data (NWD, HTML, associated image folder, PDF) to our Common Data Environment (e.g. BIM 360 Team, ProjectWise) for the different needs of the audiences (e.g. project team, manager, contractor, and client).



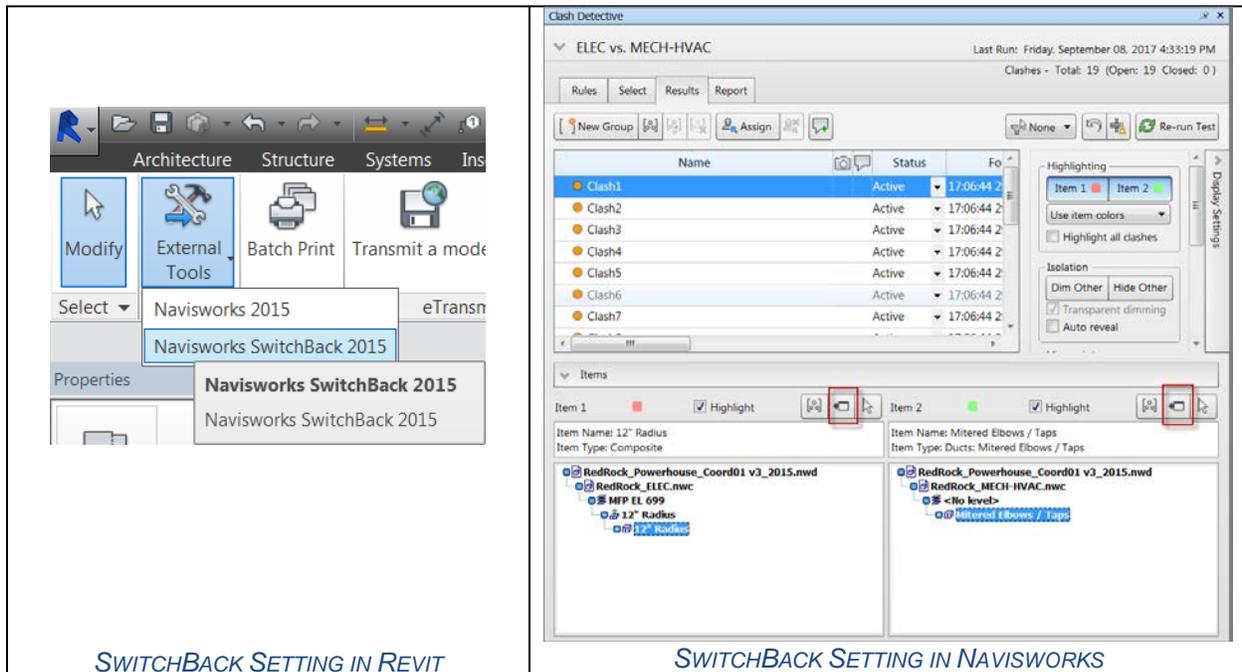
Viewpoints: Saved views in Navisworks. Typically the viewpoint may contain some markup like text, tag and comments.

NAVISWORKS MODEL REVIEW WORKFLOW

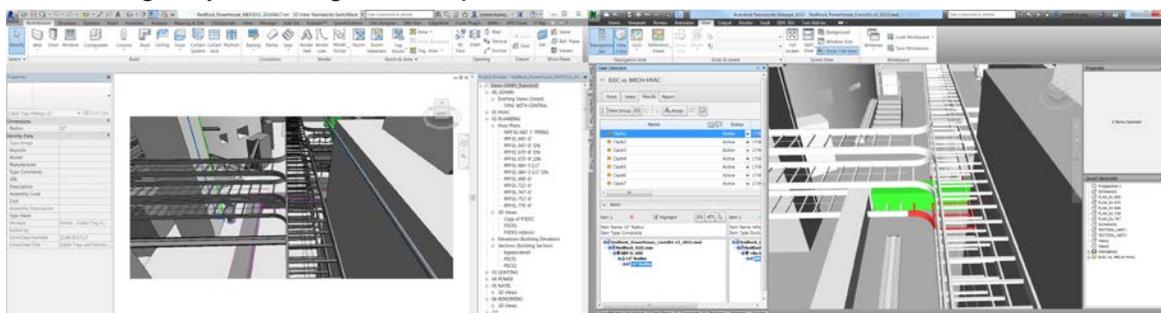
How to find the clash items in Revit model and resolve it? There are several options: (1) By visual check with grids reference in Navisworks Freedom/Simulate/Manage; (2) By Element IDs from the Clash Report and search that in Revit; (3) By using the Switch Back function between Navisworks and Revit; (4) By Dynamo script (exported Navisworks clash result XML + Clash Sphere dyn + Revit family); (5) BIM One – Clash Sphere Generator plugin for Revit.

Switchback between Navisworks and Revit:

1. Open Revit application, the same version of Revit you use for exporting out the NWC to Navisworks.
2. Click Add-Ins tab > External Tools > Navisworks SwitchBack to enable it.
3. In Navisworks Manage, Clash Detective window, on the Results tab, you can click the SwitchBack button.



4. Revit will load the relevant project, find and select the item, and zoom to it. If SwitchBack was unsuccessful with the selected object, and you receive an error message, try selecting further up the Selection Tree in Autodesk Navisworks.



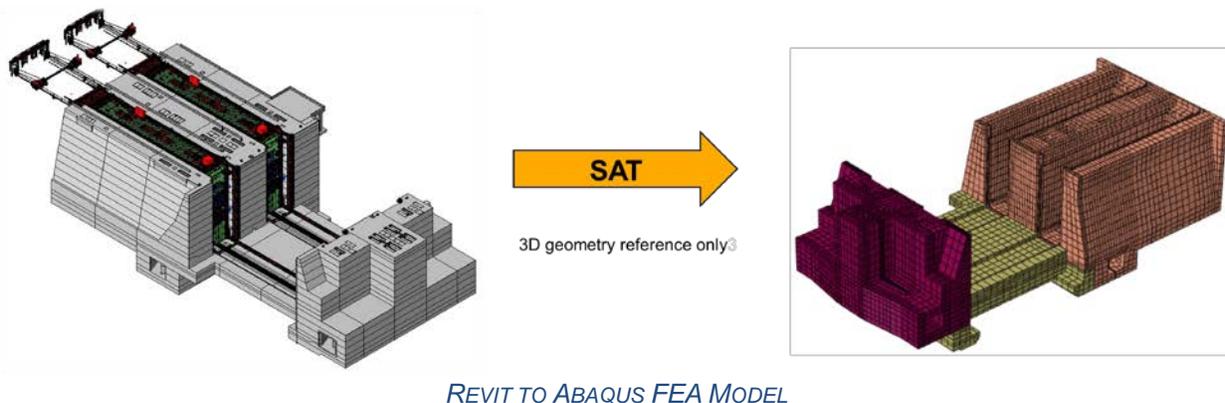
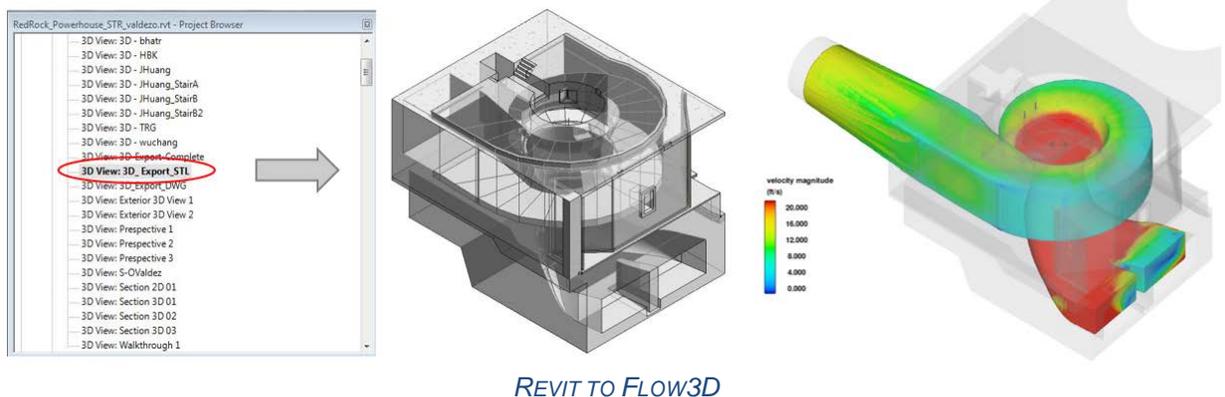
THE RESULTS OF APPLYING SWITCHBACK

Workflow #8: Engineering Analysis Integration

Design validation is an important step in the design engineering process. Typically, we use our experience and project program requirements to sketch a design layout but require engineering analysis to prove the concept and hypothesis. The analysis may consist finite element analysis (FEA) and computational fluid dynamics (CFD). In the past, the engineers created another analysis model starting from scratch. When the production drawings (or models) changed, sometimes the analysis model was not updated accordingly. In the BIM world, we use the same

model for design, analysis, visualization and drawing generation. The following solutions highlight the integrated engineering analysis workflow with BIM process.

- Revit to Flow3D (CFD): From Revit saved view; export out as .STL (watertight format) to Flow3D.
- Revit to Abaqus: From Revit saved view; export out as .SAT (solid format) to Abaqus.
- Revit to SAP 2000: CSI plugin
- Revit to ETABS: CSI plugin
- Revit to Robot Structural Analysis: direct plugin

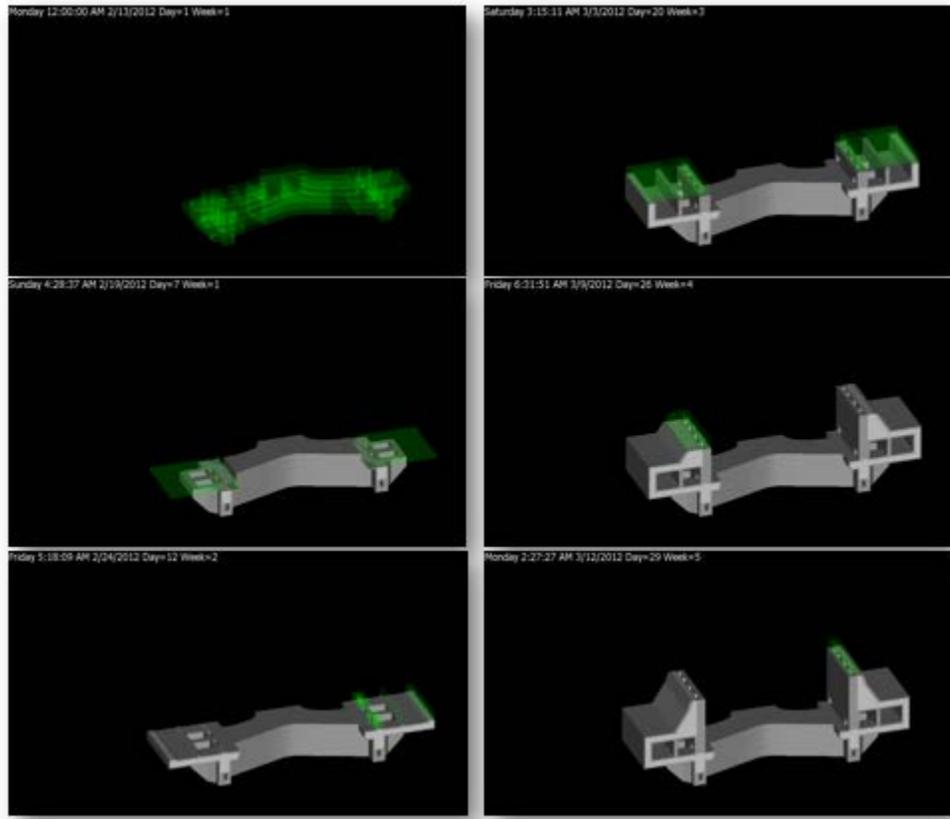


Workflow #9: 4D Modeling / Construction Sequencing

4D modeling requires some planning and setup. It is not “automatically generated” from Navisworks when those models are exported out from Revit and Civil 3D (some people assume there’s magic in the BIM world). Below are the steps to develop a 4D model in Navisworks with Timeliner.

1. Develop a CPM schedule for the project in a compatible application. Microsoft Project works well for the development of the schedule. You can also use Primavera Project Manager, but the linking of the database is a bit more challenging.
2. Open Navisworks File Set (NWF) “working file” with 3D models appended.
3. Open the Navisworks Timeliner module by going to the “Item Tools > Timeliner” menu.

4. Go to the “Links” tab and link to the schedule file by right clicking on the links area. You will then need to right click again and select “Rebuild task hierarchy from link” so that the activities in the scheduler are imported.
5. Link the 3D objects to the activities by selecting the objects in the “Selection Tree” window and then right clicking on the activity which you would like the object to be linked to and select “Attached selected”. This will link the schedule activity to the 3D objects.
6. Add an activity type to each of the activities (e.g. construction, demolition, or temporary, or you can create your own activity types).
7. After linking all the objects, you can review the simulation in the “Simulate” tab of Timeliner, and you can revise the playback settings in the “Configure” tab of Timeliner.
8. You can then export the 4D model as an .AVI file which can be easily transmitted to others. To do this, go to “File – Export – Animation” and select within the source pull-down the “Timeliner Simulation”. Note that the size of the window and the FPS (frames per second) will have a significant impact on the size of the .AVI file. You can usually set the FPS to 1 without significantly impacting the video quality. You can also select the output “Options” button to compress the video upon export.



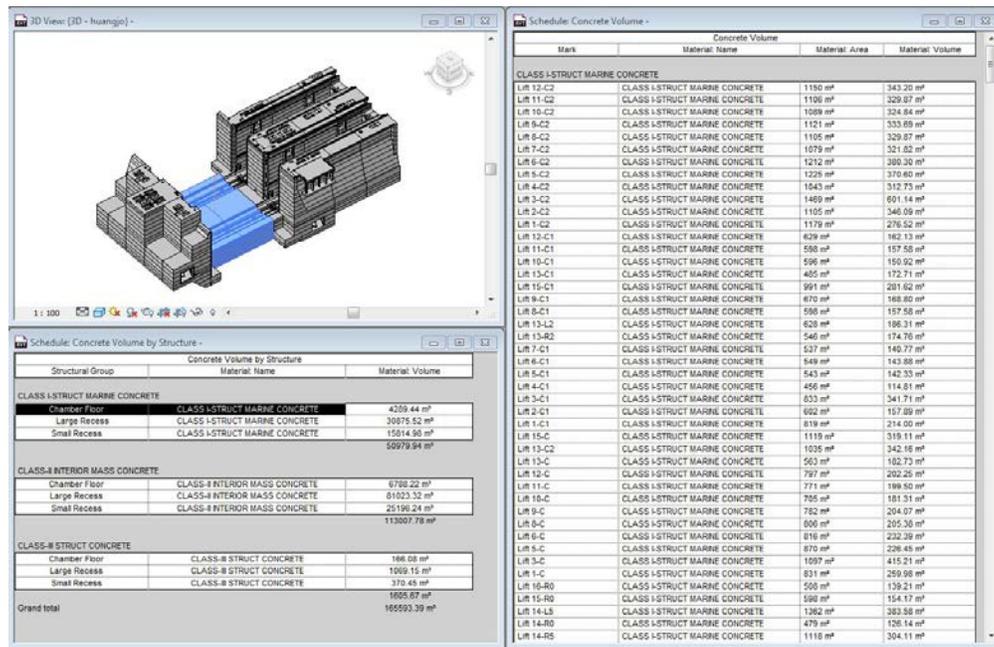
PANAMA CANAL TSL – 4D MODELING EXAMPLE

Workflow #10: Quantification (5D) from Revit and Navisworks

In Panama Canal Third Set of Locks project, we extracted all kinds of quantities from Revit schedule. It really helped for pre-construction quantity (cost) estimate. Besides Revit, the Quantification Workbook in Navisworks can create a highly accurate quantity takeoff based on the combined multiple 3D source files. It also works with 2D takeoffs from a DWF sheet set.

For more details, please see Autodesk Navisworks - Getting Started with Quantification with some tutorial videos.

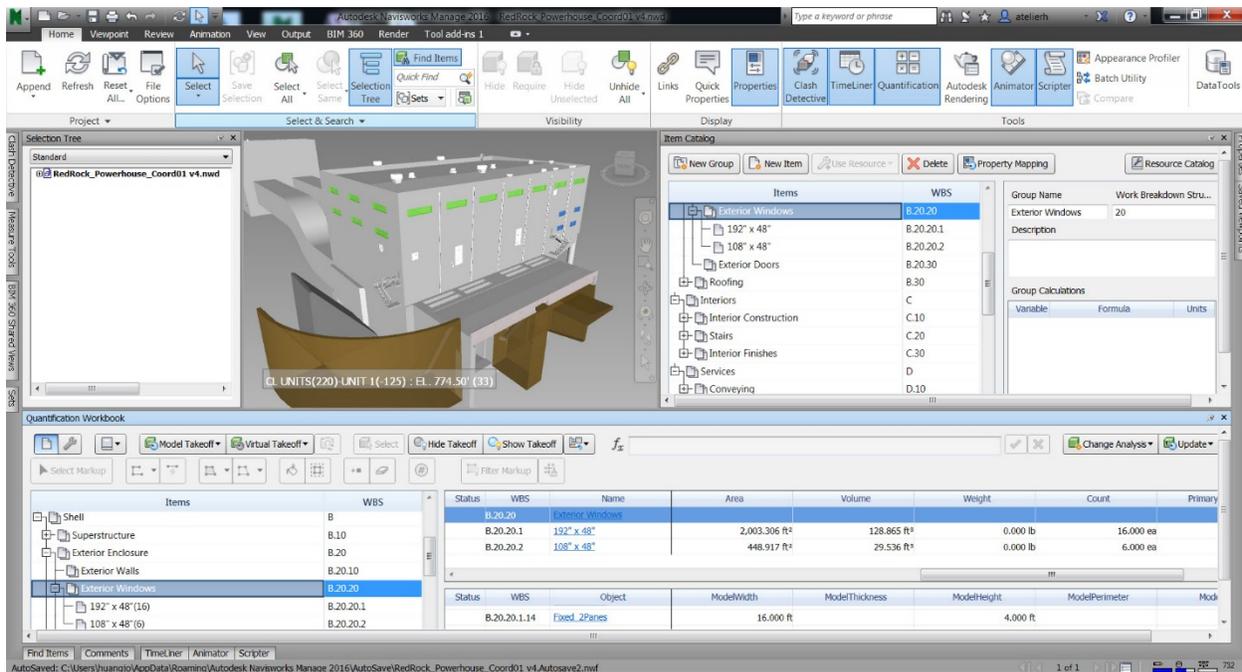
<https://knowledge.autodesk.com/support/navisworks-products/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/Navisworks-Manage/files/GUID-65A4E7A6-24E6-4551-B7E4-4B117D66B5E6-htm.html>



The image shows a 3D model of a structure in the Revit 3D Viewer on the left and a corresponding schedule on the right. The schedule is titled 'Schedule: Concrete Volume by Structure' and lists various concrete elements with their material names, areas, and volumes.

Mark	Material Name	Material Area	Material Volume
CLASS I-STRUCT MARINE CONCRETE			
LR 12-C2	CLASS I-STRUCT MARINE CONCRETE	1150 m ²	343.20 m ³
LR 11-C2	CLASS I-STRUCT MARINE CONCRETE	1106 m ²	329.87 m ³
LR 10-C2	CLASS I-STRUCT MARINE CONCRETE	1089 m ²	324.84 m ³
LR 9-C2	CLASS I-STRUCT MARINE CONCRETE	1121 m ²	333.89 m ³
LR 8-C2	CLASS I-STRUCT MARINE CONCRETE	1105 m ²	329.87 m ³
LR 7-C2	CLASS I-STRUCT MARINE CONCRETE	1079 m ²	321.82 m ³
LR 6-C2	CLASS I-STRUCT MARINE CONCRETE	1212 m ²	369.30 m ³
LR 5-C2	CLASS I-STRUCT MARINE CONCRETE	1225 m ²	370.80 m ³
LR 4-C2	CLASS I-STRUCT MARINE CONCRETE	1043 m ²	312.73 m ³
LR 3-C2	CLASS I-STRUCT MARINE CONCRETE	1489 m ²	601.14 m ³
LR 2-C2	CLASS I-STRUCT MARINE CONCRETE	1105 m ²	346.59 m ³
LR 1-C2	CLASS I-STRUCT MARINE CONCRETE	1179 m ²	276.52 m ³
LR 12-C1	CLASS I-STRUCT MARINE CONCRETE	829 m ²	182.13 m ³
LR 11-C1	CLASS I-STRUCT MARINE CONCRETE	588 m ²	157.58 m ³
LR 10-C1	CLASS I-STRUCT MARINE CONCRETE	596 m ²	150.92 m ³
LR 9-C1	CLASS I-STRUCT MARINE CONCRETE	485 m ²	172.71 m ³
LR 8-C1	CLASS I-STRUCT MARINE CONCRETE	991 m ²	281.62 m ³
LR 7-C1	CLASS I-STRUCT MARINE CONCRETE	870 m ²	188.80 m ³
LR 6-C1	CLASS I-STRUCT MARINE CONCRETE	598 m ²	157.58 m ³
LR 5-C1	CLASS I-STRUCT MARINE CONCRETE	620 m ²	186.21 m ³
LR 4-C1	CLASS I-STRUCT MARINE CONCRETE	546 m ²	174.76 m ³
LR 3-C1	CLASS I-STRUCT MARINE CONCRETE	833 m ²	341.71 m ³
LR 2-C1	CLASS I-STRUCT MARINE CONCRETE	682 m ²	157.89 m ³
LR 1-C1	CLASS I-STRUCT MARINE CONCRETE	819 m ²	214.20 m ³
LR 15-C	CLASS I-STRUCT MARINE CONCRETE	1119 m ²	319.11 m ³
LR 13-C2	CLASS I-STRUCT MARINE CONCRETE	1026 m ²	342.16 m ³
LR 13-C	CLASS I-STRUCT MARINE CONCRETE	563 m ²	182.73 m ³
LR 12-C	CLASS I-STRUCT MARINE CONCRETE	797 m ²	202.25 m ³
LR 11-C	CLASS I-STRUCT MARINE CONCRETE	771 m ²	199.50 m ³
LR 10-C	CLASS I-STRUCT MARINE CONCRETE	785 m ²	181.51 m ³
LR 9-C	CLASS I-STRUCT MARINE CONCRETE	782 m ²	204.07 m ³
LR 8-C	CLASS I-STRUCT MARINE CONCRETE	800 m ²	205.30 m ³
LR 6-C	CLASS I-STRUCT MARINE CONCRETE	816 m ²	232.39 m ³
LR 5-C	CLASS I-STRUCT MARINE CONCRETE	870 m ²	226.45 m ³
LR 3-C	CLASS I-STRUCT MARINE CONCRETE	1897 m ²	415.21 m ³
LR 1-C	CLASS I-STRUCT MARINE CONCRETE	831 m ²	259.98 m ³
LR 16-RO	CLASS I-STRUCT MARINE CONCRETE	500 m ²	139.21 m ³
LR 15-RO	CLASS I-STRUCT MARINE CONCRETE	588 m ²	154.17 m ³
LR 14-RO	CLASS I-STRUCT MARINE CONCRETE	1362 m ²	383.58 m ³
LR 14-RS	CLASS I-STRUCT MARINE CONCRETE	479 m ²	138.14 m ³
LR 14-RS	CLASS I-STRUCT MARINE CONCRETE	1118 m ²	304.11 m ³

QUANTITY SCHEDULE FROM REVIT – PANAMA CANAL TSL'S LOCK HEAD



The image shows the Autodesk Navisworks Manage 2016 interface with a Quantification Workbook open. The workbook displays a list of items and their associated WBS (Work Breakdown Structure) codes, along with a detailed table of quantification data.

Status	WBS	Name	Area	Volume	Weight	Count	Primary
	B.20.20	Exterior Windows					
	B.20.20.1	192' x 48"	2,003.306 ft ²	128.865 ft ³	0.000 lb	16,000 ea	
	B.20.20.2	108' x 48"	448.917 ft ²	29.536 ft ³	0.000 lb	6,000 ea	

THE EXAMPLE OF QUANTIFICATION WORKBOOK IN NAVISWORKS

Workflow #11: Facility and Asset Management in CMMS

In Panama Canal Third Set of Locks project, we used Revit DB Link and Access Database to associate life cycle facility management nomenclature with Revit families for tagging and Navisworks properties searching. The owner is using IBM Maximo as enterprise asset management and other computerized maintenance management systems. Without having those data in the beginning to integrate with 3D modeling during BIM process, it is very difficult to implement it after the construction phase within the limited budget. Please refer to my AU 2011 handout, Beyond the Limits: Using Autodesk Revit and Navisworks Manage for Design Collaboration on Large-Scale Projects (page 9-20) for setting up Revit DB link and Access database.

http://aucache.autodesk.com/au2011/sessions/4259/class_handouts/v1_SE4259_Beyond%20the%20Limits_Handouts.pdf

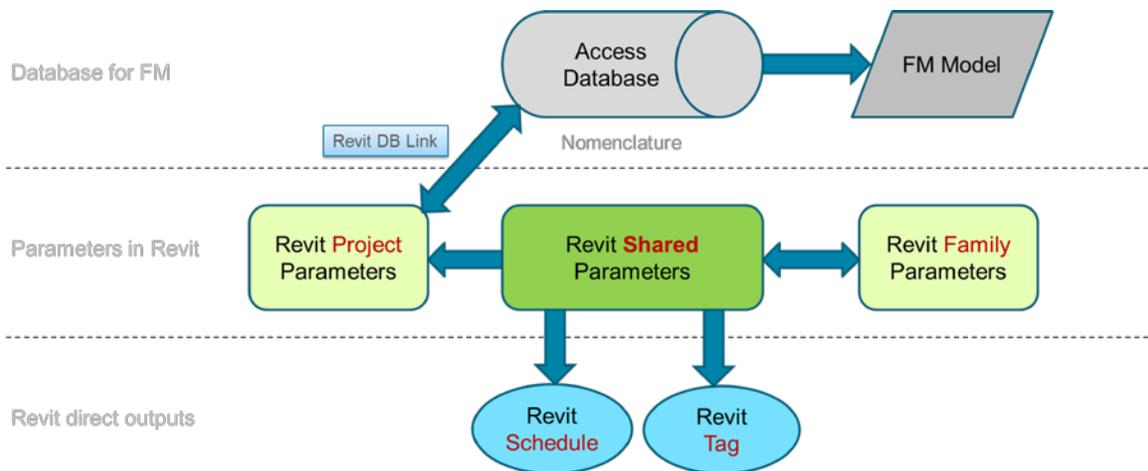
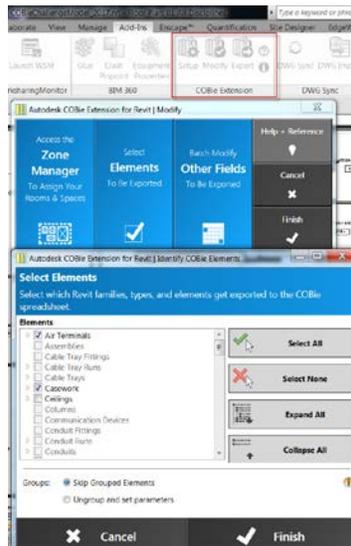


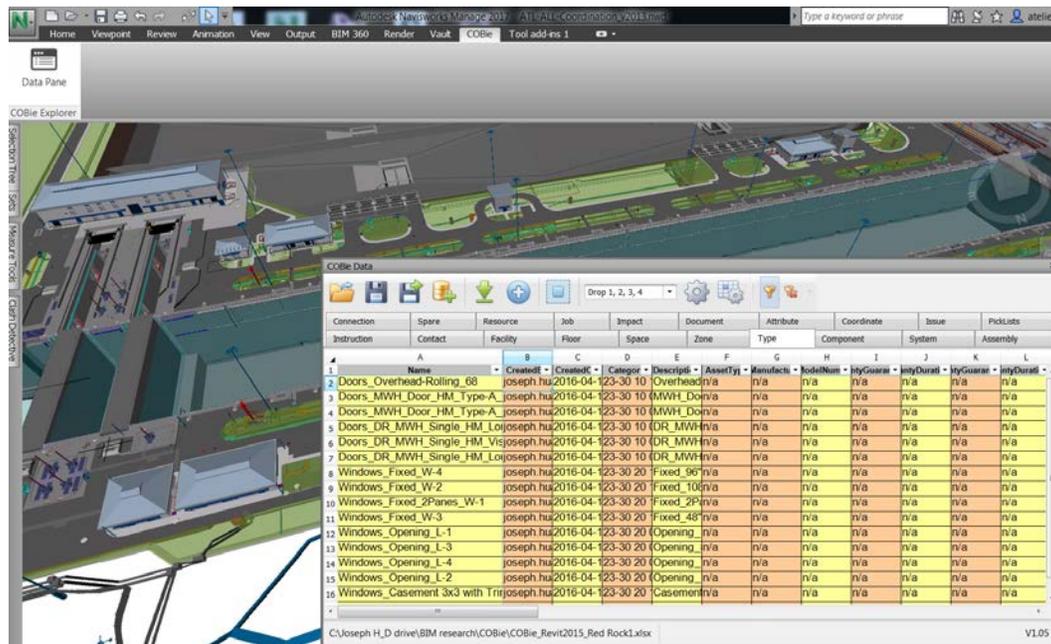
DIAGRAM OF UTILIZING REVIT DB LINK AND ACCESS DATABASE FOR FACILITY MANAGEMENT

COBie Extension add-ons for Revit and Navisworks would help the data integration during the design process. The COBie Extension is used for mapping model object properties to the COBie standard.



COBIE EXTENSION FOR REVIT

The extension for Navisworks supports reading from and writing to a SQLite database as well as exporting the COBie data as an Excel spreadsheet. The extension has been developed based on the Revit COBie output but can be adjusted to suit any model type that has the relevant COBie data available.



COBIE EXPORTER IN NAVISWORKS

Workflow #12: Advanced Visualization / Real-time Rendering

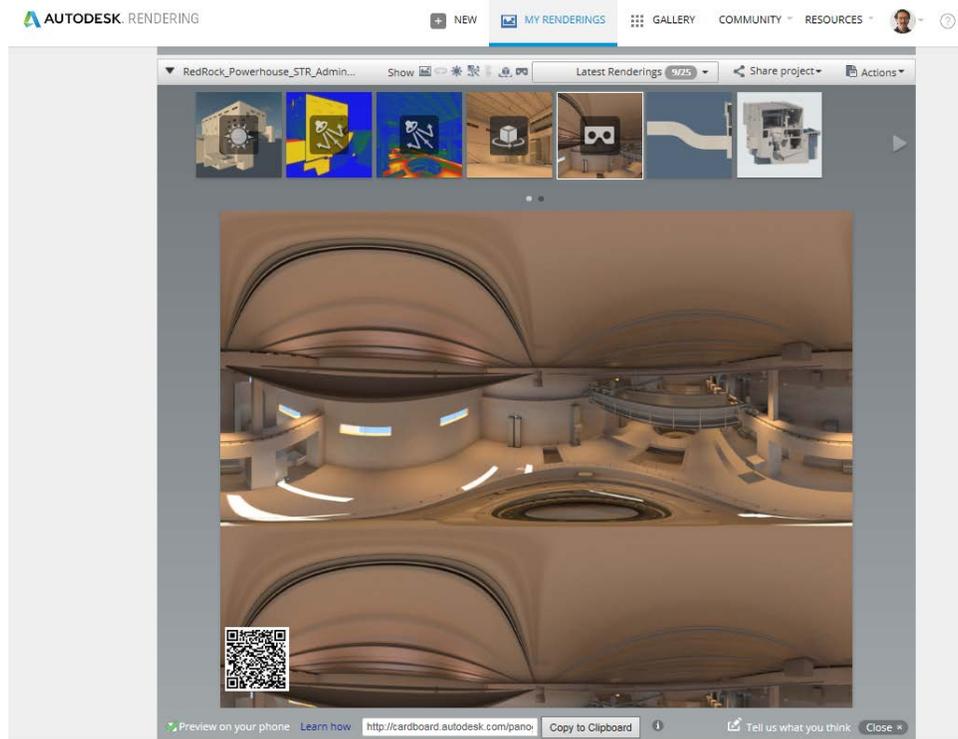
During the early phase of Panama Canal Third Set of Locks project, the visualization was done by Autodesk 3DS Max with a schematic design level of development modeling detail. At that time, the majority of Revit models were not done, so we could not utilize the information models for visualization. Once the design changed, the visualization (rendering and animation) became obsolete. Later on, we exported models from Revit and Civil 3D to Navisworks for clash detection review as well as visualization (internal audience).

Autodesk 360 rendering has been available since Navisworks 2015. Rendering options in the cloud are faster and offer many types – still image, interactive panorama, solar study, color-coded illuminance, lighting analysis, turn table, and stereo panorama. You can easily scan the QR code or share the URL to your clients for them to experience it with a cardboard VR headset.

Viewpoints, with daylight or interior lights, can be rendered “on the cloud” and files stored and reviewed on the Render Gallery. You will receive an email notification when the rendering task is completed and no longer have to wait for Navisworks to complete a rendering. Submit a view and continue to work. Images can also be downloaded if you need local copies.

Nearly the final phase of Panama Canal Expansion project, we also applied Autodesk VRED 3D visualization software for the photorealistic still renderings and animations. VRED is designed for automotive designers and digital marketers to create product renderings, design reviews,

and virtual prototypes. With Autodesk's help, we took the innovative initiative to apply it to one of the largest construction projects in the world to see the capabilities and limitations, but mainly to take advantage of Virtual Reality (VR) before a lot of popular VR-compatible, real-time rendering software like Fuzor, Enscape, and Autodesk Revit Live entered the market.



A360 CLOUD RENDERING WEBSITE



PANAMA CANAL THIRD SET OF LOCKS RENDERING BY AUTODESK VRED

Autodesk Revit Live is a stand-alone program that is an add-in to Revit that simply takes your Revit models and places them in a real-time rendering environment similar to Enscape. Revit Live has full VR capability and has an “editor” that links with Revit. The editor allows you to “publish” the live projects to a Revit Live “Viewer” that is free for anyone to download for both the PC and iPad. Revit Live also allows for you to view your BIM data from the Revit model. Besides that, we need to use Stingray if we plan to add animations in the live scene. 3dsmax Interactive is the Stingray product it has been integrated with 3dsMax and free to all 3dsMax users. For more information visit this site: <http://area.autodesk.com/blogs/the-3dsmax-blog/get-3ds-max-interactive>

Autodesk LIVE Add-in for Revit support linked files. These linked files can be local or on network drive. They can be overlay or attachment. The only limitation is linked files from BIM 360 or Collaboration for Revit (C4R). Below are the steps for preparing and exporting Revit models for Revit Live.

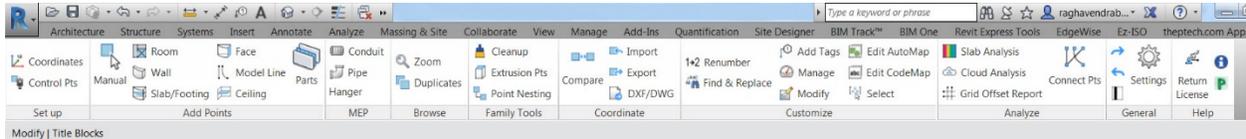
1. Start by prepping your Revit model with all the desired materials.
2. Upload your model to the cloud service via the Revit Live plug-in and click “Go Live”.
3. Download (by importing .lvmd file to Autodesk Live Editor) and customize your Revit Live scene with a variety of visual options.
4. Present your design using a variety of built-in navigation and interactive features such as virtual reality.



AUTODESK LIVE EDITOR INTERFACE

Workflow #13: Use Point Layout to Improve Office-to-Field Efficiency and QA/QC
Autodesk Point Layout is a construction layout software that helps bring greater model accuracy to the field. It is ideal for anyone who needs to conduct a layout on the job site. It creates

points on almost any objects and exports point locations to a total station. It helps not only do the layout in the field but also helps in quality assurance to check and make sure the element is installed as per the coordinated model.

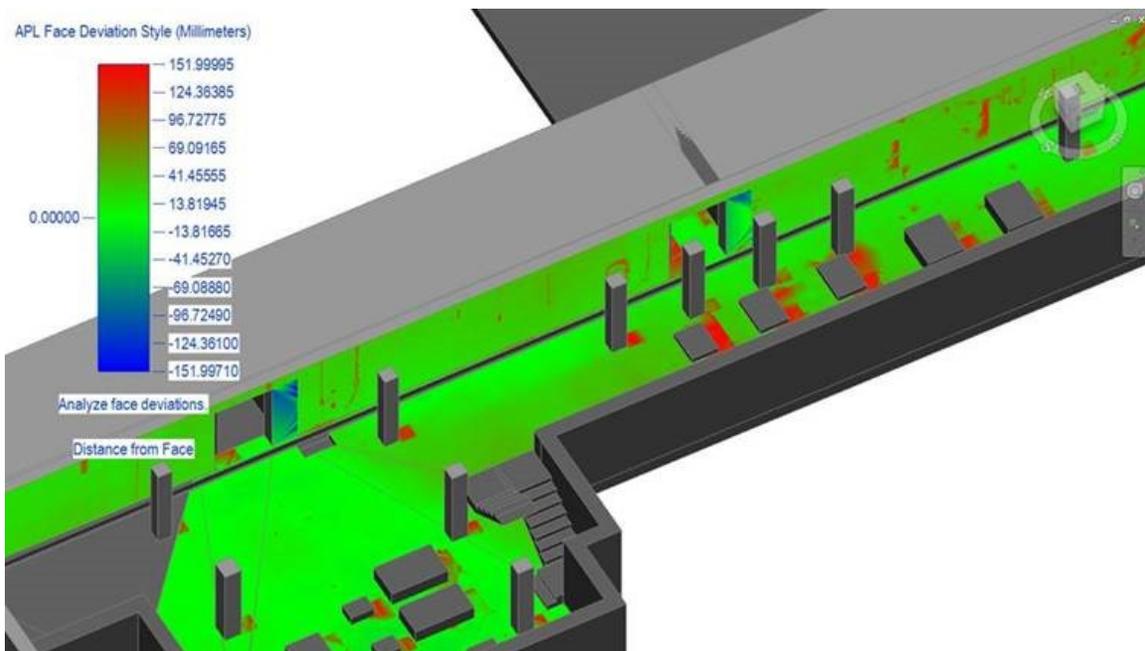


AUTODESK POINT LAYOUT ADD-ON FOR REVIT

Features:

- Create points (setout points)
- Export setout points to Total Station
- Import Field Conditions
- Perform QA/QC by comparing
- Slab Analysis
- Cloud Analysis feature can be used for verifying the accuracy of the As-built models in comparison to the point clouds captured.

By specifying the maximum face deviation we can get a heat map (as shown from the screenshot image below). It helps identifying the areas in the model that do not match the as-built conditions. From the image we can see the columns, pads and door locations are clearly displaced and not matching with the actual as-built. This can be a very good tool to verify the as-built conditions & get them incorporated.



VERIFYING THE AS-BUILT CONDITIONS BY AUTODESK POINT LAYOUT

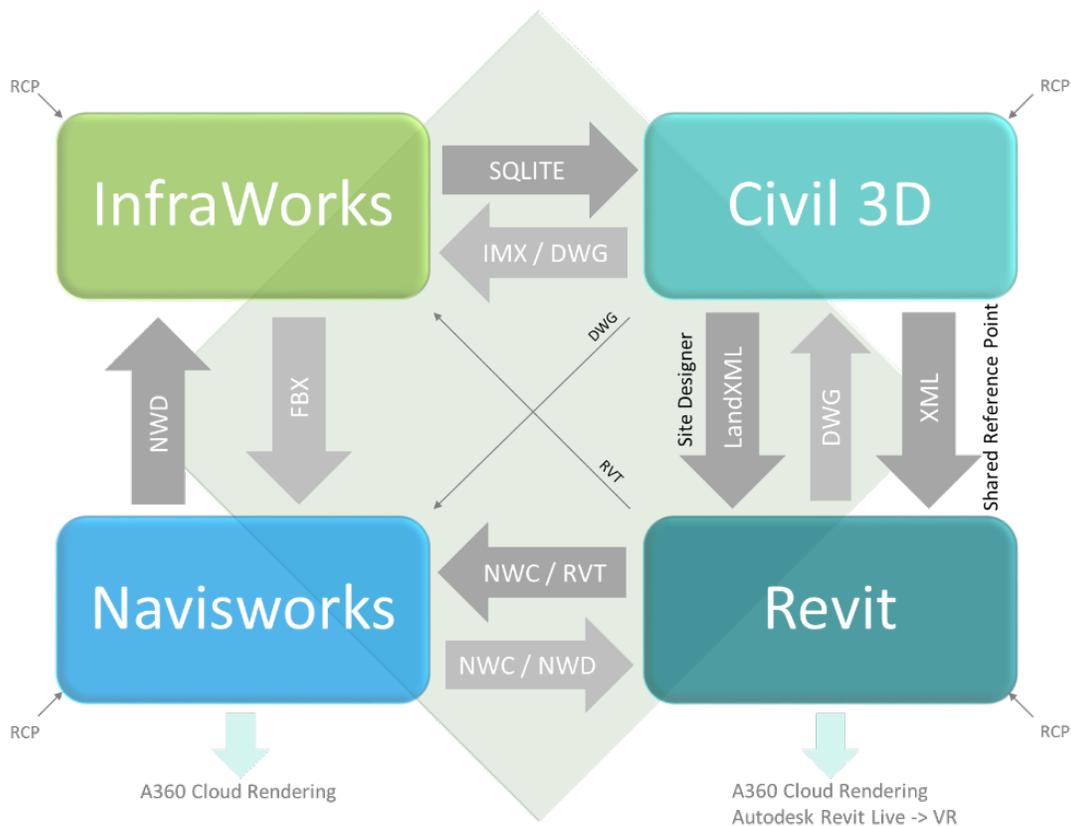
Workflow #14: Interoperability between InfraWorks, Civil 3D, Revit & Navisworks

This is a new and powerful design workflow which was available after the completion of Panama Canal Third Set of Locks project. It is worth it to document and share here for future wet infrastructure projects' reference.

- Use Autodesk InfraWorks to build the site model for study and simulate the design virtually, and present the alternative design options with analysis results to our stakeholders. "Model Builder" function in InfraWorks incorporates GIS data and Bing Maps aerial imagery to quickly generate a site model from anywhere in the world. We can import models from Revit, SketchUp, and even the Navisworks for planning and feasibility study during the early phase of design. It integrates traditional siloed data into a visually oriented, easy-to-use 3D intelligent site model to improve project visualization and enable broader decision making.
- Since Civil 3D 2016 version, we can open (insert) InfraWorks 360 .sqlite native file format directly with some configuration exchange settings.
- To bring InfraWorks 360 model data in AutoCAD Civil 3D:
<https://knowledge.autodesk.com/support/autocad-civil-3d/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/Civil3D-UserGuide/files/GUID-611B8553-3CD8-40BC-A8C1-0873AD1ABF6A-htm.html>
- To add AutoCAD Civil 3D data (.IMX export from Civil 3D or AutoCAD Civil 3D DWG) to an InfraWorks 360 Model: <https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/InfraWorks-UserHelp/files/GUID-46E7A046-B7F2-4F45-BAAF-220646B3C1F6-htm.html>
- Shared Reference Point Tool is an extension from [Autodesk Subscription Site](#), under the productivity tools for AutoCAD Civil 3D with two installers, for Revit and Civil 3D. It exports an .XML file from Civil 3D with X, Y, and Z coordinates, along with the corresponding rotation and units. This reference point defines the relationship between the site and building.
- Autodesk Site Designer Extension for Revit exports an .LandXML file from Civil 3D and runs inside Revit software. It uses native families, components, and toposurfaces, so site designs become part of the overall model. You can model alternatives for mass grading, building pads, streets, sidewalks, parking lots, and retaining walls all within the Revit environment. More easily convert a sketched line into a street, sidewalk, curb and gutter, retaining wall or parking lot in the model. You can manipulate Site Designer components using editing tools to change their location, elevation, grade or geometry, and Site Designer automatically updates and maintains the underlying toposurface.
- Although Navisworks can append Revit native file (.RVT) directly, it is recommended to export NWC (Navisworks Cache File) from Revit by Autodesk Navisworks Exporter. In this case, we can easily export NWCs from the same Revit model with switching on/off different linked models and worksets. The NWC exporter works with a range of products, including AutoCAD and Revit software-based products, as well as 3ds Max, Bentley MicroStation, and Graphisoft ArchiCAD software. The NWC file format supports transfer of both object geometry and associated metadata.
- New feature in Revit 2018 is the ability to link Navisworks files, NWC or NWD format. When you load, you have the option of relative or absolute paths and origin to origin positioning or by shared coordinates. There is also a new tab in the visibility graphics box to toggle on or off and to control the transparency. This will make coordinating with non-Autodesk software much easier. Modeling around other disciplines and correcting

clashes can be done right in the Revit model. Detailed equipment that was once very heavy in Revit can be referenced as a NWD file. While there are better workflows for many of the formats Navisworks can read, this will certainly open up some new possibilities.

- Since InfraWorks is using Navisworks as the background engine to convert the Revit model as NWC before importing to InfraWorks 360 (besides the cloud option). It would be nice to have NWC as one of the support data source formats. Typically, I use Navisworks to generate a "federated model" (NWD/NWF) with multiple Revit linked models. Then, I export the model out from Navisworks as FBX format for InfraWorks 360. Unfortunately, the file size increased a lot in FBX and end up not acceptable in InfraWorks. This is the post in InfraWorks IdeaStation I proposed back to December 2015 and received 50 votes. <https://forums.autodesk.com/t5/infracore-ideas/importing-nwc-into-infracore-360/idi-p/5962715> Recently, I found there is a secret backdoor to import NWD directly from "3D Model" data source category in InfraWorks. InfraWorks doesn't show it supports NWD from its UI but we can manually browse the file from local drive (search ".nwd" by "All Files") and preview it before import (close and refresh). No guarantee it works for all files (file size limitation?).
- InfraWorks model can be exported as FBX and bring in 3DS Max for visualization or Navisworks for clash review. You can "crop" the model by using Area of Interest (polygon or boundary box selection methods).



INTEROPERABILITY BETWEEN INFRAWORKS, CIVIL 3D, REVIT AND NAVISWORKS

Moving Forward

Technology #1: Augmented Reality

- Augmented Reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data.
- Examples: InfraWorks 360 iPad App, AR-Media with QR code and logo scanning, Google Project Tango, Pokémon Go ☺
- To use Augmented Reality from InfraWorks 360 Mobile App:
<https://knowledge.autodesk.com/search-result/caas/CloudHelp/cloudhelp/2014/ENU/InfraWorks-MobileApp/files/GUID-98459B25-3543-4335-AD72-A51C3250F2AB-htm.html>

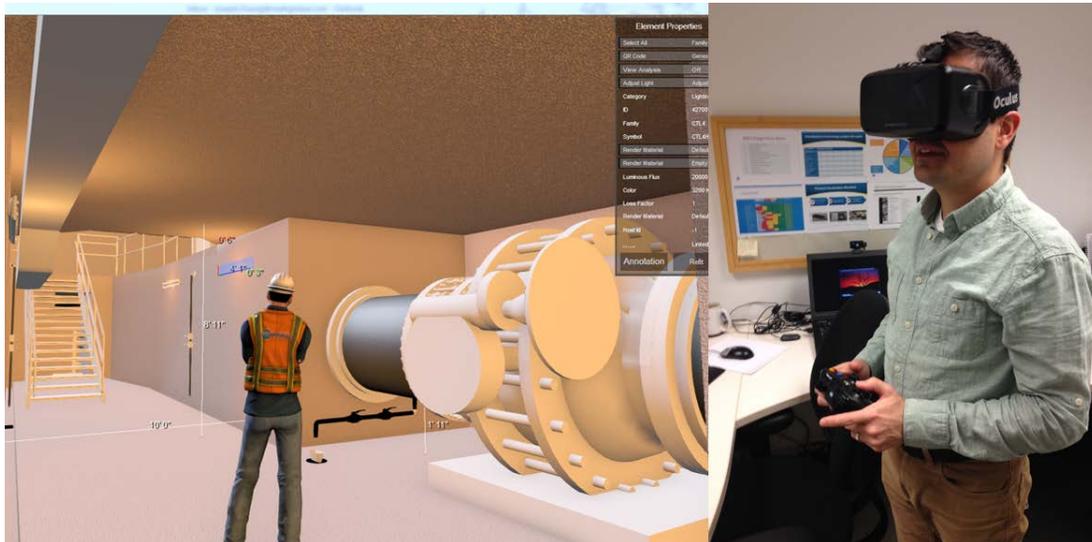


EXAMPLES OF AUGMENTED REALITY

Technology #2: Virtual Reality

- Virtual Reality (VR), also known as immersive multimedia or computer-simulated reality, is a computer technology that replicates an environment, real or imagined, and simulates a user's physical presence and environment to allow for user interaction. Most up-to-date virtual realities are displayed either on a computer monitor or with a virtual reality headset (also called head-mounted display), and some simulations include additional sensory information and focus on real sound through speakers or headphones targeted towards VR users. Some advanced haptic systems now include tactile information, generally known as force feedback in medical, gaming and military applications.
- Example: Software – Autodesk Revit Live, Stingray, Fuzor, Revizto, Enscape, etc.; Hardware – Oculus Rift, HTC Vive, Samsung Gear VR, etc.
- It can be a good supplement for clash detection especially when checking the clearance with a “human scale”, user’s perspective.

- A great opportunity for the owner is to train people during the operation and maintenance phase to familiarize them with all the basics before involving anything that would be dangerous in a simulated virtual facility.



VIRTUAL REALITY EXAMPLE (FUZOR + OCULUS RIFT)

Technology #3: Mixed Reality

- Mixed Reality (MR), sometimes referred to as hybrid reality, is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Mixed reality takes place not only in the physical world or in the virtual world, but is a mix of reality and virtual reality, encompassing both augmented reality and augmented virtuality.
- Example: Microsoft HoloLens, potential usages like design communication with a full-scale digital markup, job site punch list coordination, RFI filing.
- Unlike Oculus Rift (Virtual Reality) and Google Glass (Augmented Reality), HoloLens is combining the virtual world and real world, which is enhanced with holograms. The user can see the real world like a laptop's screen and the surrounding space while navigating the digital model/scene in front of any defined location during the same time.
- Imagine taking your HoloLens to the job site and connecting to a wireless cloud service, you can scan the space with your BIM model overlay. Moreover, you can actually place new equipment into the real environment from a catalogue of holograms/objects, then connecting them in-situ with pipework, valves and instrumentation.
- We also tested how to make a Skype call via HoloLens and draw holograms (unfortunately, the HoloLens Skype beta doesn't support Skype for Business yet). Sooner or later, we can have a Skype conference call at the job site with some real-time feedback across different parties (e.g. Designer, Contractor, and Client).

<https://www.microsoft.com/microsoft-hololens/en-us/apps/skype>



SKYPE CALL WITH HOLOLENS EXAMPLE

- MWH, now part of Stantec in UK has done some amazing development so far to explore various potentials to our daily practice. Some remarkable achievements include bringing non-graphical data from external databases into the graphical interface for asset management and overlapping the design model into the existing facility before construction.

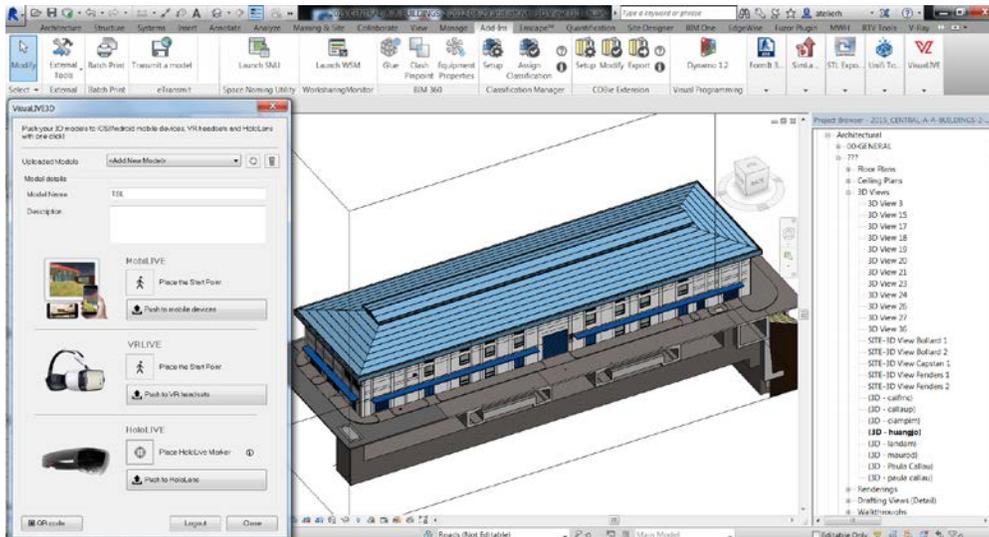


ASSET MANAGEMENT WITH VOICE COMMANDS BY HOLOLENS



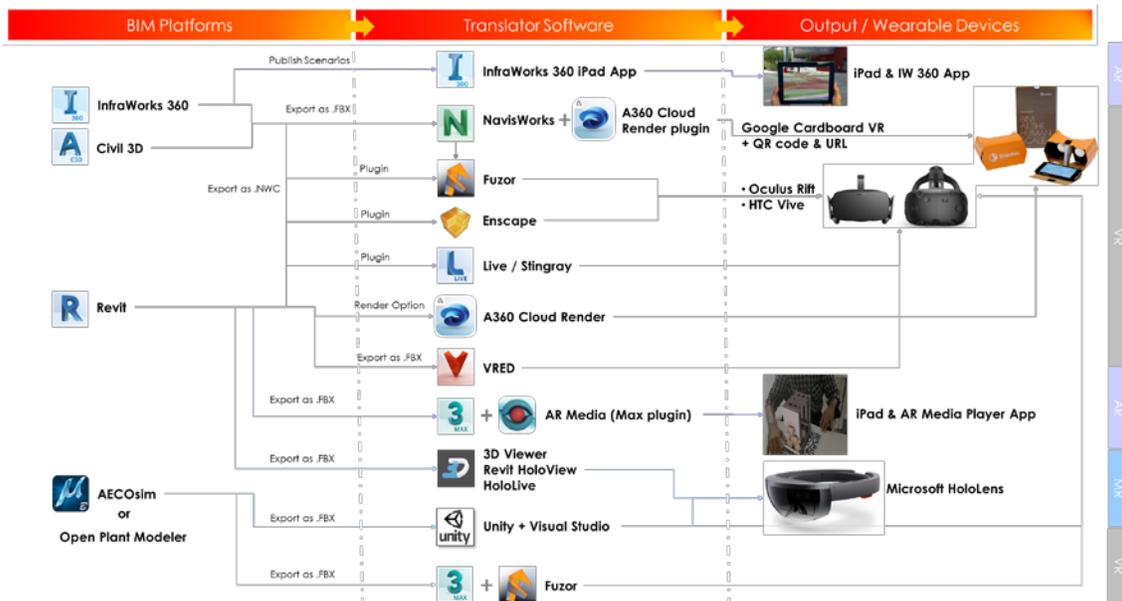
OVERLAPPING DESIGN MODEL WITH EXISTING FACILITY BY HOLOLENS

- By using Visual Live 3D plugin for Navisworks and Revit (available from Autodesk App Store), we can publish our models directly to HoloLens with HoloLive app (free from Microsoft Store), and position the model to the right coordinate system using the QR code marker/survey control in the field or you can visualize it with smaller scale using the scale tool in HoloLive app.



VISUAL LIVE 3D PLUGIN FOR NAVISWORKS

- Creating a BIM workflow diagram could be a good way to learn and document the process of using multiple software applications and output formats. The diagram below shows a variety of applications to “translate” design models from BIM platforms to the AR/VR wearable devices.



FROM DESIGN MODEL TO VIRTUAL REALITY / AUGMENTED REALITY