As-built Model Verification workflow using Revit and Scan Data

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Learning Objectives

- Learn the potential benefits of having a reliable as-built model
- Learn the challenges of getting a reliable as-built model
- Learn the workflow of verifying as-built model with scan data
- Set basic requirement for model verification

Description

The idea of using BIM Model in Facility management has been raised for many years. One major reason why it is not widely adopted in the market is the mismatch between as-built model and built structure. Using the Reality Capture technology, the scan data of the built structure can be collected and used for as-built model verification. A list of discrepancies between scan data and as-built model would be produced which team members can validate the results and amend the as-built model when appropriate.

This class will identify the workflow when using Revit to verify the as-built model with the scan data as well as the possible follow-up actions. A third party Revit plugin is used for scan data identification with model category information and perform model checking using point cloud. A sample case will be explored to demonstrate the suggested workflow.

Your AU Expert(s)

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Table of Contents

How a reliable As-built Model help?

As-built Model represents the as-built condition of a building's physical conditions, environment and its assets. As-built may not record all the things this moment, but at least it should be truly recording the location, geometry, material and many other time or cost related information of the built objects. Two major benefit area of having an As-built would be Facility Management and Building Renovation. Also, if a model can gather so many information in one system, the potential value would be huge depending on which add-on information we added in the Model.

As-built Model for Facility Management

One of the most beneficial area would be Facility Management (FM). It is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology. Better FM can improve the daily operation efficiency of a building. A reliable As-built Model would:

- Provide essential data for operations and maintenance management of assets, equipment and systems effectively
- Provide accurate model of rooms and spaces for space management
- Provide accurate data with geometrical information which reduces man-power cost to address and solve the issues
- Reduce storage space for building information in paper form
- Integrate all manual and maintenance record together for easy reviewing
- Create synergies with other BIM uses
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As-built Model for Building Renovation

Renovation of building are done everywhere. It can upgrade the building to become more modern, attractive, energy-saving, reliable and safe. Instead of demolishing and rebuilding the building, renovation would be more cost effective and most important, it can keep most of the building working while part of it under upgrade. A reliable As-built Model would make the renovation work more effective and under control. Using the As-built Model:

- Inconsistency between recorded and real condition can be reduced
- It can provide a good starting point of future modeling and 3D design coordination for renovation
- Visualization and analysis of the proposed retrofit can be easily done and it would be much easier to present to the stakeholders
- It enables embedding of future data based upon renovation and equipment replacement

Why can't we get a reliable As-built Model?

As we know, the benefit of As-built Model is huge. However, it is not widely used in reality. One of the major argument is that "The Model is not As-built". It is a very serious claim for the model when we called it "As-built". This means the model is not reliable anymore. As most of the benefit we mentioned are based on the model that can truly reflect the reality and help us to interact with it instantly, we cannot enjoy the benefit of it when it is not "As-built" anymore. In the following parts, we will look into the reasons why as-built model is not as-built.

As-built in Construction Process

Ideally, building would be constructed as same as the original construction drawings which are distributed by the Design Team (Architect/ Engineer) to Construction Team (Builder/ Contractors). In fact, the built structure would not be exactly the same as the original drawings (sometimes totally different) due to the unforeseen conditions on site and owner's changes in mind during the construction stage. The change would be recorded by the contractors as the diagram below.
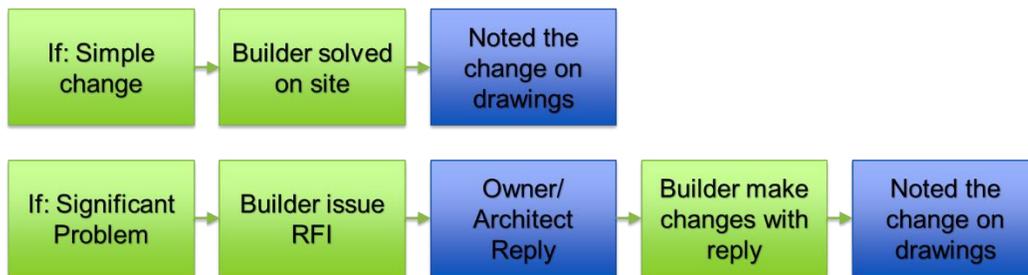
CHANGE RECORD PROCESS IN CONTRACTION STAGE

If the unforeseen condition need simple modification only, builders can handle and solve the problem on site by themselves. If the condition need significant change to the original design or the builders cannot solve the problem by their own, they would issue a request for information (RFI) to ask for further instruction from owner and architect. Normally, builder will receive a new revision of drawing and continue the building process.

Many problems of As-built recording would occur during construction stage:

1. Lack of Motivation
    Some contractors are unwilling or incapable to do quality As-built works. Due to rushing in site environment, they lack sufficient time, staff and budget to do the As-built record. Even if they do the job, the responsibility would usually be assigned to someone with least experience or lowest ranking staff. Those people would be too fresh to understand the construction process and do not know which is important and needs recording.

2. Broken Work
    Usually, main contractor performs less than 50% of the work with their own effort. This number would be much less when a project become larger and larger. Most of the works would be divided and subcontracted out. Sub-contraction is necessary as a construction project requires many professional skills which the main contractor can only rely on subcontractors with various experts.
    At the same time, too many parties are involved in the construction process. It is difficult to ensure all the subcontractors to do a quality As-built record. The situation when confessing who should take the responsibility to record As-built would also happen as some parts of the project involved multiple subcontractors to work together. Main contractor may also have the difficulties on generating a final As-built record by collecting and combining so many information.

3. Various Expectations
    In a contract, as-built specification tends to be short. In most of the cases, it just mentions the contractor has the responsibility to record any modification on site on as-built drawing/model. Without a clear explanation, every stakeholder may have various expectations for as-built record due to their own assumptions and experiences.

As-Maintain in Building Operation

As mentioned previously, renovation is done everywhere. You may get a reliable as-built record after the building is built. While building is in operation, it may have many maintenance and renovation works that causes the building to be slightly different from its built condition. For example,

- Some piping may be moved when the toilet get repaired
- Socket outlet position may be changed when you want to renew your bedroom
- Air conditioning connection may be modified when you rearrange your office partition
- Etc.

Accumulating those small changes throughout year by year can make a big difference. Recording the modification works and keep it as-maintain is necessary, but the job would also be challenging due to different kinds of issues:

1. Lack of Profession

    During daily building operation and maintenance, records of changes are usually missed. In most cases, external workers are hired to do the maintaining and repairing works. On one hand, those external workers are doing many small jobs. They may be working on different jobs in different locations every day, they do not have the intention to record every single change they made. On the other hand, the person in charge of the building, whose main duty may be dealing with admin works rather than engineering works, does not have full understanding to record as-built. Maybe both of the workers and manager do not even know how to use AutoCAD or Revit.

2. Dispersed works

    For the renovation works taken in building operation, the project can also involve multiple subcontractors and similar problems of As-built recording may occur. Although the scale would be smaller, the renovation works can be taken in different times with different groups of people. It would be harder to combine their information in consensus.

Scanning – Solution for the problem

Although we can think of many other solutions to solve the mentioned problems, the working culture of the people cannot be changed in no time. The best way is to hire a team aiming to record those changes and modification in construction site or buildings under operation. The team should be small in size and able to record the change quickly and detailedly to minimize disruption to the construction works and daily building operation. Scanning would be the answer.

Laser Scan can record the as-built work in a very short time with many geometrical details. Depending on the project scope, scan data can be one kind of data format recorded in BIM model. The information can be recorded on the model later on by professional modeler. Gathered scan data can be used for verifying previous As-built model, discrepancy could be found and model can be updated to truly As-built.

What is the workflow of verifying As-built Model with Scan Data?

In simple words, the workflow should start from preparing an initial As-built Model and Scan Data. Then we put them together to verify the model and report discrepancies. Model can be updated and ensure it matches the reality to be As-built.
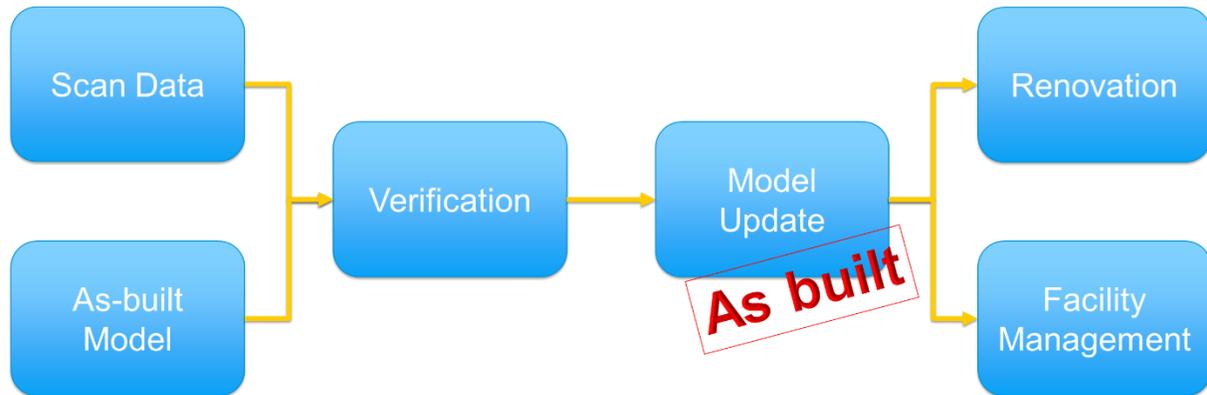
SIMPLE WORKFLOW OF AS-BUILT MODEL VERIFICATION

Scan Data Collection
Today, with laser scanning, we can collect 3D surface image in a very easy and accurate way. Most popular brands, FARO and LEICA, cover 90% of the laser scanning market share. Large scale scanning may take several days and detailed planning is needed before working it out. In our cases, we are focusing on much smaller area such as a room and need to take As-built record in a very short period of time. Recent years, many handheld scanners come to the market. Scanning can be done on the laptop or tablet, so the whole data collection process from setting up to scanning can be finished in a much faster way.
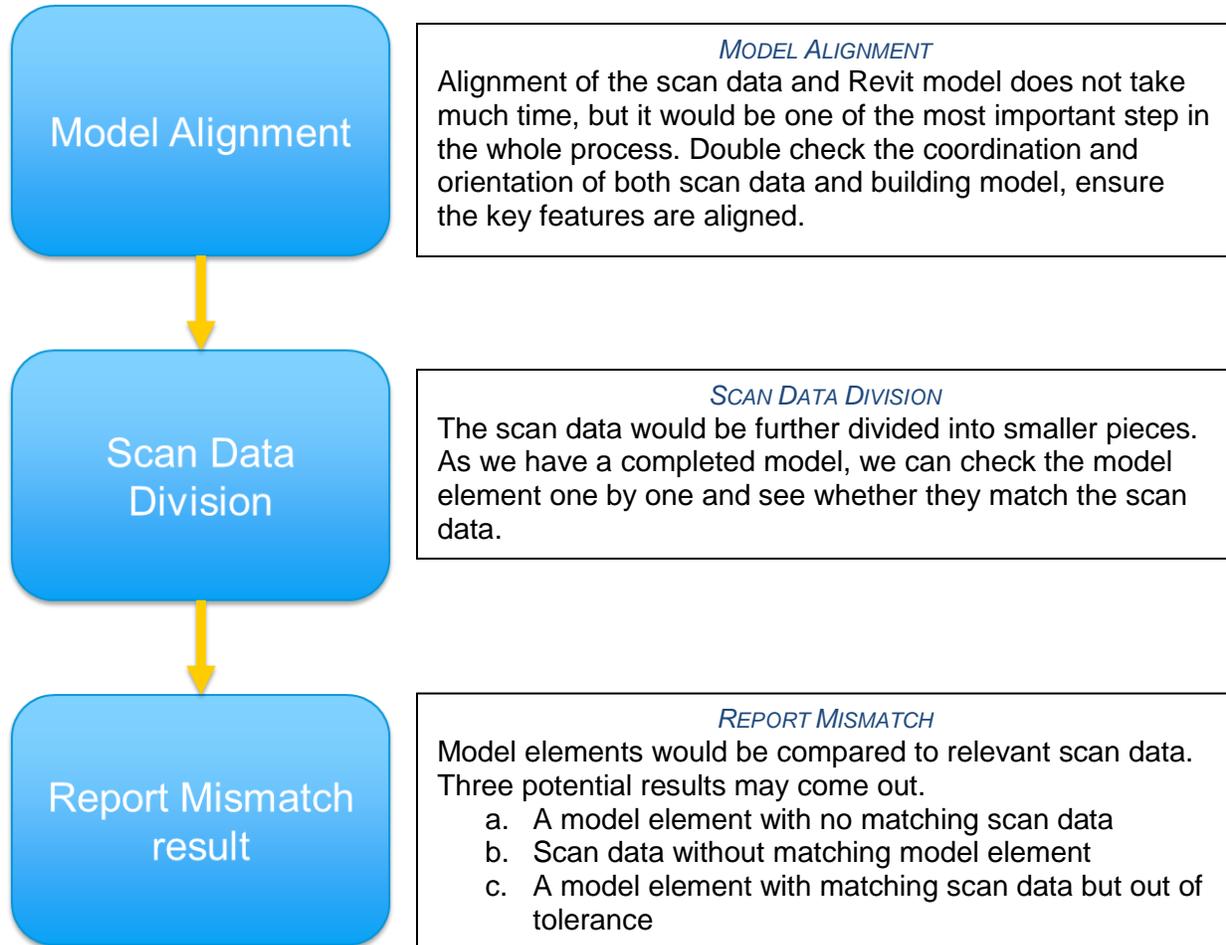
First "As-built" Model
We can obtain the first As-built model in several ways:

1. Scan Data
   The most obvious way is to model the scan data directly. The jobs rely heavily on the point cloud modeling tools. For Revit, we have CloudWorx, Pointsense, Edgewise, Scan to BIM, etc., these tools can help the modeling work in Revit. The As-built model from Scan Data would also be verified while modelling, so it may not need further verification process if the scan data is most updated.

2. As-built Drawings
   Another method is to model the building with the As-built drawings. The drawings would provide information of main building design, structure and equipment.

3. As-built Model
   For the building already using BIM in design and construction, an As-built model would be obtained after the construction stage. It can be used for As-built verification directly without further modeling work. In the coming future, most of the building would be designed and constructed with BIM and it would be the case we need model verification with scan data most.
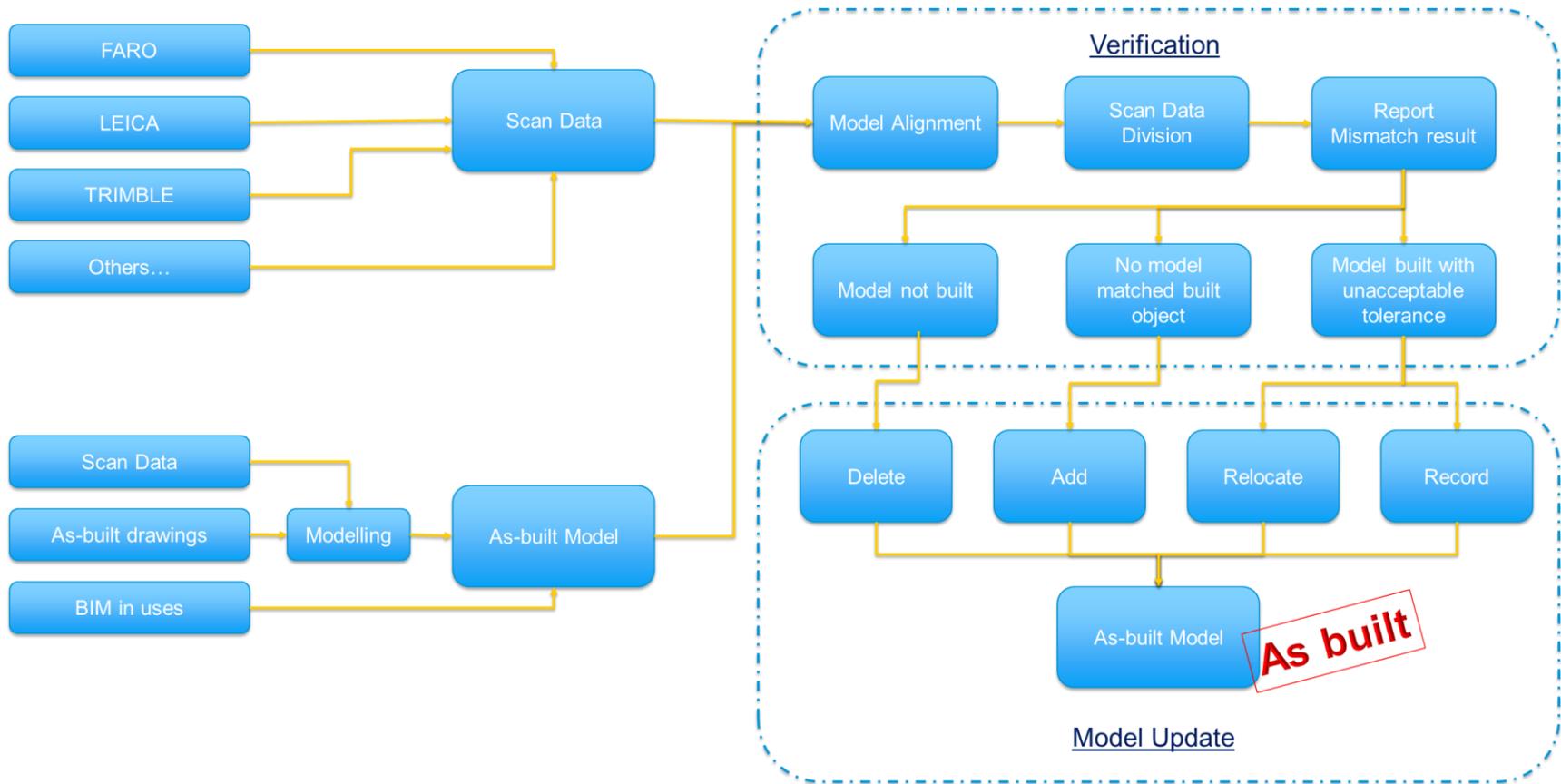
Verification Workflow

For the detailed verification workflow after having both scan data and model in Revit, three main steps would need to be gone through.

Model Alignment	***MODEL ALIGNMENT*** Alignment of the scan data and Revit model does not take much time, but it would be one of the most important step in the whole process. Double check the coordination and orientation of both scan data and building model, ensure the key features are aligned.
Scan Data Division	***SCAN DATA DIVISION*** The scan data would be further divided into smaller pieces. As we have a completed model, we can check the model element one by one and see whether they match the scan data.

Report Mismatch result	***REPORT MISMATCH***
	Model elements would be compared to relevant scan data. Three potential results may come out.
	   a. A model element with no matching scan data
	   b. Scan data without matching model element
	   c. A model element with matching scan data but out of tolerance

Model update with verification results

Based on the verification results, the model elements should be updated according to the type of mismatch. Typically, the decision is simple including removal of the redundant elements, addition of missing elements and correcting the out of tolerance elements to fit the scan data. One thing needs to be pointed out, Revit is a design-orientated modeling tools and the model created are ideal, straight and plane. It would be difficult to record every geometry we found in reality. For example, a plumb wall and a curved pipe may not be easier modeled by System Family in Revit. In these cases, generating a one-page report for the mismatch elements and record them as a link in the element parameter would be a better method to "update" the stage and more realistic.

WORKFLOW FOR AS-BUILT MODEL VERIFICATION

Which items should be considered before As-built Model Verification

Many information can be gathered from the scanning and all of them can be stored inside the BIM model, but don't overdo the work. Although the scanning work on site can be short, the time and resource for data analysis and modeling may increase exponentially if higher accuracy and more detailed work are requested. Do consider the followings before the project starts.

Scope of Works

The scope of the works should be considered at the very beginning of the project. It is not necessary to capture all the elements in construction site or building. General speaking, a large part of the as-built should match with the reality. Area of interest should narrow down to one or two room(s) size, so the scanning can be finished instantly. Some areas that have frequent design changes in construction, plant rooms that need to be accessed in a quick and precise way, offices that have been renewed recently, these parts are the examples which needs to be verified in a higher priority.

The user should also consider what kinds of objects are more important (MEP equipment, building structure or others). The answer would affect what the tolerances of different objects should be.

Common Reference

Reference point or geometry must be defined well before the project starts. The quality of model verification would rely on a common reference point as it directly links to the model alignment process.

Quality of Scan Data

The quality of scan data is important. It should not contain too much redundant information or noise which may greatly affect the model verification quality. The site should be clear or as least rubbish-free before scanning. Scanning team should be alerted on whether a component is an important target of scanning, so they can tidy up the scan data before handing it to model verification.

Quality of First Model

The source of the first model may be built by other team with their standard and purpose. Check the model quality and LOD of the model to match with the project requirement.

Model Tolerance

The scan data and Revit model might not perfectly fit to each other. An acceptable tolerance should be assigned to the project. Also, objects in different categories should have their own tolerance range. For structure component like walls, framing, slab, the geometry is standard and simple, so the tolerance should be less. For some components that have more features like door, window, MEP equipment, the geometry could be complicate and would not be modeled exactly the same, therefore higher tolerance should be allowed. It would be better to prepare a list and to write down the targeted categories as well as their respective tolerances.

Tools to be used

The tools for model verification should also be considered before the project starts. Different tools will have their own strength and capability in scan data checking. Several scan data modeling add-ins in Revit include surface analysis function, such as PointSense and Scan-to-BIM, could be the options. Automation in scan data modeling is doing great in many software,

we are looking forward to having software which can verify the model elements in different categories and generate reports automatically.

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