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A REVIEW OF SCAN-TO-BIM TECHNOLOGIES IN ASSISTING PROJECT COORDINATION AND MANAGEMENT

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Abstract: Scan-to-BIM technologies are the process of scanning a project, facility, or building site to generate a 3D point cloud of the site's information. Then, manipulating the scan into a 3D model compatible with software packages, like Autodesk, allows for a single BIM model for decision-making and analysis of the site. This growing technology assists the architecture, engineering, construction, and facility management (AEC/FM) industry. Scan-to-BIM has many applications. A few examples are as-built models, progress monitoring, defect detection, and more. The purpose of this study is to review how project coordinators and project managers can use scan-to-BIM. This will be complemented by using the current applications on a small case study. The case study is a new entrance to Head Hall, the engineering building, on the University of New Brunswick Fredericton campus. This new entrance is a mass timber expansion project. A 3D Laser scanner (Leica RTC360) completed the scanning and pano images. The scanning process started from the basement and worked upwards, scanning on each floor level. Each scan was shown as a 'setup' in the whole point cloud model; those setups were linked as a bundle on-site during scanning using the Cyclone Field app on a tablet. Then, after scanning, the point cloud model was uploaded into Cyclone Register for preliminary modification, including fixing errors, checking links between setups, and removing noise points such as passersby and reflection points. Lastly, the scan was imported to Cyclone 3DR for further modification and analysis. Once the model is completed, it can be used in Autodesk programs like Navisworks and Revit to analyze the current application that the project coordinator and manager use.

Keywords: LiDAR Scanning; Building Information Modelling (BIM); Project Management

1 INTRODUCTION

Scan-to-BIM technology assists and benefits the architecture, engineering, construction, and facility management (AEC/FM) industry. Currently, in the research field of scan-to-BIM, discussions are being held about each application and are reviewed. However, each review only explores one scan-to-BIM application on multiple case studies. Additionally, many case studies in literature that use 3D laser scanning point cloud datasets are focused on urban and outdoor areas. In contrast, synthetically or RGB D data collection devices are used for indoor areas (Alsuhaibani et al. 2023). This research will use a qualitative case study research design method to explore an indoor case study using laser 3D scanning to collect the data. Then, identify all the different applications and determine which are helpful to use through the project management and project coordination process. Lastly, of the applications that project managers and coordinators can use, the ones that apply during the construction execution phases will be applied to a case study.

2 LITERATURE REVIEW

The literature review focused on the following areas: project management, project coordination, LiDAR scanning, Building Information Modelling (BIM), scan-to-BIM, and scan-to-BIM applications. The scan-to-BIM section reviewed all the applications at different phases, focusing on the applicable applications during the execution phases.

2.1 Project Management

Project management involves applying knowledge, skills, tools, and techniques to all project activities during construction to meet the project requirements. A project manager must understand project details. However, the project manager focuses on managing the overall project (Project Management Institute 2008, 26). Project coordinators help the project manager with the details, typically in an area the project coordinator specializes in (Lee, Ahn, and Kim 2023). Depending on the project size, more or fewer project coordinators will be needed to assist the project manager. Project coordinators coordinate sub-systems, identify workforce requirements, develop schedules and budgets, and document project performance (Lee, Ahn, and Kim 2023).

Construction has five phases: initiating, planning, executing, monitoring and controlling, and closing (Project Management Institute 2008, 3–14). For this study, the focus will be on the responsibility project managers and project coordinators have during the execution and monitoring and control phases. Throughout these phases, the responsibilities are to monitor activities, keeping the project's schedule and budget on track, inspections, and communicate all project developments to the project parties (Project Management Institute 2008, 26). Different methods, tools, and techniques are implemented to complete these responsibilities. The most popular project management tools are applications like Procore or Autodesk Build and BIM Collaborate or a company equivalent. These applications can track all project activities, update the schedule and budget, and are a single location for all documentation. Within these applications, there is often a tab for a model to be added, and the documentation can be synced to the location of the problem on the model, resulting in clear communication of information.

2.2 LiDAR Scanning

LiDAR Scanning is a non-contact, non-destructive technology that digitally captures the shape and appearance of physical objects, structures, environment, or persons using a line of laser light and then uses that data to construct digital 3D models. LiDAR technology works by emitting laser pulses toward an object or surface and measuring the time it takes for the reflection to return. This process generates precise distance measurements, culminating in detailed 3D models of environments and objects. It is ideally suited to measure and inspect the contoured surfaces and complex geometries requiring massive amounts of data for accurate description. Its integration into various workflows in construction projects enhances accuracy and streamlines processes, from the initial planning stages to inspection after construction and future maintenance.

2.3 Building Information Modeling (BIM)

The definition of BIM varies from research to research. For this research, the definition of BIM that will be used is from the National BIM Standard (V3): "Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decision during its life cycle" (National Institute of Building Sciences 2015).

2.4 Scan-to-BIM

Scan-to-BIM is defined in several ways. Badenko et al. (2019) described the scan-to-BIM process as creating an as-built model, where the data was collected through laser scanning a building to obtain accurate parameters and primarily geometric. Similarly, Alsuhaibani et al. (2023) define the scan-to-BIM process as converting 3D point clouds to an as-built 3D building information model. Then, Rocha et al. (2020) defined it as integrating photogrammetry and laser scanning into BIM workflow. This research will use a combination of the three as the definition. Scan-to-BIM collects 3D point cloud data by integrating photogrammetry and laser scanning to develop an as-built BIM model.

2.4.1 Applications of Scan-to-BIM

Overall, scan-to-BIM has several applications. Depending on when the scan is completed, it will change how the model will be used. Suppose the scan is complete at the end of the project. In that case, the model can be created for the use of the owner or final client for facility management, digital twins, or digital assets (Alsuhaibani et al. 2023). Facility management is the management of a facility, which involves coordinating demand and supply to support the organization's efficiency (Kok, Mobach, and Omta 2011). Digital twins or digital assets are defined by Ramonell, Chacón, and Posada (2023) as the exchange of information between the physical and virtual system; the virtual representation of the physical system can contain information about the environment and process of the system. Alternatively, suppose scans are completed at the beginning of a project before construction execution. In that case, the pre-construction scan model is used as a planning tool for both design and constructability. This is ideal when the project is an expansion project or a historic building where an HBIM model can be created (Alsuhaibani et al. 2023; Badenko et al. 2019; Rocha et al. 2020). Rocha et al. (2020) used Murphy, McGovern, and Pavia’s (2013) description of HBIM as “a parametric model generation solution, where architectural elements are not only represented in their geometry but also in the corresponding attributes of a historical database.” Lastly, if the scans are done throughout the execution of construction, then the as-built model can be used for scan-vs-BIM, inspections, and construction progress monitoring (Alsuhaibani et al. 2023; Bosché et al. 2015; Jiang et al. 2022). Bosché et al. (2015) and Jiang et al. (2022) define scan-vs-BIM as an approach in which 3D LiDAR scanned points are aligned in a coordinate system and then compared to the as-designed or planned BIM model to identify differences. These differences can include placement errors, locations of holes for future work, or incorrect item sizes. Construction progress monitoring assesses the construction performance of activities to reduce project delays and budget overruns, which consists of data collecting, analysis, and status reporting (Jiang et al. 2022).

Some identified problems in literature are as follows. For Scan-vs.-BIM, there is a lack of case studies exploring the whole project. Mechanical, Electrical and Plumbing (MEP) elements are often excluded from the analysis for various reasons, including the circular cross-section of the pipes causing inaccurate data (Alsuhaibani et al. 2023; Bosché et al. 2015). This research will include and analyze the MEP elements that are built at the time of each scan. Typically, for the scan-vs.-BIM analysis, the process is to take the scan and develop a BIM model from the scan, then compare the two models to see the differences (Bosché et al. 2015). However, this is a time-consuming process and requires advanced BIM modellers. This research explores an alternative approach to the Scan-vs.-BIM where advanced BIM modellers are not necessary. The process includes overlaying the point cloud scan and the planned BIM model to see discrepancies between the two. There are a number of case studies using Scan-to-BIM applications; of the articles reviewed, a common comment was the analysis is a time-consuming process. This paper will provide information about the level of effort (LOE) in hours for the industry and other researchers. This will help both identify the LOE in terms of time when adopting scan-to-BIM applications into their project management/ coordination process if the project is of similar size to the case study analyzed in this research.

3 METHODOLOGY

This research will explore a qualitative case study research design method. The methodology will review the following processes: 3D scanning and Scan-to-BIM applications. The 3D scanning section will discuss capturing, preparing, analysis of the scan and then how the scanned files were exported into Navisworks. Due to construction starting on the case study, this research will explore two applications: scan-vs-BIM and construction progress monitoring. For construction progress monitoring, the analysis will examine the original and December update schedules to see if the scan model matches the work that should have been completed.

3.1 3D Scanning

The scanner used in this project was a Leica RTC360 3D Laser Scanner (Figure 1). It is a portable, automated scanner with a resolution of 3/6/12mm@10mm. It has a laser sensor to measure the distance between the camera and an object, and it can identify 3D points calculated from photos and depth measurements using triangulation. Altogether, these 3D points form a point cloud.

Figure 1: Leica RTC360 3D Laser Scanner. Photograph by (Leica Geosystem AG - Part of Hexagon 2024)

The software that cooperated with the scanner was the Leica Cyclone product family, which provided a good solution for capturing, preparing, and analyzing reality capture data.

Capture: Leica Cyclone FIELD 360 is a mobile device app connected to the scanner to get an instant preview of the point cloud data as it is captured and pre-align scans in the field.

Prepare: Leica Cyclone Register is used to stream data, process data, and publish data to industry standard formats.

Analyse: In Leica Cyclone 3DR, data is transferred from points and images to create meshes, models, DTMs, BIM inspections, volumetric reports, floor plans, and classifications. This provides functional digital reality deliverables like CAD plans, BIM models, floor flatness, or deviation reports. Leica CloudWorx is a plugin for CAD systems, including AutoCAD, Revit, BricsCAD, Bentley, and more. It produces CAD plans and BIM models by combining the CAD package’s native tools and its specialized point cloud commands.

In this case, the appearance of the extension and the surrounding environment was first estimated visually to decide where to place the scanner. The positions were shown as Setups in the point cloud. There were 84 Setups in total, covering each floor of the extension, connecting to the hallway, stairwell, and facade. This guaranteed the whole model was continuous to ensure the locations of different floors were right. The scanning process started from the basement and worked upwards, scanning on each floor level. All the setups were linked as a bundle on-site during scanning using the Cyclone Field app on a tablet. After scanning, the point cloud model was uploaded into Cyclone Register for preliminary modification, including fixing errors, checking links between setups, and removing noise points such as passersby and reflection points. Then, the scan was published in different formats with a report showing the connection quality of each link. Lastly, the scan was imported to Cyclone 3DR for further modification and analysis.

Following the scan being manipulated in Leica Cyclone Register and Cyclone 3DR, the next step was to go into Navisworks. In Navisworks, the Autodesk Recap (*.rcs, *.rcp) files were appended. There were 84 scan files of cloud points with millions of points within each file. The model would lag if all 84 files were to be appended, resulting in ineffective analysis. Therefore, the files were uploaded in groups of 10 to keep the system manageable and to determine which files were connected to each level. Once all the files were coordinated with each level, the file was saved as a Navisworks (.nwd) file to make a single model for each level.

3.2 Scan-to-BIM Applications

The first application of scan-to-BIM analysis is scan-vs-BIM, which compares the planned model (BIM model) with the as-built model (scanned model). This process was completed using Autodesk Navisworks. The planned model for the case study was appended to a new Navisworks file. Then, depending on the level being compared, for example, level B, all other floors were hidden. The same level of the scanned model was appended to the file. Once both models were in the same file, they were saved as a new model. These steps were completed for all levels (B, C, D, and E). The next step was to align the two models. This was done using the Item Tools tab to move and rotate the selected model. To make the alignment process easier, under the viewpoint tab, “Enable Sectioning” was selected to create a section view. The default section view is plain view. This was changed to a cube. Next, the cube was moved and sized to fit the area being aligned. To ensure the alignment of the two models was correct, the models were aligned with corners or parts of the existing building—for example, the stairwell, columns, or doorframes. Following the alignment, the next step is to review where the planned and as-built models differ. This will start with using the measure tool point-to-point feature under the review tab to see the distance between items that don’t match between the models.

The second application is construction progress monitoring. This will be completed by comparing the original and December update schedules to what has been completed, as seen in the scanned model. This process started with reviewing each schedule (original and December update), and then all the tasks that were said to be completed by the time of the scan (February 9) were compiled into a list. After all the tasks were identified, the list was compared to the model, and each task was determined as completed, not completed, or in progress.

4 CASE STUDY

The case study used for this process was the Engineering Commons Head Hall Renewal project. This project is a new entrance to Head Hall on the University of New Brunswick (UNB) Fredericton campus. The new entrance will hold the coffee shop (Head Rest), the Dean’s spaces, classrooms, laboratories, study spaces, etc. In parallel with the expansion, select offices, laboratories, graduate study spaces, and other parts throughout Head Hall will be renovated.

For a bit of background about Head Hall, it is the UNB Fredericton campus engineering and computer science building. The original building was built in the 1900s and consisted of only the Civil Department. There was a gym located uphill from the engineering building; this gym was renovated and changed into the Electrical Department. These two buildings were then connected to make what is now called “Old Head Hall.” In the 1960s, an addition was added to Head Hall, often called “New Head Hall.” This was added for the Chemical, Mechanical, and Geodesy & Geomatics departments. Following the 1960s expansion, Gillian Wing was added in the 1980s for the Computer Science and Software Engineering programs. After the Gillian Wing expansion, the ITC wing was constructed to further expand the computer science spaces. The Engineering Commons Head Hall Renewal project will be the fifth expansion of Head Hall. Figure 2 below shows a model of the new entrance.

Figure 2: 3D Model of Case Study. Model by Murdock Boyd Architects.

4.1 Scanned Model

Figures 3a and 3b below show the scanned as-built model results. These figures are screenshots of the Autodesk Recap files being opened and converted to Navisworks (.nwd) files. Figure 3a is an external view of the case study, and Figure 3b is an internal view of the D-Level showing the mass timber elements. These scans were taken on February 9, 2024.

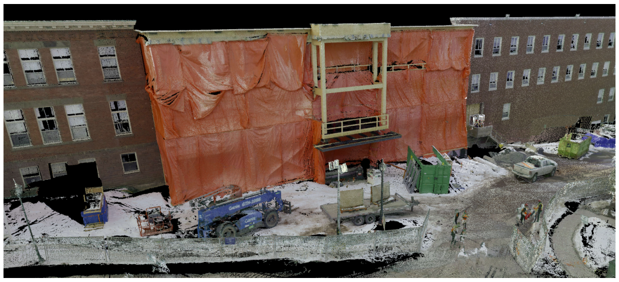

Figure 3a: External View of The Case Study

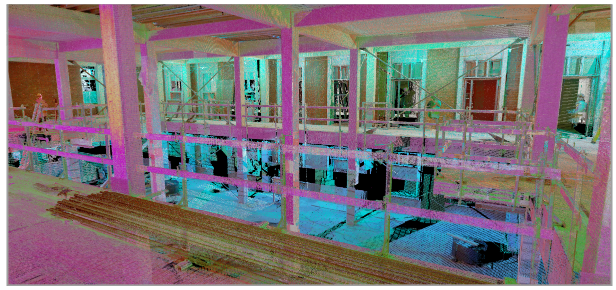

Figure 3b: Internal View on D-Level

4.2 Scan-vs.-BIM

Figure 4 shows B-Level scanned model aligned over the BIM 3D model. It shows how only a cubic section of the BIM model is being viewed. Limiting the two models over one another to a small section makes the model easier to work with.

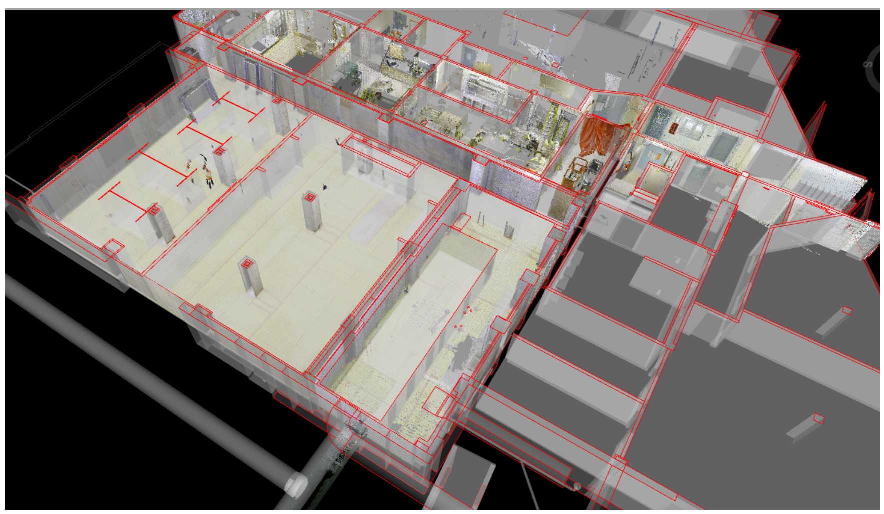

Figure 4: B-Level Scan Over BIM Model

Table 1 shows the elements that were not aligned when comparing the scanned and BIM models. It has the element's level, line location, and the distance the element was off in the X and Y directions. For the columns, whereas the mass timber columns are located on top of one another, the values in the x and y directions are for the C/ D/ E level. For measuring, elements that needed to be moved up or to the right are positive values and down or to the left are negative values. Examples of measuring are shown following Table 1.

Table 1: Scan vs BIM Model Results

Level	Line Location	Element	X-Direction (m)	Y-Direction (m)
B	7: 7.8 BB	Ductwork		
		Top Hole	0.454	0
		Bottom Hole	0.432	-0.088

B	4 BB	Piping	2.181	0.068
C/ D/ E	3.1 BB 3.1 AA 3.1 A.8 3.1 B.6 3.1 B.9	Columns	0.226/ 0.146/ 0.026 0.198/ 0.122/ 0.041 0.163/ 0.123/ 0.034 0.154/ 0.114/ 0.027 0.100/ 0.043/ 0.094	-0.073/ -0.024/ 0.023 -0.086/ -0.032/ 0.026 -0.098/ -0.038/ 0.049 -0.107/ -0.045/ 0.058 -0.098/ -0.018/ 0.090
C/ D/ E	4 BB 4 AA 4 A.8 4 B.6 4 B.9	Columns	0.184/ 0.117/ 0.029 0.164/ 0.104/ 0.009 0.152/ 0.103/ 0.010 0.113/ 0.098/ 0.007 0.070/ 0.029/ 0.087	-0.059/ -0.019/ 0.013 -0.068/ -0.024/ 0.044 -0.085/ -0.030/ 0.047 -0.092/ -0.039/ 0.045 0.080/ -0.006/ 0.087
C/ D/ E	5 BB 5 AA 5 A.8 5 B.6 5 B.9	Columns	- / 0.115/ - 0.134/ 0.090/ 0.015 0.139/ 0.098/ 0.009 0.087/ 0.078/ 0.020 0.042/ 0.012/ 0.084	- / 0.008/ - 0.045/ -0.010/ 0.054 0.058/ -0.004/ 0.053 0.076/ -0.028/ 0.054 0.061/ 0.006/ 0.077
C/ D/ E	6 BB 6 AA 6 A.8 6 B.6 6 B.9	Columns	0.0157/ 0.102/ - 0.108/ 0.097/ 0.011 0.120/ 0.070/ 0.011 0.060/ 0.067/ 0.020 0.023/ 0.001/ 0.057	0.040/ 0.016/ - 0.029/ 0.032/ 0.015 0.043/ 0.027/ 0.040 0.060/ -0.024/ 0.066 0.042/ 0.012/ 0.071
C/ D/ E	7 BB 7 AA 7 A.8 7 B.6 7 B.9	Columns	0.120/ 0.198/ 0.013 0.085/ 0.090/ 0.006 0.078/ 0.070/ 0.015 0.036/ 0.059/ 0.022 0.020/ 0.019/ 0.040	0.036/ 0.047/ -0.008 0.020/ 0.035/ -0.002 0.040/ -0.006/ 0.043 0.043/ -0.020/ 0.028 0.002/ 0.001/ 0.066
C/ D/ E	7.8 BB 7.8 AA 7.8 A.5 7.8 B 7.8 B.5 7.8 B.9	Columns	0.105/ 0.094/ 0.037 0.078/ 0.073/ 0.035 0.070/ 0.075/ 0.039 0.042/ 0.073/ 0.021 0.037/ 0.070/ 0.021 0.015/ - / -0.014	0.046/ 0.045/ 0.017 0.035/ 0.039/ 0.029 0.017/ 0.037/ 0.034 0.029/ 0.031/ 0.059 0.004/ 0.027/ 0.060 0.021/ - / 0.090
E	3.1 B.6: B.9	Piping	0.151	0.003

Figure 5a of the ductwork on B-Level shows the actual ductwork should be to the right and down to align with the planned model. Measuring the columns was done by comparing a point from the corner of the scanned model to the corner of the column in the BIM Model. This is shown in Figure 5b.

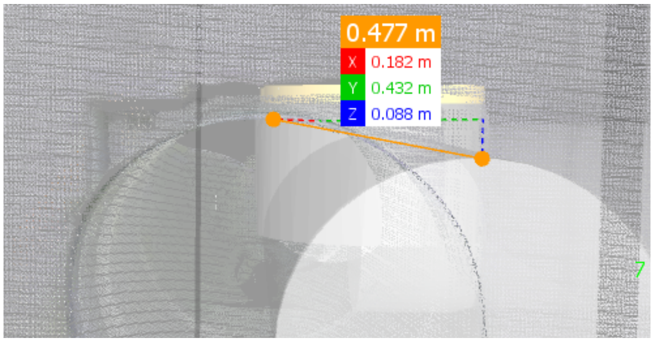

Figure 5a: Measuring Ductwork on B-Level

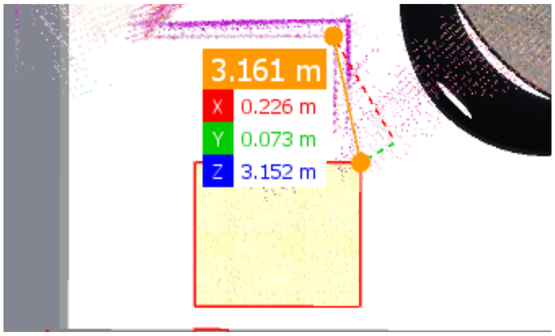

Figure 5b: Measuring Columns Example

The scanned and BIM models aligned well for comparing planned versus as-built analysis. There were just a few elements for level B. The first was the column sizes: the scanned model columns were larger than the BIM model. The reason for the difference in column sizes is that in the planned model, the columns were to be steel columns. This was then changed to concrete columns. Secondly, the piping layout online BB 4: in the BIM model, the piping ran under the slab, up the exterior of the wall (Line 4), and then connected into the Old Head Hall. However, in the scanned model, the piping came up through the slab, ran up the wall's interior (Line 4) and then through the wall to connect into Old Head Hall. When reviewing level C, it was determined that all the columns were out of alignment by varying degrees. The average difference for C-Level columns was 0.103 meters in the X direction and 0.002 in the Y direction. For D and E levels, the columns were off in the X direction by an average of 0.085 meters for D-Level and 0.030 meters for E-Level and in the Y direction, an average of -0.000 meters for D and 0.049 meters for E. Then, due to the mass timber column members being off to varying degrees, the detan rod bracing was also not aligned to varying degrees on each floor (C, D, and E). The degree of variation was unable to be measured due to the members being small and cylindrical. The Navisworks program could not ensure the correct member and point were selected, resulting in non-accurate reading. Besides the mass timber columns and the detan rod bracing, D-Level aligned very well with the planned model. Finally, the analysis for E-Level followed the same trend as C and D levels. For E-Level, the walls on this floor had not been built at the time of the scan and could not be analyzed. However, between lines B.6 and B.9 on line 3.1, a pipe came up through the slab and ran upwards: this was off primarily in the X direction. Besides some pipes, the mass timber columns, and the detan rods, everything else aligned between the two models.

4.3 Construction Progress Monitoring

Table 2 shows the status of the tasks that were to be completed prior to February 9 according to either the original or December updated schedule.

Table 2: Scan vs BIM Schedule Results

Task	Original Completion Date	Update Completion Date	Status
B-Level Slab	-	Dec 22/ 23	Not Completed
C-Level Slab	Oct 30/ 23	-	Completed
E-Level Topping Slab	-	Dec 21/ 23	Not Completed
D-Level Topping Slab	-	Jan 19/ 24	Not Completed
Mass Timber	-	Dec 15/ 23	Completed
Roof Parapets	-	Dec 19/ 23	-
Roofing	-	Jan 12/ 24	-
Skylight	Dec 22/ 23	-	In Progress
Curtain Wall	-	Jan 24/ 24	Not Completed
Sprinkler rough in	Feb 05/ 24	-	In Progress
Plumbing rough in	Feb 05/ 24	-	Completed
HVAC rough in	Feb 05/ 24	-	In Progress
Electrical rough in	Feb 05/ 24	-	In Progress

Comparing the schedule to the scan model showed that of the tasks that could be seen, 27 percent were completed. The rest of the tasks were either not completed or in progress. The remaining tasks could not have a status determined as the tasks were elements that were not captured through the scan, i.e., roofing elements. Some tasks still needed to be completed, including concrete work and curtain wall.

Table 3 shows the advantages and disadvantages of the process tasks explored through the case study. It also includes a column dedicated to the level of effort (LOE) and resources used to complete each task. The gross area of new space for the case study is 1880 square meters, of which 498 square meters was the new building area. The scan only captured the new building area; therefore, all LOE ratios used the 498 square meters. The analysis LOE was 37 hours. This allows for a ratio of 0.074 hr/m^2 (4.457 min/m^2). The capturing of the building would have a ratio of 0.010 hr/m^2 (0.602 min/m^2). The ratio for preparing and analyzing the scanning process was 0.016 hr/m^2 (0.963 min/m^2).

Table 3: Case Study Analysis Overview

Application	Element	LOE (Hr)	Resources	Advantage	Disadvantage
Scanning	Capturing	5	Leica Cyclone Field 360	Point cloud model can be viewed and linked on site.	Model become very messy when there is too many Setups.
	Prepare	6 (4 waiting on program)	Leica Cyclone Register	Preliminary modification can be finished easily.	The file needs about 2 hours to import and 2 hours to publish.
	Analysis	2	Leica Cyclone 3DR	Different categories of building (facade, furniture, piping) can be captured smartly.	It is hard to pick the right point when measuring.
Point Cloud to Navisworks	Organizing .rcs files	2	Navisworks	Limits and controls amount of scanned data viewable at once.	Files are too large to view in a single file without a point cloud online viewer.
	Converting .rcs files to .nwd file	1	Navisworks	Up to 22 .rcs files being converted into .nwd works well.	
Scan-vs.-BIM	Aligning	4	Navisworks – Sectioning Tool & Item Tool	Easy to move and rotate in Navisworks.	Small mouse movement results in large model movement and time consuming.
	Finding the Difference	4	Navisworks	Visually shows the difference between the models.	
	Measuring	10	Navisworks – Measure point-to-point function	Navisworks point-to-point measure tool allows for a good estimate between the models.	When zooming in the points from the scan become hard to view and are hard to select to get an accurate reading.
Construction Progress Monitoring	Schedule	3	Project Schedules & Navisworks	Visually shows what has been complete and what is needed to be completed.	Doesn't allow scan on non-level areas, i.e., roof elements for evaluation.

5 CONCLUSION

The purpose of this paper was to review the different applications of scan-to-BIM and determine the application that could be used for project management and project coordination. These applications were then explored on a case study to review how project managers and coordinators could implement scan-to-BIM. The applications of scan-to-BIM found were facility management, digital twins, digital assets, pre-construction scans, HBIM, scan-vs-BIM, inspections, and construction progress monitoring. The applications best suited for project managers and project coordinators are pre-construction scans, scan-vs-BIM, inspections, and construction progress monitoring. These applications benefit the construction process by visualizing site information and construction progress. Some scan-to-BIM applications require BIM implementation on the project. For example, scan-vs.-BIM must have an as-planned BIM model to compare the scan model to. This research helps in supporting BIM adoption by exploring other uses for the BIM model outside of the typical BIM clash detection used. The concept behind implementing scan-to-BIM into the project manager and coordinators' process to analyze the project throughout construction execution is beneficial. However, the execution of the process and analysis is very time-consuming. This research provided an LOE for the industry and researchers to understand the time-consuming nature of some process elements. However, the articles explored during the literature review did not provide information about the LOE in terms of time for the process used, and the data was unable to be compared to see if the scan-vs.-BIM process used for this research took more or less time than other methods. Alternatively, this paper provides an idea of the time required to adopt scan-to-BIM applications into the project management process if the project is of similar size to the case study analysis in this research. Additionally, this research shows a need to discuss LOE when implementing new construction processes. Finally, this paper adds another indoor case study of using 3D laser scanning to support the use of 3D laser scanning for other areas besides urban and outdoor projects. The case study used for this paper is an ongoing project, and the scans are dictated by how the project progresses. Due to this, the paper was limited to a single scan. However, additional scans could be presented. Future research in this field will be to do a full case study from pre-construction scan through to a completed as-built model of the project to see the full benefit of using scan-to-BIM through the project management and project coordination analysis process. Additionally, the analysis process of the case study was limited to a manual process in Navisworks. There may be alternative manual or automated processes of scan-vs.-BIM that would support the industry better. However, that was outside of the scope of this review. Future research could explore the time saved versus lost during collecting and analyzing the scan and comparative research examining the timelines for each scan-to-BIM analysis process to see which would add the most time to the construction timeline by adding scan-to-BIM analysis to a project.

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