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SMART 360-DEGREE PHOTOGRAPHY FOR ENHANCING CONSTRUCTION PROGRESS REPORTING

A Thesis Submitted to
The Department of Construction Engineering
in partial fulfillment of the requirements for the degree of
Master of Science in Construction Engineering

BY

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[2023]

Declaration of Authorship

I, [Ahmed Bahakim], declare that this thesis titled, "SMART 360-DEGREE PHOTOGRAPHY FOR ENHANCING CONSTRUCTION PROGRESS REPORTING" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
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Abstract

Periodical construction progress reports are essential in project evaluation and review. They impact stakeholder communication, transparency, and trust. While conventional pictures and videos (Captured Data) are currently the norm in supporting progress reporting, their use is not always efficient. As a result, 360-degree photography can now be integrated into progress reports using commercial products. However, there is a shortage of academic studies that actually assess the effectiveness of such tools. The goal of this research is to develop and test a user-friendly framework for progress reporting that integrates 360-degree photography.

The research started by collecting information from construction experts to determine the used methods of progress reporting and the level of utilization of 360-degree photography in the MENA region. Then, an innovative framework that integrates 360-degree photography was developed. To evaluate the effectiveness of the developed framework, a 3-month pilot study was conducted where the developed framework was utilized in three ongoing construction projects in Egypt.

After a thorough analysis of meeting, correspondence, and interview transcripts before, during, and after using the technology; the results indicate that the proper use of 360-degree photography in progress reports has a positive impact on the overall coordination, transparency, trust, and responsibility division between the project parties. The obstacles of utilizing such framework and recommendations on how to overcome them were also discussed so that future researchers can further improve the process of progress reporting.

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Special thanks also to the amiable assistance of Eng. Ayman El Hakea, System Development Manager, CRC Dorra, who provided permission to apply the framework in the New Giza University project and other residential projects. Further, I would like to thank Mr. Harun Al-Soufy who encouraged me to apply the framework to the Maddi Tower Project. And my thanks and gratitude to the Hadhramaut Foundation for Human Development for its moral and financial support throughout the period of my master's Studies, in particular, Sheikh Eng. Abdullah Ahmed Bugshan, Chairman of the Board of Trustees of Hadhramaut Foundation. I would also like to express my gratitude to the American University in Cairo (AUC), especially the construction engineering department, for providing funding and assistance through this work. Further, I would like to express my deepest love and gratitude to my parents, whose unconditional love, patience, and support have always helped me through life. Rest in peace with my last words to my deceased father, whom I shall never forget his words of support. Finally, I would like to thank all my amazing and caring friends who have given me tremendous support, encouragement, and inspiration during my studies.

Ahmed Khaled Bahakim

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List of Abbreviations

AoD: Angle of Departure

RFI: Request for Information

NCR: Non-Conformity Report

WIR: Work Inspection Request

MIR: Material Inspection Request

PQ: Performance Qualification

AEC: Architectural, Engineering, and Construction

QR: Quick Response

VR: Virtual reality

UAVs: Unmanned Aerial Vehicles

AR: Augmented Reality

BIM: Building Information modeling

HTML: Hypertext Markup Language

MENA: Middle East/North Africa

GC: The General Contractor

A/E: Architect/Engineer

CM: Construction Manager

KPIs: Key Performance Indicators

RADAR: Radio Detection and Ranging

LIDAR: Light Detection and Ranging

3DLS: Laser Scanning or Three-Dimensional Laser Scanning

AI: Artificial Intelligence

OAC: Owner-Architect-Contractor

CHAPTER 1: INTRODUCTION

1.1 Background

A construction progress report is a report prepared periodically by contractors and project managers to inform employers of project progress and lay out plans for sharing projects in future stages (Gardiner, 2019). It contains many details such as a detailed evaluation of construction progress to date in comparison with the project plans (with explanations of issue such as delays, if any), a detailed description of any material problems (such as, but not limited to, use wrong material of pipe), and a statement of expected delivery dates for project tasks, along with ensuring the effectiveness of the project schedule (Saad, 2022). One reason for developing and issuing construction progress reports is progress monitoring; where stakeholders involved in the project regularly assess the progress status and understand how the project is performing throughout the process. It is ineffective to wait until the project is in an advanced stage to find out that the project cannot be completed on time. Regular alerts and progress updates are necessary as they identify issues in development and schedule corrective actions quickly. Consequently, this may include identifying causes of delay, managing the risk, and developing recovery plans. Another reason for progress reporting is contractual requirements; where contemporary contracts include requirements such as Project Logs (Shop Drawings, Material Submittal, Request for Information (RFI), Non-Conformity Report (NCR), Work Inspection Request (WIR), Material Inspection Request (MIR), Performance Qualification (PQ), Progress curves, or Site Photographs. All these requirements may differ from one project to another (Saad, 2022).

Reporting on construction project progress takes time and impacts the communication process, which is critical to speed up decision-making. Therefore, progress reports should be

clear and understandable as accurately as possible to avoid obstacles or conflicts (Calis, 2021). Reports often have many uncertainties and different points of view in the construction field. Hence, they are enhanced with pictures to increase the credibility and transparency of the report.

Construction reports include many pages of captured data, such as conventional pictures; however, they do not cover the full details of the site (Ellis, 2021). While photos and videos are now in heavy use to enhance and support progress reporting, many construction companies still face issues with using job site photos, such as: firstly, the turnaround is slow, which means it takes time to attach job site photos to progress reports, so stakeholders often don't receive them that day (or that week) (Ellis, 2021). While waiting, the photos quickly become outdated and do not accurately reflect the job site. Secondly, full coverage using regular pictures wastes time and effort because for example, covering a room from each side requires more than six regular photos instead of one 360-degree photo. Finally, it is not easy to locate the image in site layouts.

Currently, some 360-degree photography software applications are highly used for summarizing construction project reports and managing site photos, especially in the US, such as HoloBuilder, StructionSite, Reconstruct, VisualPlan, CUPIX, OpenSpace OnSiteIQ, and ContextVR (Ellis, 2021). The main components of the app are 360-degree cameras and cloud-based software, and its goal is to create and share 360-degree views of construction sites and buildings. The mechanics of the app are the same as VR apps, requiring internet access to upload data, such as VR tours that can be found on Google Maps Tours. These applications are considered to be the solution to many problems in the field of construction management such as: (a) using a laptop or smartphone for taking a tour of the project site, (b) organizing and comparing the captured data side by side as past and actual photos, (c) minimizing risk and eliminating costly rework, (d) increasing the collaboration between project team members and

between the field and the office (Behzadi, 2016)

1.2 Problem Statement

Several marketing campaigns led by the developers of 360-photography applications highly recommend using such applications in construction progress reporting (Ellis, 2021). However, those applications are still relatively costly, and their advantages are not validated by academic literature. Additionally, a survey conducted by researchers in three Middle Eastern countries, namely Yemen, Saudi Arabia, and Egypt, revealed a lack of knowledge about and use of 360-degree photography in construction progress reporting in the Middle East and North Africa (MENA) region. Therefore, there is a need to develop an affordable user-friendly method for integrating 360-degree photography in construction progress reports in the MENA region and study its effectiveness.

1.3 Research Goal

The goal of this research is to develop and test a user-friendly framework for progress reporting that integrates 360-degree photography. To this end, the following objectives were established:

1. Develop a smart framework that enhances progress reporting and takes advantage of 360-degree photography.
2. Study the effectiveness of using this framework in progress reports throughout testing it in real projects.
3. Provide guidance for professional users and future researchers on the use of 360-degree photography in progress reports based on lessons learned from this study.

1.4 Research Methodology

The research methodology is as follows: First, a comprehensive literature review is conducted to identify gaps in different techniques for using captured data in construction management to enhance progress reporting. Such comprehensive literature review shows the extent to which 360° photography applications are highly involved in the construction industry, real estate, and collaborations with academic research. Secondly, a smart user-friendly progress report framework is developed using currently available 360-degree photography technology. Thirdly, the framework is tested on three real projects to verify the output. Finally, lessons learned from the role of 360-degree photography in enhancing progress reporting are presented for use in future research. The methodology used in this research is summarized in figure 1:

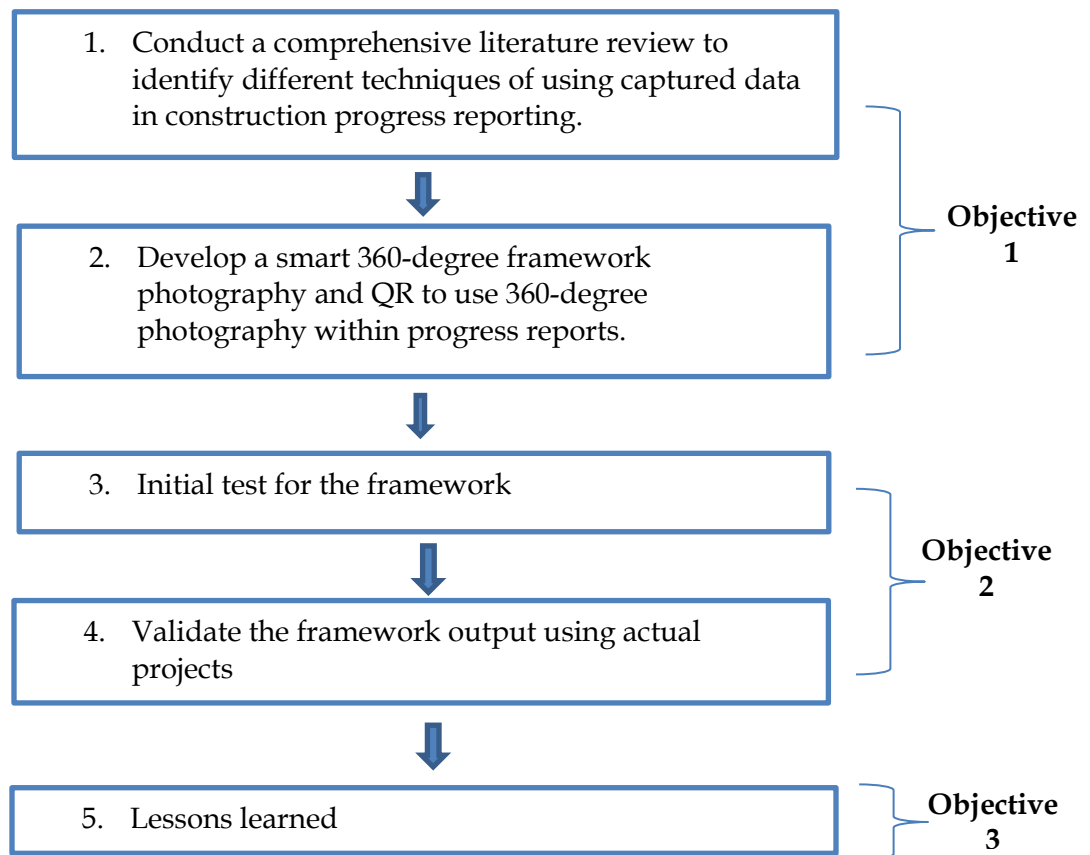


Figure 1: Research Methodology

1.5 Thesis Structure

This thesis report contains six chapters as follows:

CHAPTER 1: INTRODUCTION

This chapter provides a brief introduction to progress reporting in the construction industry and the role of 360-degree photography and its application in developing construction management. It also includes the problem statement, research objectives, and methodology used.

CHAPTER 2: LITERATURE REVIEW

This chapter discusses the literature review supported by academic case studies. It also focuses on relevant definitions, the benefits of using captured data in the construction industry, and approaches to QR applications and hyperlinks. In addition, it examines the reasons why some new technologies such as 360-degree imaging in reports are preferred to laser scanning.

CHAPTER 3: INVESTIGATING THE VISUALIZATION PRACTICES IN PROGRESS REPORTS IN THE MENA REGION

This chapter focuses on the stakeholder's awareness and impressions of using 360-degree photography technology in progress reports in the MENA region (Egypt, the Kingdom of Saudi Arabia, and Yemen). So, the main purpose is to create a clear view of the current captured data in reports in these countries and to what extent 360-degree photography and its applications can involve in progress reports.

CHAPTER 4: DEVELOPING AND TESTING THE REPORTING FRAMEWORK

This chapter focuses on different techniques for enhancing the framework for progress reports using 360-degree photos, and in the same way simulates the purpose of commercial applications such as HoloBuilder or Openspace. Besides, there is a mention of how the framework is built; in addition to explaining the reasons for choosing several techniques such as QR in the framework.

CHAPTER 5: DISCUSSION:

In this chapter, the researcher discusses the observations through eight comparison criteria using actual project sites to validate the framework's effectiveness. Further, the output is compared to the claims of contractors, engineers, owners, and the researcher's reflections are highlighted. Then, it concludes with some advantages and limitations.

CHAPTER 6: CONCLUSION:

This chapter contains the research's main conclusions as well as provides expected and promised results for future research areas.

CHAPTER 2: LITERATURE REVIEW

This chapter begins by discussing the rapid development of panoramic photography through several case studies and applications that use captured data, such as photos and videos, to enhance the construction industry. Second, comes an introduction to the development and activation of QR technology in some construction applications. The discussion is then geared to the role of the 360-degree photography application in construction management and the available research in literature tackling this point.

2.1 Current Panoramic Photography and Applications

Videos and photos can be used as documentary evidence of actual progress reporting at a specific time. Supporting photos by date, location, and notes of a project are highly recommended (Parry, 2009). With the development of technology and the integration of cameras into the monitoring and follow-up process, it has become easy to track workflow and present transparent progress reporting. Many researchers have investigated using cameras in monitoring construction sites, such as the research conducted on the benefits of using the application of camera-equipped Unmanned Aerial Vehicles (UAVs) to control the collection, analysis, visualization, and communication of the visual data captured of projects (Bohn &Teizer, 2010). Another example is the use of surveillance cameras for analyzing tower crane operations throughout a workday to monitor construction activities (Yang et al., 2014).

In recent years, the use of 360-degree cameras has appeared in many domains, including education, tourism, and entertainment, in addition to the recent use in the construction field. For example, the use of 360-degree cameras has the ability to record detailed 360-degree videos to enrich tours on the project site (Wehking et al., 2019). The use of a 360-degree camera and virtual reality technology allows students in earth science classes to be more inclusive. This

method has been implemented in three high schools and shows an improvement in student learning by 22-28% (Jitmahantakul & Chenrai, 2019). Another case study in Malaysia; where 360-degree technology were used to developing and evaluating tourist destinations in selected areas, found positive results of the 360-degree technology in driving users to visit these destinations (Osman et al., 2009). A similar study was conducted in Indonesia and correlations between the 360-degree technology and positive impact on tourism was found (Adriyanto et al., 2015).

In real estate, 360-degree photography is used and integrated in online websites and applications to enable buyers to better visualize the displayed units. This was proven to increase the confidence of the buyers and drive up the sales (Felli et al., 2018). Another paper presents and explains Matterport, which is a software that uses 360-degree photos as a new platform for marketing that aims at helping real estate businesses survive during the COVID-19 pandemic (Sulaiman et al., 2020), as shown in figure 2.



Figure 2: Matterport 3D Virtual Tour (Matterport, 2022a)

Matterport is a 3D data platform that can create virtual tours by using different types of compatible devices such as Matterport Pro2 3D camera, Matterport Pro2 Lite 3D camera, Matterport Pro 3D Camera, Insta360 ONE X, Insta360 ONE R, Insta360 ONE X2, and Ricoh Theta Z1 (Matterport, 2022b). The Matterport platform has been widely utilized in a variety of industries, such as architectural and archaeological conservation research (Karnicki, 2020). Also, Leica BLK2GO and Matterport are used to survey and map a 3D narrow space which is in high demand for many applications (Piniotis et al., 2020).

Referring to (Sulaiman et al., 2020) study, Table 1 summarizes the differences between traditional approaches (site visit, digital photography, 2D video presentation, drone photo & video) and Matterport (virtual tour). Overall, the Matterport application has proven its merit in improving the real estate field.

Table 1: Comparison between the conventional approaches with the Matterport in real estate

(Sulaiman et al., 2020)

Themes	Conventional (Site Visit, Digital Photography, 2D Video Slideshow, Drone Photo & Video)	Matterport (Virtual Tour)
Accessibility	<ul style="list-style-type: none"> • Costly (equipment) • Limited time (site visit) 	<ul style="list-style-type: none"> • Mobile friendly • Social sharable • 24 hours
Visual Capture	<ul style="list-style-type: none"> • Limited for interior or exterior (drone) 	<ul style="list-style-type: none"> • Easy to DIY • Interior & Exterior
Details Information	<ul style="list-style-type: none"> • Limited information 	<ul style="list-style-type: none"> • Measurements • Labelling
Visual Experience	<ul style="list-style-type: none"> • Limited viewpoint 	<ul style="list-style-type: none"> • Self-tour • Maximum reality

2.2 Integration of Early Computer Technology in Construction Reporting

Several studies contributed to developing construction progress reports through computer applications and automated processes. For example, (Schoenbauer & Bognar, 1999) developed a system to manage multi companies and manage the construction process . Usually, these types of companies have many subcontractors with various levels of project management. The system aimed to highlight the main objectives of the project in reporting, such as scope definition, scheduling, estimating, and performance reporting.

Moreover, the research (Lampthey & Fayek, 2012) establishes a method by which reports can be summarized through a dashboard with a visual interface that acts as a medium of communication for reporting project status at-a-glance using key performance indicators (KPIs) that are important to the project's success. This helped to reduce the report pages within a schedule by using alerts like red (▼), indicating bad performance, and green (▲) indicating good performance; these alerts are based on threshold boundaries set by each company. This method also helps develop the company's decision-making by identifying the process trend, whether red or green. The report output quickly reveals trends in project activity, allowing to spend more time studying data and less time searching for information.

When it comes to QR codes, there are currently many case studies in the literature of using QR as a tool to convert paperwork into electronic form and to use Building Information Model (BIM) and Augmented Reality (AR) on mobile phone screens (Zaki& Khalil, 2015). This unique step inspired attaching 360-degree photos that cannot be printed in 2D paper reports.

2.2.1 Introduction of QR in Reporting (Case Studies)

A barcode is a code that contains information in the form of horizontal parallel lines with different thicknesses and gaps. Accordingly, it can be said that barcodes present data in one

direction. On the contrary, a QR – short for quick response - code contains information both horizontally and vertically. As a result, the QR code can carry over a hundred times more data than that carried by barcodes (Govtech, 2020). Hence QR code is an innovative technology and process that is shifting paper dealing and documentation to virtual data and information documentation. QR codes are black squares arranged in a square grid with white background and fiducial markers (such as three small squares with a specific ratio of black-to-white areas as shown in figure 3).



Figure 3: QR Codes Anchoring by Squares in the Corner - 360-degree Photo -New Giza University Project

2.2.2 Using QR Codes in Construction Reporting

QR codes can be used in many ways to reduce efforts, but many construction engineers are still unfamiliar with the technology (Ozkaya et al., 2015). Therefore, motivational reasons are needed to teach target users how to use QR codes and their benefits in construction (Dinnie, 2011)

There are several suggestions for using QR that can benefit the Architecture, Engineering, and Construction (AEC) industry. For example:

- It was suggested that integrating BIM with QR-codes interaction on a construction site

can be used to keep track of the movement of staff, machines, as well as the stages of the building process (Vasilyev et al., 2020). This study is based on the significant increase in the use of smartphones in the past decade, which will make it easier to read QR codes. Implementation of such a technique brings improvement in parties' communication at different levels as well as increases in decision-making quality.

- For additional information in drawings, (Nerd, 2012) suggested on adding the QR code in the layout of the architectural drawing, as is shown in figure 4, which enables adding more information and details such as the project site on Google Maps, information about the engineering office, and pictures of the layout.



Figure 4: QR Code on Blueprint to Add More Information (Rizwan, 2017)

- Procore's Location QR Codes function to print and put a QR code on each room to identify the required activities in each room or place (Koenen, 2021b). The QR code indicates the required activities such as painting the wall, the method of use, and some required details in the room such as the color and type of paint. When a stakeholder scans the code, he/she is able to find a list of activities or other descriptions as shown in figure 5.



Figure 5: QR Codes on the Wall to Describe the Required Activities on the Room (Koenen, 2021)

- Another application of QR codes in construction is assisting in equipment management (Gocodes, 2020). The project site has many contractors and subcontractors working on the same job site with different types of equipment. This may cause theft or accidental misuse as most of the equipment are rented or located in remote locations and it is difficult to identify their owner. But by attaching QR codes to every piece of equipment, any construction worker can scan the QR code using his or her smartphone to identify the owner, get more information and easily classify in warehouses.
- Equipment maintenance can be tracked by using QR codes (Gocodes, 2020). This method can determine the appropriate time to replace equipment that improves the regular maintenance schedule. First, QR code tags are attached to each piece of any equipment or vehicle, such as trucks and cranes. This code specifies the requirements for each piece of equipment and the time required to start maintenance.

2.2.3 Comparison of Different Techniques for Capturing Pictures in Construction

Captured data clarify the report data and may reduce several reports to one page. There are several options for enhancing reports using digital cameras. For example, a 360° image shows an entire room from ceiling to floor and all surrounded walls. On another hand, Laser scanning or three-dimensional laser scanning (3DLS) is a modern technique that uses light detection and ranging (LIDAR) to create accurate 3D images. It is similar to radio detection and ranging (RADAR), except instead of using radio waves, it employs light to determine range or distance (Su et al., 2006). Despite the development of laser scanning technology in creating as-built, the 360-degree panoramic image has become a competitive tool that may serve the same purpose in the future quickly and inexpensively. Additionally, extensive research (Lerma et al., 2010) was conducted to clarify the difference in time, cost, and error in creating point cloud data using 360° panoramic photogrammetry and laser scanning techniques:

The first result of the discussion is the time spent on data capturing and processing. Although the processing time for the two procedures is not considerably different (60 minutes for Laser Scanning vs. 40 minutes for 360 Panoramic Photogrammetry), the data capture time for Laser Scanning is more than seven times slower than taking 360 panoramas on the site Table 2.

Table 2: Time Spent (in minutes) in Laser Scanning VS 360 Panoramic Photogrammetry (Lerma et al., 2010)

	Laser Scanning	360 Panoramic Photogrammetry
Data Capturing Time:	75 sec	10 sec
Data Processing Time:	60 sec	40 sec
Total Time:	135 sec	50 sec

The second main comparison is the cost like a high-quality laser scanner costs around \$40,000 to \$65,000 (Cropp, 2021). By comparison, a 360 panoramic photogrammetry camera costs about \$500 (Subramanian &Gheisari, 2019). This significant difference gives 360-degree

photography an edge over laser scanning in capturing pictures, especially that the extremely high accuracy is not needed when the function is just to observe progress.

Third, quality, which is the percentage of measurement error when comparing the actual site with data captured from 360 panoramic photogrammetry or laser scans. It can be calculated by the following formula:

$$\text{Percentage of Error} = \frac{\text{Point Cloud Measure Value} - \text{Onsite Tape Measure Value}}{\text{Onsite Tape Measure Value}} \times 100\%$$

Subramanian and Gheisari (2019) took measurement of ten random items in construction sites once from 360-degree picture and once from a laser scanner and compared the measurements to the true measurements on site, as can be seen in figure 6. The results in Table 3 show that the average error of panoramic photogrammetry is about 5-6%, while the measurement error of laser scanning is about 2%.

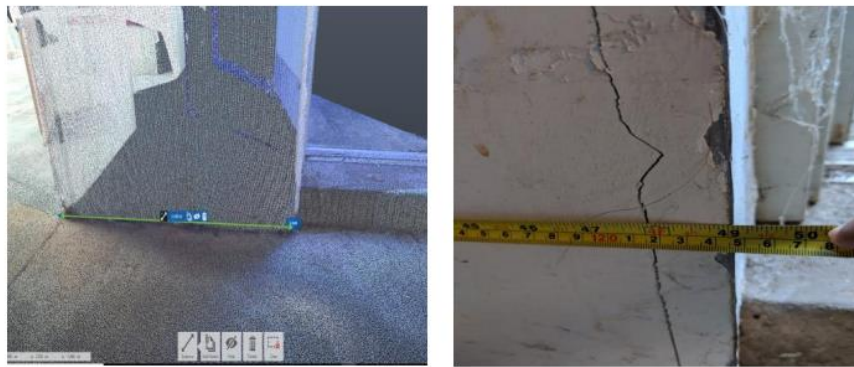


Figure 6: An Example of Measurement from Recap Pro and Onsite Tape Measure

Table 3: Percentage of Error for 360 Photogrammetry and Laser Scanning Techniques (Subramanian & Gheisari, 2019)

#	Description	Onsite Tape Measure Value (Ft.)	Point Cloud Measure (360 Photogrammetry) Value (Ft.)	Point Cloud Measure (Laser Scanning)	360 Photogrammetry % Error	Laser Scanning % Error
1	Wall (Width)	4.15	4.26	4.07	2.65	1.93
2	Column Flange	0.81	0.72	0.79	11.11	2.46

3	Column Web	1.00	0.89	0.96	11.00	4.0
4	Electrical Box (Length)	2.05	1.93	2.02	5.85	1.46
5	Mech Duct (Width)	2.50	2.46	2.49	1.60	0.40
6	Exit Signage (Length)	1.40	1.50	1.34	7.14	4.28
7	Door (Width)	3.50	3.38	3.57	3.43	2.00
8	VFD Box (Width)	0.11	0.10	0.11	9.09	0.00
9	Pipe Fitting	1.00	0.98	0.99	2.00	1.00
10	Air Duct (Width)	2.4	2.35	2.4	2.08	0.00
				Average	5.60	1.753

Although 360-degree Photogrammetry produces point clouds with a higher percentage of error than laser scanning, it may still be a suitable method for situations where a lower degree of accuracy is needed. Additionally, it has shown that the difference in cost is significant and high; laser scanning is ten times higher than a 360-degree camera. Finally, the time spent in capturing data using 360 panoramic photogrammetry is less than that of laser scanning. Since the extremely high accuracy is not needed when the function is just to observe progress, it is concluded that 360-degree photogrammetry is more appropriate than laser scanning in progress reporting.

2.3 Current 360-degree Applications in Construction Progress Reporting

Building a proper database of site pictures to monitor progress requires taking pictures of different locations and items that change and progress over time. Therefore, a complete construction site requires a large number of pictures (generally more than five per room), and even then, it is not efficient to capture every corner of the room (Hedmond, 2017). As shown in

Figure 7, example of arranging several pictures of a project site by saving them in different fields by date or location. This method usually leads to the creation of many complex and difficult-to-use files.

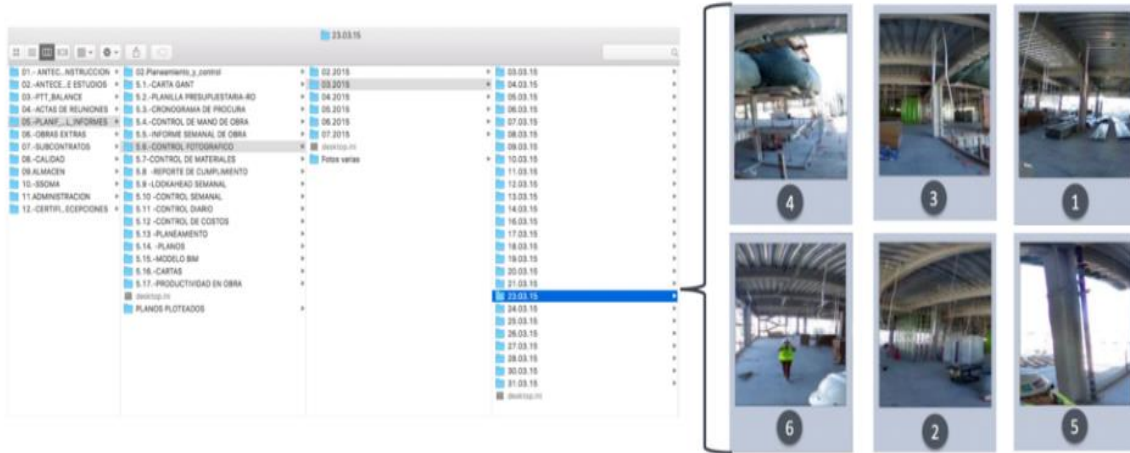


Figure 7: Showing the Common Method of Saving and Organizing Capture Data

There are several software applications that can be used in integrating 360-degree photography in construction management, such as HoloBuilder, StructionSite, Reconstruct, VisualPlan, CUPIX, OpenSpace OnSiteIQ, and ContextVR. They have different tools and techniques, but the standard process is capturing with a 360° camera; then, the photos are mapped to plans and viewed interactively. Figure 8 shows how the 360° application concept works in construction progress reporting. The first step is using 360° cameras to capture photos; some assisted tools are recommended, like a stand or selfie stick. In the second step, 360° photos are uploaded into the online cloud by an application like OpenSpace or Holobuilder. In the last step, the 360° photos are shared between stakeholders as virtual tours that allow them to monitor and control the site remotely, like adding comments and comparing the site now and before the period.

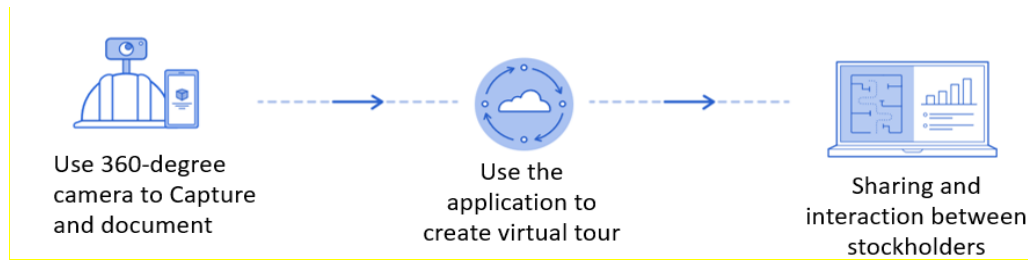


Figure 8: Explain the Methodology of Using the Application (OpenSpace, 2022)

These applications offer time savings, complete documentation, cost reduction, and better collaboration. Moreover, there are several ways to prepare a virtual tour for project sites using a 360-degree camera application. For example, 360-panoramic pictures are taken from different places or rooms and later uploaded in an application manually like Matterport. But This method in Matterport is usually easy to use for real estate purposes because it does not need to be repeated many times. Another method, as is seen in figure 9, is to install a 360-degree camera on a helmet while visiting the site, and the camera uses artificial intelligence (AI) to automatically take many 360 panoramic pictures to create a virtual tour (VT) for the site. This method which is used by OpenSpace and Holobuilder is suitable for monitoring and control purposes.

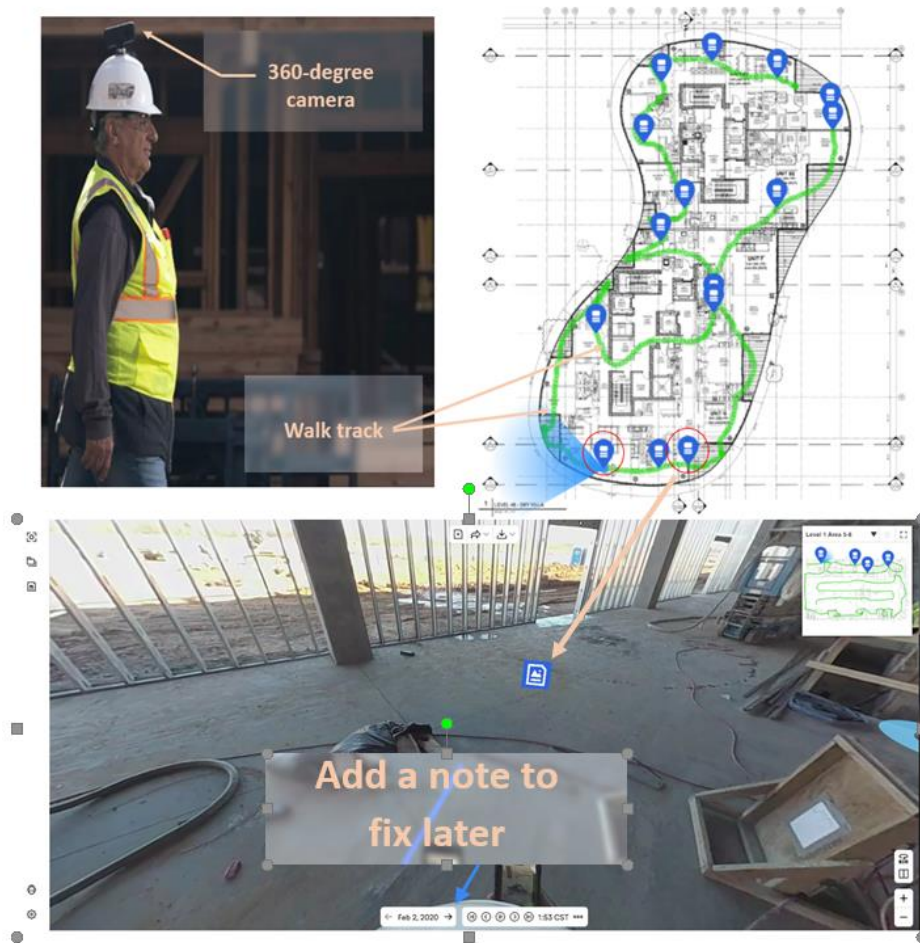


Figure 9: Illustration of Integrating a 360-degree Camera in the Application to Create a Virtual Tour

A limited number of studies focuses on the use of 360-degree cameras in engineering applications. For example, the study of (Afsari et al., 2021) used the Holobuilder application with the Four-Legged Robot to capture site photos. A 360° camera called Ricoh Theta V is connected to the mobile device that runs the JobWalk App with 2D floor plans. The objective was to automate building progress monitoring and learn about the benefits and drawbacks of using this process. The discussion in that study presented some opportunities for automating construction progress monitoring by integrating a 360-degree camera with the Holobuilder application during automated image capture. Such study showed the possibility of decreasing time and labor in the data collection process.

As there is a shortage of academic studies investigating the effectiveness of 360-photography in progress reporting, companies that develop 360-photography software and construction virtual reality software are the key providers of information on such effectiveness from a marketing perspective. For example, OpenSpace app is a 360-degree construction photo documentation software. It aims to minimize travel time and cost, resolve conflicts, and reduce risk using 360-degree photography. To illustrate; Provident General Contractors, a full-service contracting firm based out of Dallas, had struggled with collecting and managing store Jobsite photos documentation. Therefore, it started to test the OpenSpce app on a residential project in Tulsa, Okla., with 300,000-square-foot. Then the research finds that using the application to document the construction site is ten times faster than manual capture and provides an integrated view of the site from all directions (OpenSpace, 2019).

Another research is in CEC company that used OpenSpace to improve communication with general contractors (Irving et al., 2020). CEC has established itself as one of Texas' most reputable and largest subcontracting companies. With over 500 dedicated employees, it is an innovative specialty provider of electrical, mechanical, controls, technology, and facilities services (Dallas Commercial Construction | CEC Facilities Group, 2020). The results state that using the application put CEC company in a solid position to defend against project delay allegations due to the high accuracy and completeness of the documentation.

Another company called lee Kennedy construction company highly recommends the OpenSpace application as a tool to arrange and locate captured data (OpenSpace, 2021). The company has a problem determining the image on the reality in projects with large areas, where they usually put a mark or spray on the wall while the photo is shooting. Even so, many of the images were hard to locate in reality. Using OpenSpace as an alternative to specifying the

location of the image is significant in improving collaboration in OAC (Owner-Architect-Contractor) meetings.

Additionally, OpenSpace announced the launch of a new integration with BIM 360, which would help construction teams speed up RFI and QA/QC procedures. As seen in figure10, images captured using OpenSpace's cutting-edge AI technology can now be automatically mapped to BIM 360 project plans. Visual references and accurate locations may be immediately connected to BIM 360 RFIs and Issues, reducing ambiguity and facilitating stakeholder collaboration. OpenSpace images may also be linked to punch lists and make project management more efficient.

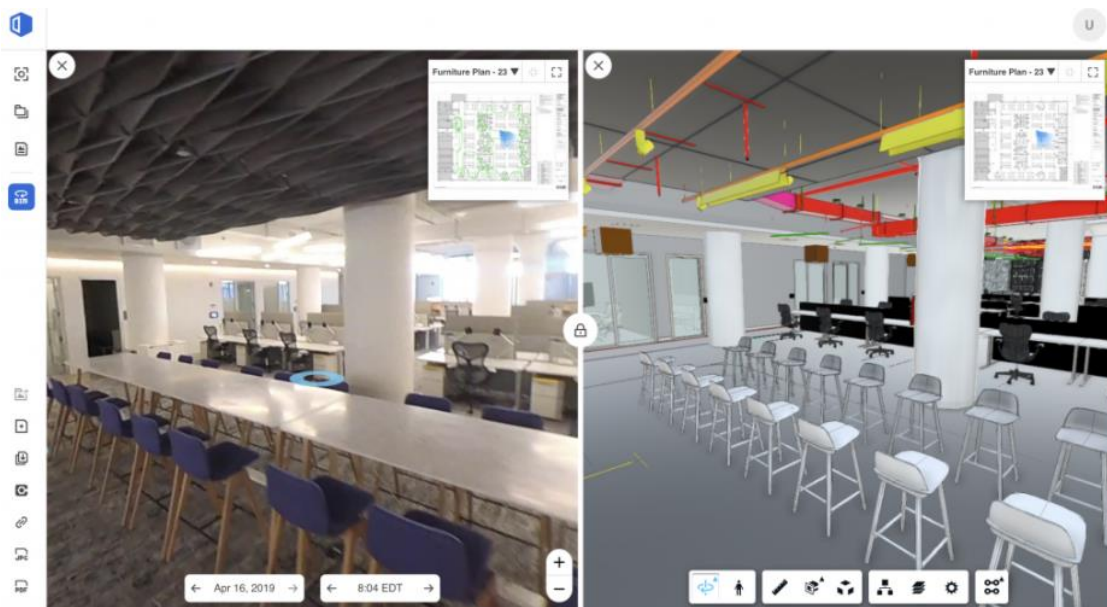


Figure 10: Interface of OpenSpace with Integrating BIM Side-by-Side

2.4 Chapter summary

This chapter highlighted the significant role of photography in the construction field. It presented several case studies that illustrate the involvement of photography technologies in different construction sectors, such as monitoring and controlling and real estate. There was then the focus

of the 360-degree construction visual experience by developing fast 360-degree photography using an app like Matterport. Moreover, the literature review clarified the significant role that QR and 360-degree photographs performance in construction. Many companies and start-ups have been working to take these ideas in real projects. In addition, this section discussed different types of 360-degree cameras and investigated the differences between using 360-degree cameras and laser scanning as tools in construction photography. It also presented some commercial applications that work on developing construction progress reporting by using 360-degree cameras such as Holobuilder or OpenSpace.

Research gaps in the literature revolved around the software of 360-degree cameras. Though the wild existence of companies and software packages for incorporating 360-degree cameras into progress reports, such as HoloBuilder, StructureSite, Reconstruct, VisualPlan, CUIX, OpenSpace, OnSiteIQ, and ContextVR, these software packages are still expensive and unavailable in the MENA region. Furthermore, they are marketed by industry, but their benefits have yet to be validated by academic publications.

CHAPTER 3: INVESTIGATING THE VISUALIZATION PRACTICES IN PROGRESS REPORTS IN THE MENA REGION



An investigation has been conducted to measure the construction market's level of using 360-degree photography technology in progress reports in Egypt, the Kingdom of Saudi Arabia, and Yemen as a sample representing the MENA region. A questionnaire has been developed to create a clear view of the current captured data in progress reports in the MENA region before applying the framework, which is Smart 360-degree photography for enhancing construction progress reporting and to what extent they will accept it.

3.1 Investigating 360-degree Photography Technology on Construction Sites in the MENA Region

This general survey consists of four sections as follows: the first section is a short biography of the respondents, such as years of experience, job title, and country of employment (figure 11-a). The second section covers the used methods and the best data capturing tools to consider. It also addresses the importance of data capturing in the construction industry (figure 11-b). While the third section is all about the rate of respondents' knowledge and awareness of using 360-degree cameras and their application in the construction industry (figure 11-c). The fourth section is about responses' expectations for incorporating this technology to enhance construction management in several aspects, such as saving time, effort and cost, resolving disputes, following-up the workflow, improving collaboration, increasing productivity, and reducing errors (figure 11-d).

General survey

Biography of the respondents

 ahmedbahakim@aucegypt.edu (not shared) [Switch account](#) 

Name

Your answer _____

Job title

Your answer _____

Years of experience

Your answer _____

Country of employment

Your answer _____

Figure 11-a: First Section

The method currently used and popular tools for capturing data

What tool do you use to document the site or project: (whether images or video)

Phone camera

Normal camera

Professional Camera

Other: _____

Are the pictures taken of the project useful to you in following up the workflow and making reports?

	Always	Often	Sometimes	Rarely	don't use
Daily	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
weekly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Monthly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Annual	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 11-b: Second Section

Awareness of using 360-degree cameras and their application in the construction industry

Do you know about using the 360-degree photography technology in construction site?

Yes

No

Maybe

Do you know about using virtual tour or virtual walkthrough in construction site?

Yes

No

Maybe

Figure 11-c: Third Section

Expectations and opinions of the participants

Expectations for incorporating this technology to enhance construction management in several respects

Do you think the transition from normal photography technology to 360-degree photography will help in construction reporting?

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Saving time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effort saving	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost saving	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Resolving disputes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Following up the workflow	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving collaboration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increasing productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reducing errors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 11-d: Fourth Section

Figure 11: General Survey

3.2 Data Collection

The questionnaire focuses on construction companies in Egypt, Yemen, and the Kingdom of Saudi Arabia. It also aims to receive a clear indicator of acceptance and knowledge level using 360-degree photography technology on construction sites in the MENA region. 56 out of 80 questionnaires that have been sent out were completed. A pilot test is conducted in section one to ensure the clarity and accuracy of the questionnaire. Figure 12 shows basic information for 56 respondents; There are 26 responses from Egypt, 16 from KSA, and 14 from Yemen. Employee's country, company name and field, job title, and years of experience are considered. For instance, the average response experience in the construction field is around seven years. And the composition of the respondents, whether they are contractors, engineers, or owners, is described in figure (12-B). In this survey, the observations show that stakeholders effectively use images in each daily, monthly, or yearly report by phone camera. On the contrary, new technology, such as 360-degree cameras, is not well known, and the lack of knowledge is high. Which inspire researchers to implement such this technology and measure the effectiveness

**PERCENTAGE OF PARTICIPANTS
FROM EACH COUNTRY**

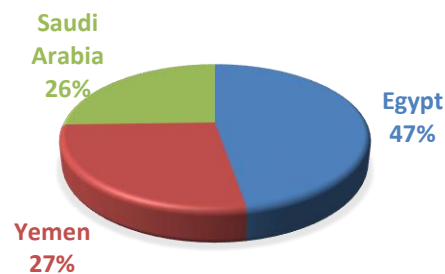


Figure 12-A

Composition of the Respondents

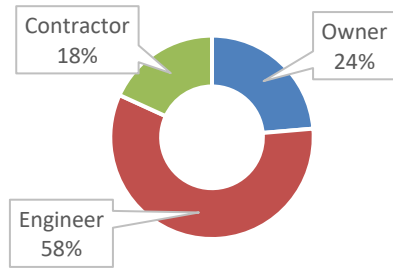


Figure 12-B

Experience in the Construction Industry

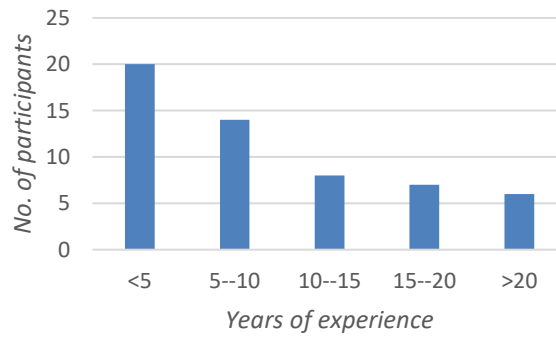


Figure 12-C

Figure 12: Basic Information of Respondents Before Applying the Framework (General Survey)

3.3 Observations and Findings

Numerous indications are found using survey responses and site monitoring. For instance, figure 13 (bar chart) shows that phone cameras are the most widely used device for photography on construction sites.

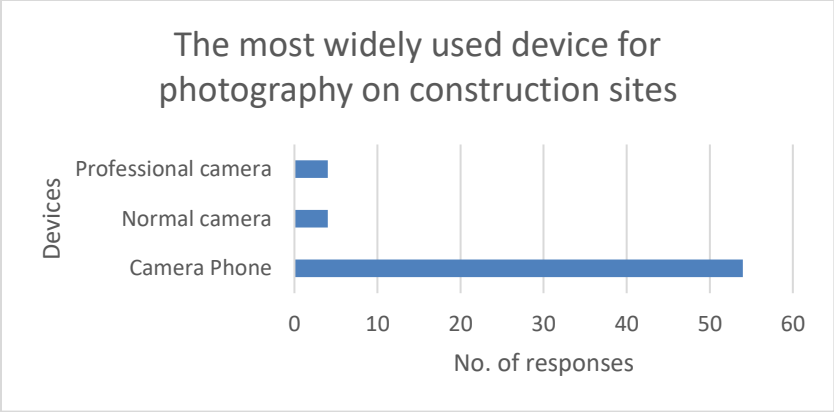


Figure 13: General Survey Results to Identify Cameras Used on Construction Sites

The next question clarifies the importance of images in enhancing the progress reports, whether the time period is daily, monthly, or yearly. The bar charts (Figure 14) provide indicators of what extent stakeholders agree on using images generally to enhance progress reports. Most participants in the survey strongly agree with the importance of images to enhance daily, weekly, monthly, and yearly progress reports.

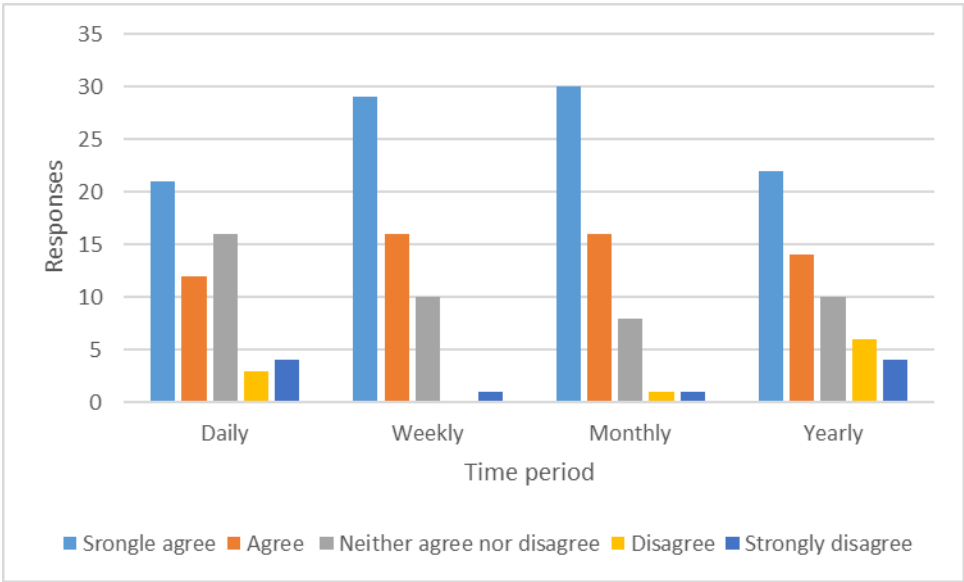


Figure 14: Importance of Images in Enhancing Progress Reports

Obviously, construction photography, in all its forms, can have significant benefits for construction projects of any size during and after the project. This is also confirmed by some of the comments made by the survey respondents about the 360-degree imaging technology as follows: *“Construction photography creates essential visual documentation and instills credibility and transparency between the stakeholders”*. Another respondent said: *“An effective photographic documentation report is a guide to documenting what happens at the site”*. On the other hand, there are many comments about the obstacles of using phone photos as follows: *“showing a whole room requires at least more than six photos, reports cannot include many pages of photos when the project is big, and there is difficulty locating the photo in a multi-story project”*.

Figure 15 shows the stakeholders' knowledge of 360-degree photography technology in construction sites and its applications (virtual tour). Overall, the result indicates that 89% of the respondents know nothing about the 360-degree camera or its uses in construction. The same thing with virtual tours, where 71% of respondents say they do not know about this technology. So, the lack of knowledge proportion is high compared with those who know about using 360-degree photography in construction. These findings provide a strong point of departure for the research in hand to implement this technology and test its effectiveness.

Responses about the knowledge level of 360-degree photography technology in construction site

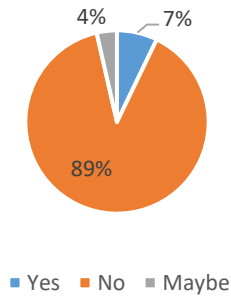


Figure 15-A

Responses about knowledge level of virtual tour in construction site

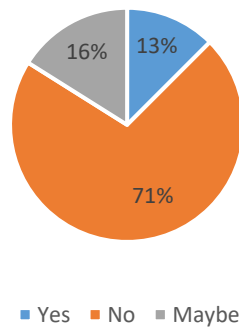


Figure 15-B

Figure 15: Knowledge of Participants about Technologies in the Construction Industry

CHAPTER 4: DEVELOPING AND TESTING THE REPORTING FRAMEWORK

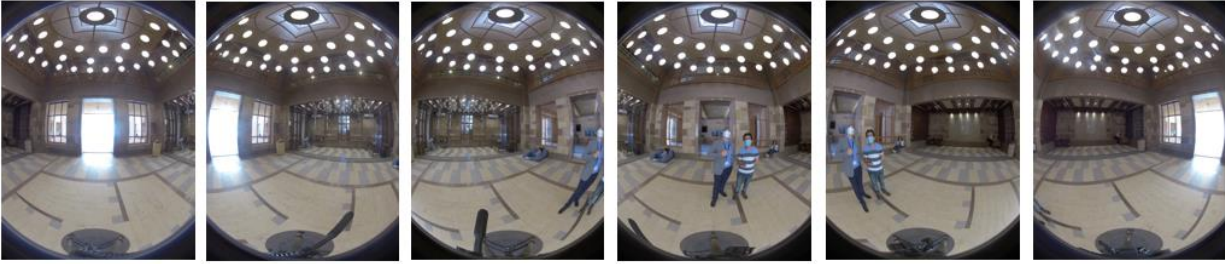
This chapter discusses the development and testing of the proposed reporting framework by integrating 360-degree photography. In addition, it highlights the lessons learned through addressing the obstacles that were faced and overcome.

4.1 Investigation of Current Available 360-degree Cameras

An omnidirectional camera (from "omni," meaning all), often known as a 360-degree camera, has a field of vision that covers almost the whole sphere or at least a full circle in the horizontal plane. This type of camera usually contains two lenses (Dual Fisheye) or more to take two or more photos at the same time. For example, the Insta 360 Pro 2 camera includes six wide-angle lenses in opposite directions. All lenses capture all directions at all times. After that, the images are stitched together to create a spherical 360-degree panorama image.

Image stitching is the process of converting two or more regular wide-angle pictures in to one 360-degree shot, as demonstrated in Figure 16. Panoramic images can be presented on conventional devices like smartphones or laptops, but sometimes 360-degree viewer applications are needed to rotate photos freely on the screen. The most comprehensive and detailed records of construction sites can be presented from one 360-degree photo per room or area instead of much more regular pictures.

Photos before the stitching process



Photos after the stitching process



Figure 16: An Example of a Photo Captured with 360-degree Camera Called Insta360 Pro2

Nowadays, 360-degree cameras come in many different forms and types. When people prefer one type of camera to the other, they take not only the brand into consideration (Insta360, Samsung Gear 360, Garmin VIRB 360, and Ricoh, Insta360 Pro2), but also the use. It is highly recommended to use (Insta360 R, Insta360 ONE X2, or Ricoh Theta Z1) when using (OpenSpace, Holobuilder, StructionSite, or Matterport) applications. This is due to the flexibility of these cameras, ease of use and acceptable picture quality (Amaya, 2022).

Insta360 Community is an online forum which has approximately 27000 members who use or are interested in 360-degree cameras. The Insta360 Community – can be accessed at <https://forums.insta360.com/> - conducted an initial survey in 2021 among their members and

received 115 responses. The initial survey shows that the 360-degree camera is the best type of camera, and it can be easily used in real-estate or construction. The survey also shows that 67% of respondents prefer the Insta360 ONE X2, 26% prefer the Insta360 R, 3% like to use the GoPro Fusion 360 camera, 1% like to use Ricoh Theta Z1, and 3% prefer other 360-degree cameras (Insta360 community, 2021).

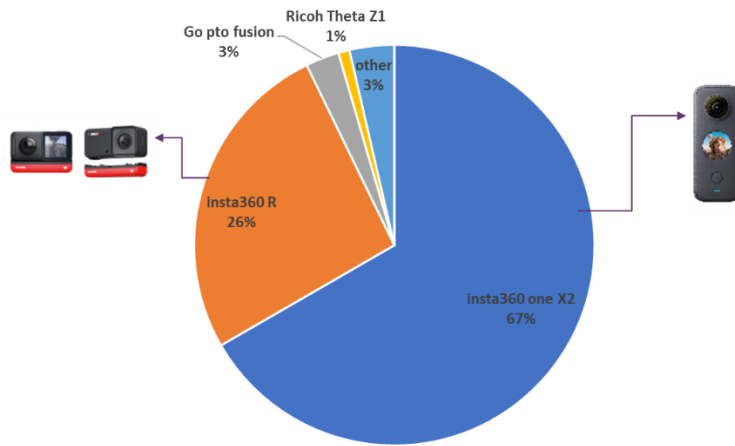


Figure 17: Suggested Camera for Using in Real Estate by Conducted Survey in Insta360 Community (Insta360 community, 2021)

In general, 360-degree camera technology is constantly evolving with new features, so the high price means a camera with more flow state stabilization, high resolution, more data storage, and flexible software. Insta360 cameras are the optimal choice for many people because the performance of tasks using software and applications on phones is easy and fast in terms of editing photos or videos, uploading, downloading, sharing and stitching.


The price of the Insta360 ONE X2 and Insta360R cameras is approximately US \$500 - \$1,000. Price changes based on where and when to purchase (Cameron et al., 2021). Multiple lens cameras have incredible features. However, this study focuses on small portable devices. Several features should be taken into consideration before using a 360-degree camera as follows:

- 1) Resolution: It is the most incredibly appreciated feature on camera. Higher resolution means more image detail. However, it requires a large SD card, and it drains the battery fast.
- 2) Battery: It is a crucial factor in 360-degree cameras, so purchasing a high-capacity replacement battery camera is the best option.
- 3) Stabilization: Image stabilization helps minimize blur caused by camera shake. To avoid that, it is important to use a good stabilization camera, a traditional tripod, a monopod, or a selfie stick.
- 4) Memory: Ricoh Theta V and Theta Z1 cameras have a fixed-capacity memory, which is a problem for those who take a lot of pictures during travel. Therefore, it is important to purchase a removable memory card camera with a MicroSD card slot.
- 5) Other features include frames per second, waterproof or not, and the price for repairing the camera.

Three types of 360-degree cameras were selected for comparison and evaluation, as shown in table 4. There are many different types of 360-degree cameras, but some are too expensive, or not of acceptable quality. The choices have been narrowed down based on the recommendations of the 360° camera community, as shown earlier in figure12. Based on the researcher's experience using several 360° cameras and the survey results, the Insta360 one X2 camera was an excellent option for this research. Its features include photo resolution of 360: 6080 x 3040

(2:1); Panorama: 4320 x 1440 (3:1), 1400mAh battery, stable flow state, horizon algorithm, no gimbal required, replaceable memory, 1 Micro SD up to 1TB, and waterproof up to 10m

Table 4: Suggested Camera Specifications Comparison (360 camera & VR guides, 2022)

Name	Insta360 One X2	Insta360 One R	Ricoh Theta
Image			
Number of Lenses	2 x f/2.0	<ul style="list-style-type: none"> 360 Module: 2 x f/2.0 4K Module: 1 x f/2.8 	2 x f/2.0
Max Video Resolution	<ul style="list-style-type: none"> 5.7K @ 30fps 4K @ 50fps 	360 Module: <ul style="list-style-type: none"> 5.7K @30fps, 24fps, 25fps 4K @50fps, 30fps 3K @ 100fp Wide Angle Module: <ul style="list-style-type: none"> 4K @ 60fps, 30fps 1080p @ 120fps, 200fps 	3840×1920 @ 29.97fps
Photo Resolution	18.4 Megapixels	18 Megapixels	15 Megapixels
Memory	MicroSD up to 256GB	MicroSD up to 128GB	Internal only -19GB
Battery	1400 mAh	1200 mAh	80 Minutes Continuous Recording
Other Features	<ul style="list-style-type: none"> AI Video Editor RAW Photo HDR Video Pureshot Hyperlapse Night Shot Voice Control Ambisonic Audio 	<ul style="list-style-type: none"> AI Video Editor RAW Photo HDR Video Hyperlapse Night Shot Voice Control 	Spatial Audio, Auto HDR Photo Mode
Price Without tax	\$ 479	\$ 479	\$ 399

4.2: Framework Development Process

Smart 360-degrees photography in the progress reporting is a documentation method that presents a virtual tour through an interactive site layout. It is achieved by linking the images through a hyperlink in the case of using a portable document format (PDF) or by using QR

codes. The images' location on the project site can be found easily through layouts by clicking on the black dots or the numbers in schedule down. This method selects the place fast, and gives contractors, owners, engineers, architects, trade partners, inspectors, and investors, remote access to project sites and 360-degree views of current and past developments. Also, it minimizes the number of reporting pages and covers the whole site from different directions instead of using several conventional photos.

The main purpose of the framework is to build a virtual tour for the site using a 360-degree camera. Therefore, the developed framework is based on three main steps:

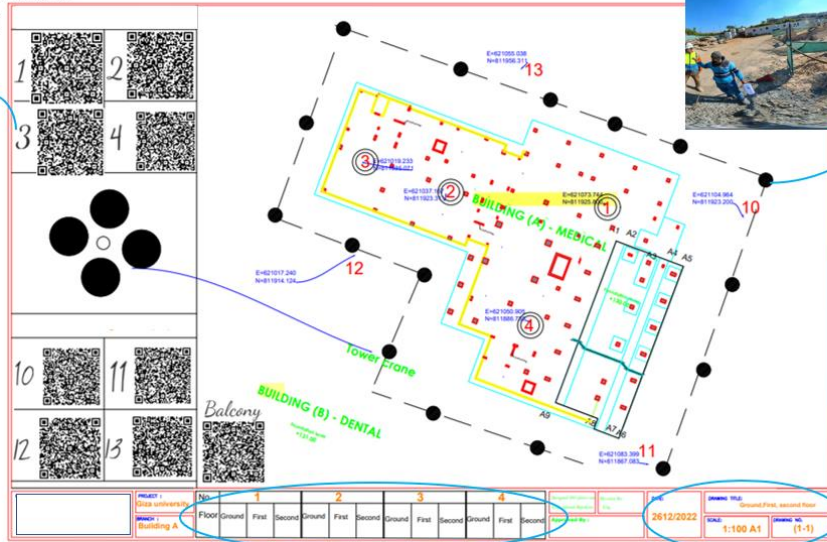
1. **Preparation:** The preparatory step entails clarifying the primary purpose of integrating the 360-degree camera into progress reports to all project stakeholders, such as engineers, owners, and contractors; then, informing them how they will receive progress reports. Even if the framework is available for use in construction reports, there are challenges in adopting the new management method among stakeholders. Therefore, it is highly recommended to perform this step before applying the smart 360-degree framework to avoid the challenges and hurdles of implementing a new approach. For example, people are resistant to change and have insufficient training. The main barriers are Technical; low levels of usability technology, Managerial; low levels of management commitment, lack of client support, and low utilization level (Demian, 2014).

In addition, fixed points in the project site should be identified with the help of a surveyor (if possible). These points help taking fast photos periodically and assist in several future uses, such as the comparison process when putting pictures side-by-side to follow the progress.

2. **Building the Framework:** Building the framework aims at setting all the 360-degree

panorama stock images on one site layout sheet. A 360 Panoramic image captures a location's whole 360-degree field of view, which frequently seems distorted when shown as a flat picture. Therefore, a 360 Panoramic image needs at least two 180-degree images combined together throughout image stitching, which is done automatically through the system loaded in modern 360-degree cameras. After that, captured project images are uploaded to an online cloud platform for free called an Insta360 app. This application can be found in Google Play Store or Apple Store. As a result of the previous investigation of available current 360° cameras, which suggests using Insta360 ONE X2, the Insta360 app is compatible with this type of camera unless another 360-degree camera is used. This cloud allows access to files anytime and anywhere. The next step is to link the images in one sheet layout using Hyperlinks and QR. For example, in the framework, the hyperlink is put on the black dots, as shown in figure 18. Moreover, the QR is used when the progress reports are on paper. After linking the images in the layout, the framework is ready to be used in the reports. Furthermore, the enhancement of reports with images becomes only one sheet.

You can scan any QR in the model to see the place from all directions



You can take a virtual tour by clicking on any black dot.

You can go up and down in the same place when there are multiple levels of the building. Like clicking in the ground, first, second in schedule

There is information about the date and location of shooting the photos.

Figure 18: Example of a Framework Applied in New Giza University

3. **Evaluating the Framework:** Evaluation of the developed framework is conducted through applying it in multiple projects and investigating its impacts through a questionnaire distributed to the stakeholders of the test projects. The developed framework is evaluated in terms of saving effort, time, and cost, resolving conflicts, enhancing collaboration between the stakeholders, increasing productivity, and reducing errors.

Figure 19 summarizes the steps for developing the proposed framework. More details are described in the following sub-sections, including detailed steps with visual demonstrations and screenshots.

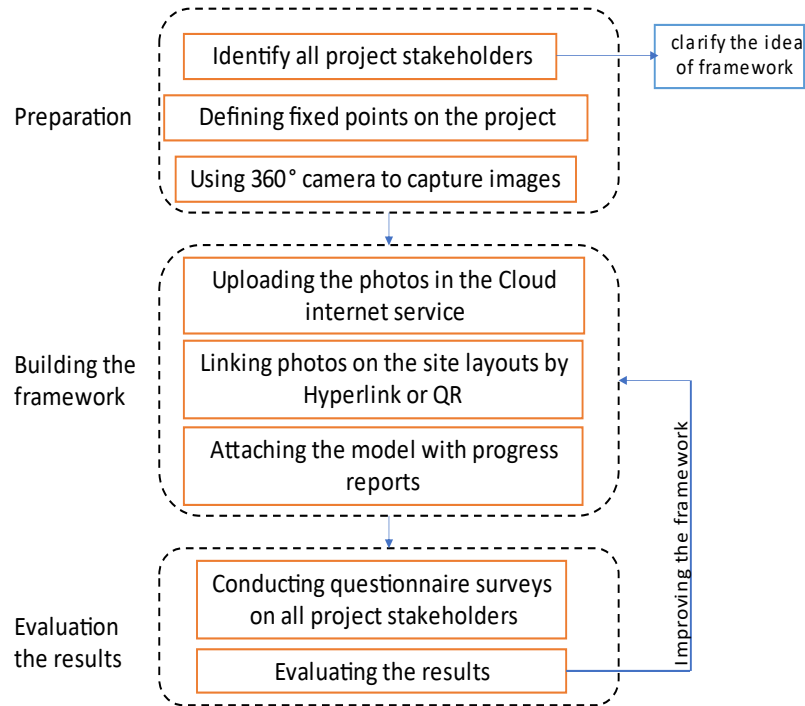


Figure 19: Proposed Framework of Smart 360-degree Photography and QR codes for Enhancing Construction Progress Report

4.2.1 The Preparation Step

The aim of this step is to create a straightforward interface that will be easily used later, and to integrate all inputs fast. All of these will be discussed in the following screenshot's photos.

4.2.1.1 Identify All Project Stakeholders

The objective of using a framework should be clarified, such as explaining to what extent the project can increase the communication and transparency between stakeholders instead of using traditional methods in photography. These framework's benefits should be clear to enhance

stakeholders' participation. One example is explaining how a virtual project tour will introduce all details of current and historical progress and gain remote project's access for the owner, engineers, and workers. Therefore, the framework's incorporation into the progress report should clearly achieve high-benefit objective in stakeholders' projects.

4.2.1.2 Defining Fixed Points on the Project

The site's layout is mostly in AutoCAD, so before converting the format to PDF format, visible dots should be added as fixed points in layouts as shown in black in figure 20.

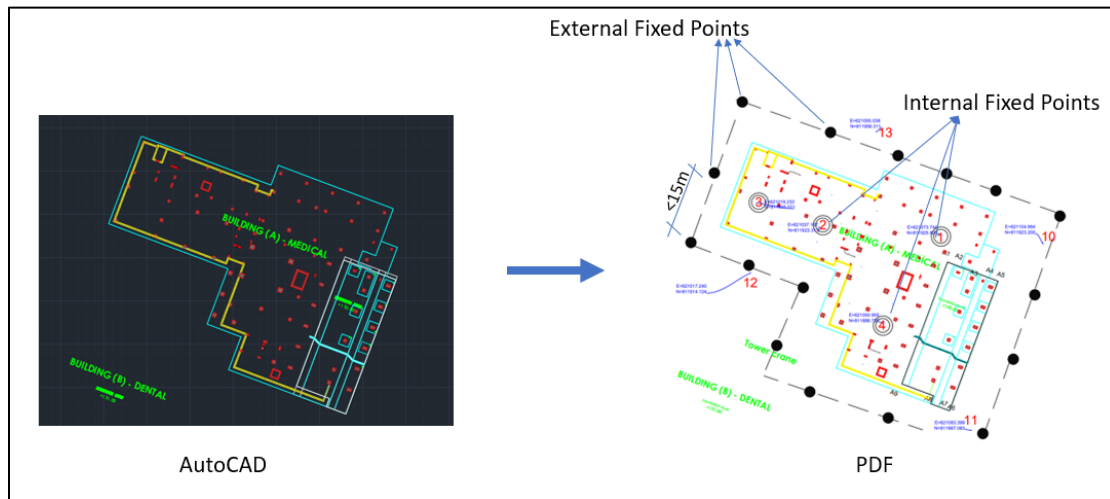


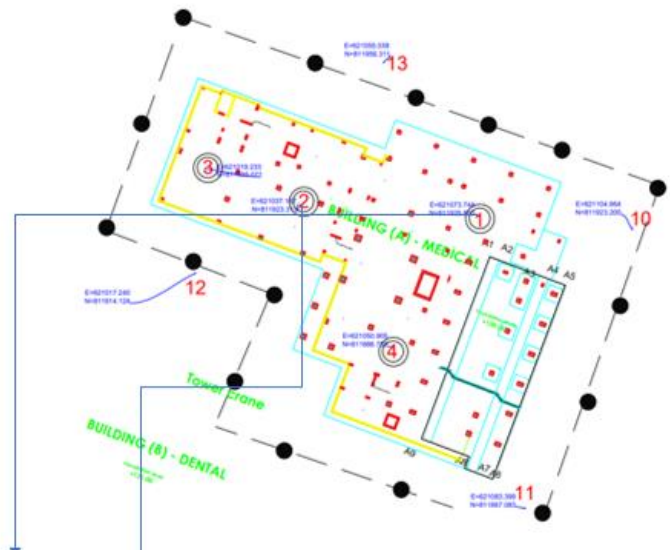
Figure 20: Converting the Site's Layout Format to PDF Format and Adding Some Fixed Points

The fixed points mark the photos' location that will be taken on the project site frequently. Therefore, the numbers and points' location are different from one project to another depending on the stakeholders' needs and the project size. For example, if a project is in the stage of external finishing, all the project's requirements are images from external fixed points and no need for internal fixed points. Furthermore, the more rooms there are, the more internal points are needed. This means that some small projects need just four 360-degree photos to cover a project site from the outside, while others need more. The suggested distance depends on the

resolution of the camera. The Insta360 one X2 camera is used in this research, and to obtain accurate and precise details, distance between the fixed points should not exceed 10 meters in the internal shots and 15 meters in the external shots.

Figure 21 shows an example of an actual project in the new Giza university in Egypt that implements our framework. It shows in case there is a multi-level project. Therefore, many pages of layouts in progress reporting such as the ground, first and second floors. To minimize that into one page, the table contains columns for the fixed points, whether internal or external and rows for the points' level. So, the content of the table can guide the stakeholders to move from one floor to another. As seen, the first row includes some of the fixed points. For example, point number 1 has three 360° photos in the same coordinates but at different levels. To illustrate, in the table, by pressing on the word of ground under the number 1, the hyperlink presents pictures of this fixed-point number on the ground floor and the same thing with other floors.

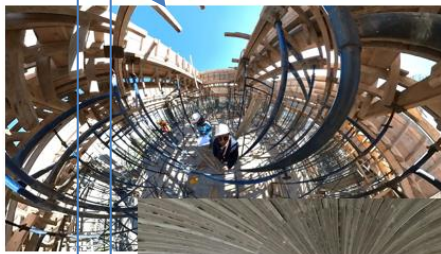
The framework contains flexible interfaces that can be adjusted according to project requirements. For instance, in Figure 22 and Figure 23, the framework includes pictures of multiple floors of a building over a period of time. So, the user can move between floors and rooms through a timeline of images. In other words, instead of making each image capture date on a separate page, the user can make a matrix table with the dates of the captured photos. The developed matrix table can create well-organized project documentation during a period of time. A square logo is needed to see the image's location on-site and its date. The box blank has left in case the photo is not taken in that date.



Table

No.	1			2			3			4		
Floor	Ground	First	Second	Ground	First	Second	Ground	First	Second	Ground	First	Second

Point no.1, second floor



Point no.1, first floor



Point no.1, ground floor

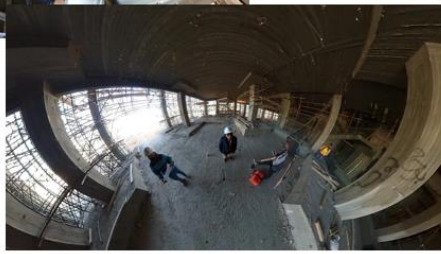


Figure 21: The Role of a Table in the Framework for Multi-Levels in Project (A. Bahakim, 2022)

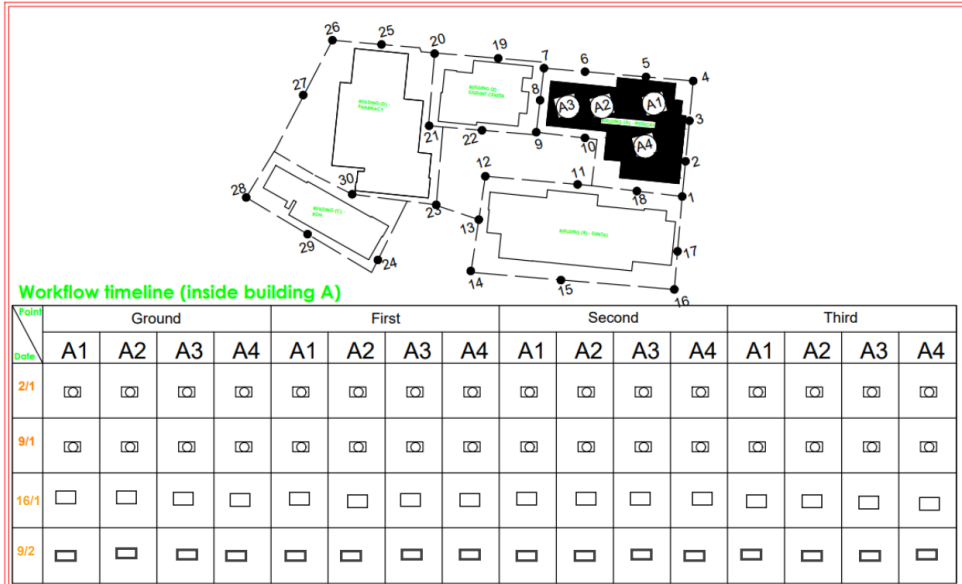


Figure 22: Developing the Framework Table to Include the Date and Minimize the Page of Progress Reporting

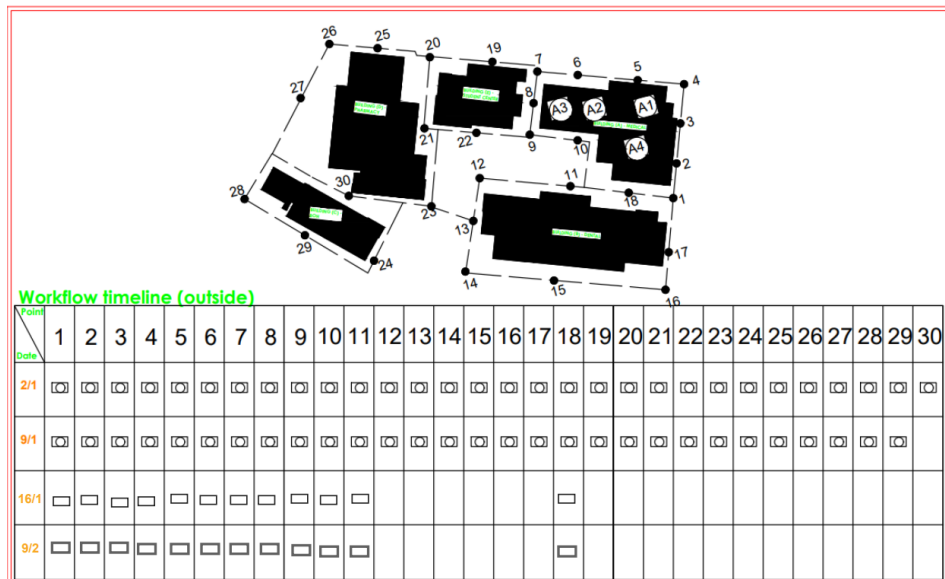


Figure 23: Developing the Framework Table to Include the Date and Minimize the Page of Progress Reporting

4.2.1.3 Using 360-degree Camera to Capture Images

Indeed, the process of taking pictures varies from camera to another. In this research, the camera used is Insta360 ONE X2. It can take pictures of the surrounding view from a particular point.



Figure 24: 360-degree Camera Called Insta360 ONE X2 (Adams, 2021)



Figure 25: Insta360 ONE X2 with an Assortment of Accessories (Adams, 2021)

In figure 25, the Insta360 ONE X2 bundle is a reasonable package in capturing images and avoiding issues in the site. This package includes a Selfie Stick, an extra battery and case to carry it, a 32 GB MicroSD card and SD card adapter, two charging cables (USB-A to USB-C and USB-C to Lightning), a carrying case, and a soft pouch.

4.2.2 Building the Framework Step

This is started by uploading the captured photo and then attaching it to the layout site in the progress report, as discussed in the upcoming paragraph.

4.2.2.1 Uploading the Photos in the Cloud Internet Service

Currently, with the development of the Internet, it is easier to store data in the cloud services and run it over the Internet instead of storing the data on local computers. It also assists in sharing data through web browsers like Google Chrome or Firefox anytime and anywhere.

In this research, the Insta360 application is used to upload the photo from camera to the internet. Firstly, the camera has to be connected to the phone by Wi-Fi. As shown in figure 26, when the Insta360 app is opened, the user can press the camera icon at the bottom of the app homepage and select "Connect now" in the Wi-Fi panel. Then, choose the ONE X2 and follow the onscreen instructions to connect device.

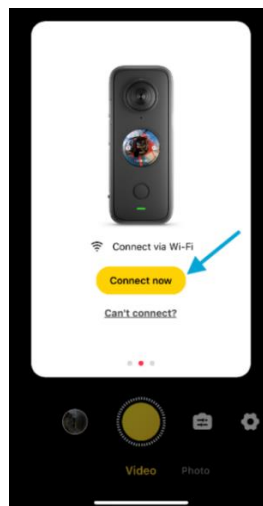


Figure 26: Connecting the Insta360 App with a Phone to Upload the Photos (4 Connecting to a Phone - ONE X2 Support, 2022)

Next, the user enters the photos' album in the camera that needs to be exported. In the upper right corner of the page, user can click on the share icon, as shown in figure 27. This will directly export photos to the phone.



Figure 27: Export Capture Data from Camera to Phone and Uploaded to Insta360 Platforms(2 Download, Export, and Share Files - ONE X2 Support, 2019)

This option of platforms creates a 360-degree sphere that may be moved around to see different angles of each photo. To avoid some constraints, the exported 360-degree photo has a glance briefly at the phone's local album or paper documents.

4.2.2.2 Linking Photos on Site Layouts by Hyperlink or QR

While setting up the site layout, the photos must be connected and uploaded to the Insta360 app; then, the PDF site layouts should include all of the uploaded 360° photos from the insta360 app.

This can be done via a hyperlink or QR, as the following steps explain:

- Appropriate programs to link, edit, and add hyperlinks in PDF format have to be chosen. There are many online programs or websites that can do that, such as Sejda. To illustrate, as seen in figure 28, Sejda is an online service that does not require installation and it is easy and simple to add Hyperlinks into PDF format.

- The link of the uploaded photos from the Insta360 platform has to be copied.

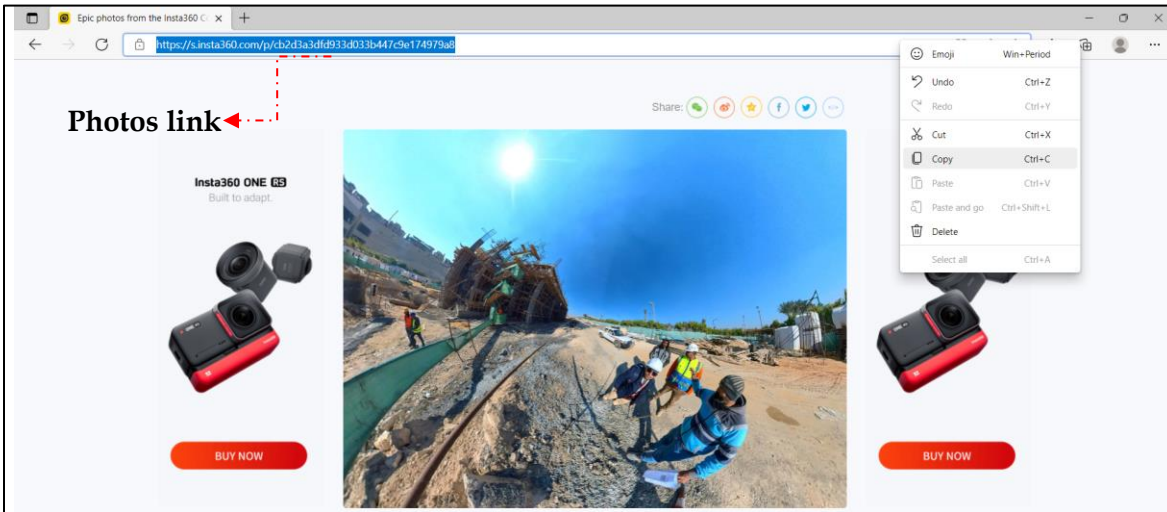


Figure 30: Illustrate Copying the Link of Photos Uploaded from the Insta360 Platform

- The photos link has to be inserted into site layout using Sejda insertion tools. The inserted photo should be in the same location on-site project.

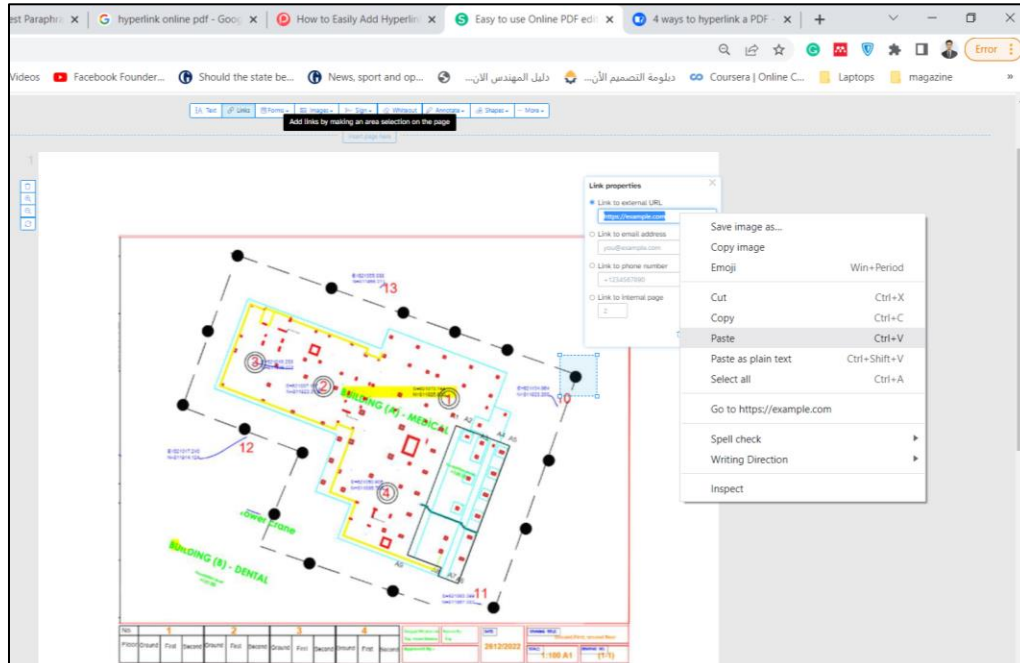


Figure 31: Using Inserting Tool in Program

- The QR code of photos can be taken in multiple ways; one is through a tool in the

Insta360 app to extract the QR of 360 photos, as shown in figure 32. The 360-degree photo can be shown by scanning the QR code below.

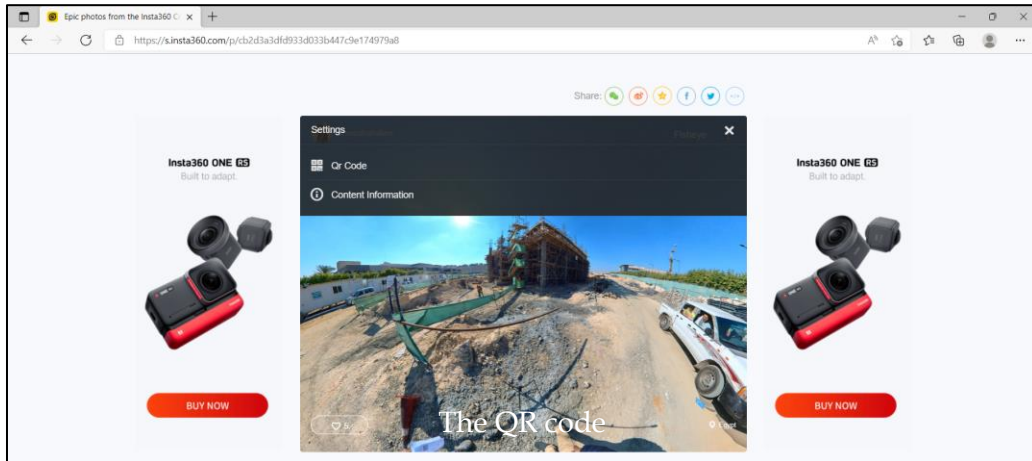


Figure 32: Creating QR Code Photo by Insta360 app

4.3 Evaluation of the Developed Framework

A pilot study was conducted through applying the developed framework in three different projects in Egypt, as seen in figure 33 by scanning the QR. The first project is The New Giza University expansion project which consists of five educational buildings: Building (A) is medical, Building (B) is dental, Building (C) is behind the house (BOH), Building (D) is pharmacy, Building (E) is student center. Its total building area is 55000 square meters. In addition, the average number of building floors is four, and the daily average number of site's workers is 150. Weekly site visits were conducted in the period of 26/12/2021 to 09/02/2022. Efforts were made to convince the project manager to implement this framework; in contrast, the owners' engineers were interested and supportive of the idea. This is due to the large amount of work, many details, many comments, and many edits, which may delay the progress of acceptance, especially for contractors.

The second project is an eight-story residential building with a total construction area of 576 square meters. The researcher has visited the project site four times during the one-month period from 01/02/2022 to 30/02/2022. The construction process of this project was progressing slowly. Therefore, progress reports have not been reported on a regular basis but reported based on the completion of a certain task or based on the stakeholders' request. Therefore, there was no fixed time to take pictures of the progress of the project and put them in the report.

The third project was a two-story residential villa with a total construction area of 225 square meters. The project site has visited four times per week from 01/01/2022 to 10/02/2022. It has more than 100 villas constructed simultaneously, which means the stakeholder's needs are wide range such as they needed a drone camera to cover all sites. Hence, they decided to take one villa as an example to implement the framework and measure its effectiveness. In general,

all projects were in the process of development, and their location in Google Maps is as shown in figure 36.

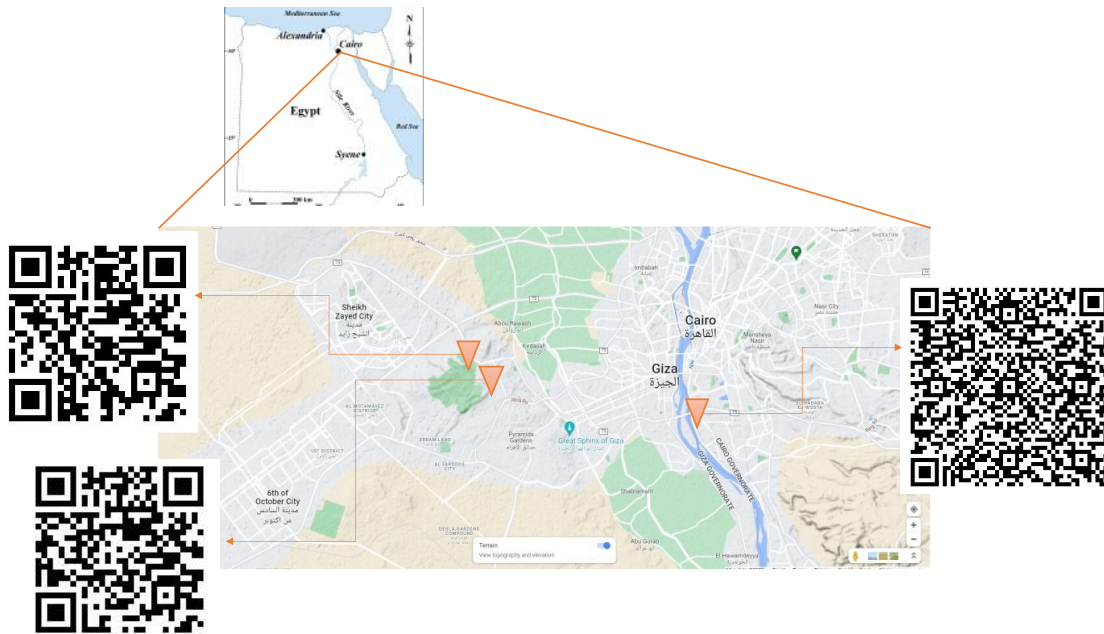


Figure 33: The Location of Pilot Case Studies on Google Maps (A.Bahakim, 2022)

Figures 34 to 36 show the final layouts of the three pilot projects that implemented the framework to enhance the progress reports. PDF versions with hyperlinks can be provided by the author by request.

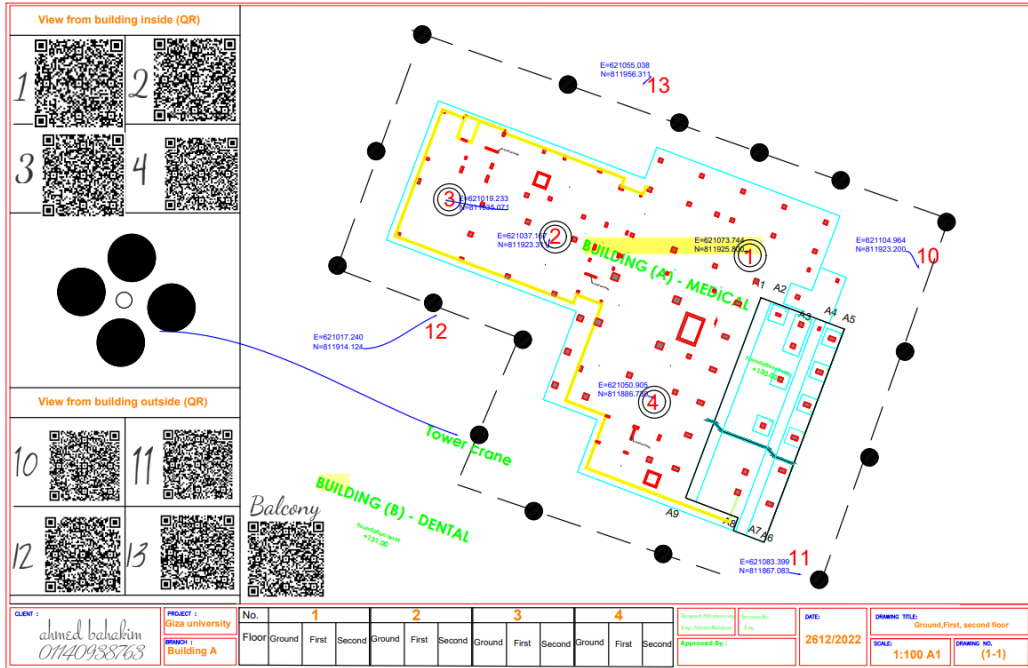


Figure 34: The New Giza University project no.1

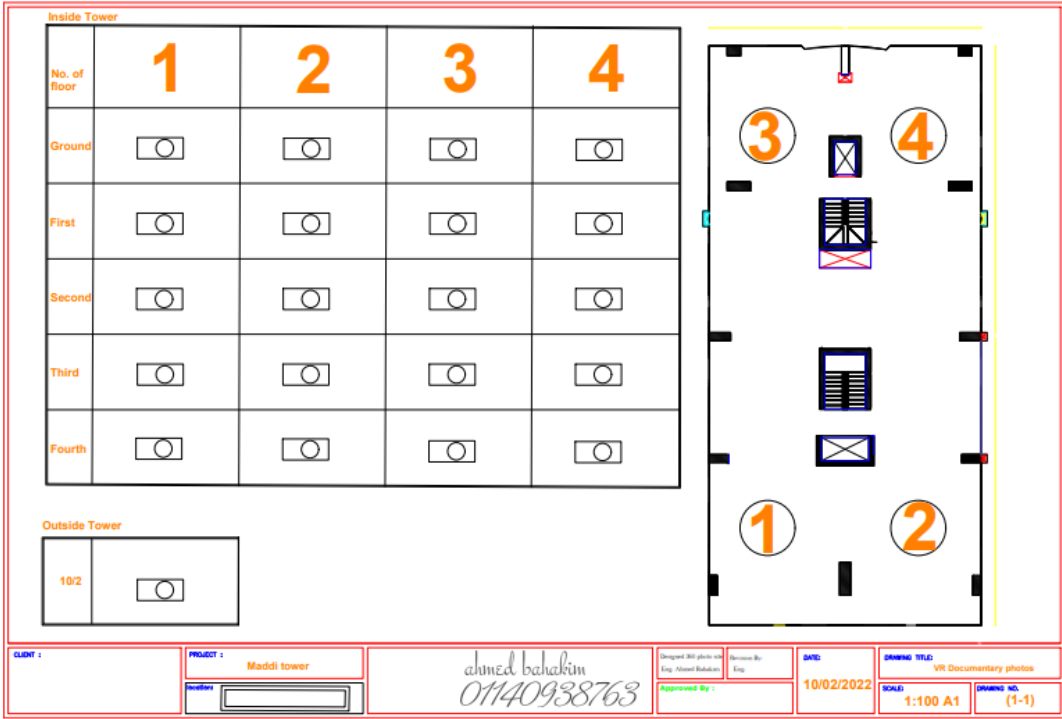


Figure 35: An eight-story residential tower project no.2

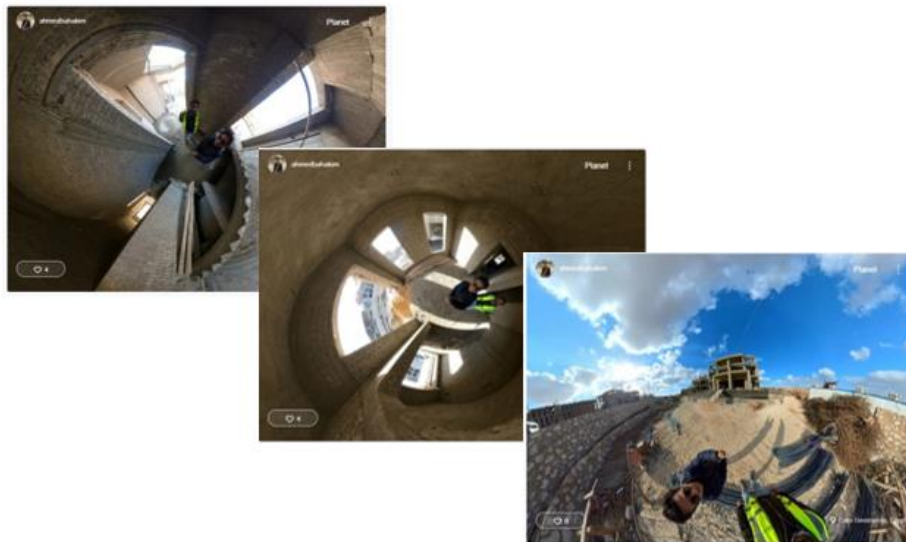
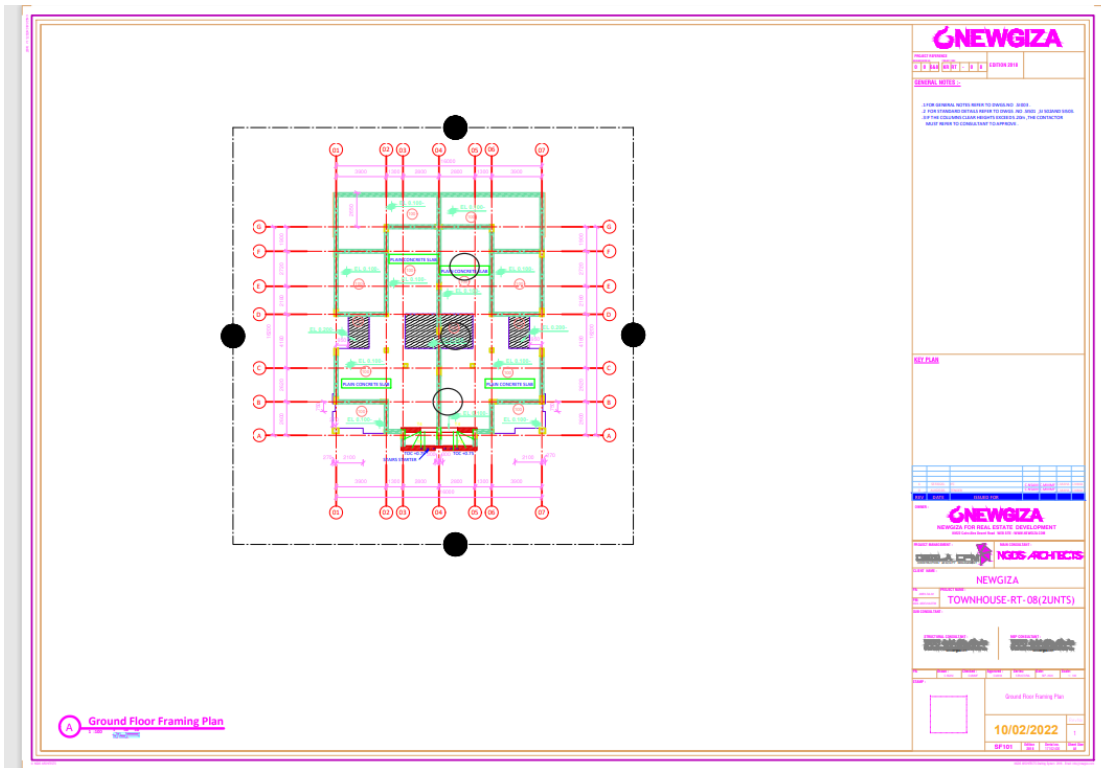


Figure 36: A two-story residential villa project no.3

A survey was conducted after using the developed framework in each of the three pilot sites. There are four sections in the survey. The first section is about the biography of responses; to ensure the accuracy of the questioners by asking about the name, contact number or email (optional), job title, experience years, and project name (Fig. 37-a). The second section is about

testing the effectiveness of integrating the Smart 360-degrees framework and QR codes in progress reporting, in which the current methods are compared. The same criteria applied in the initial survey to save time, effort, and money. Moreover, the Likert Scale was conducted to measure and evaluate the results (Fig. 37-b). The third section is for investigating the obstacles and difficulties that prevent applying this technology in construction reports (Fig 37-c). The last section is about expectations and opinions of the participants (Fig 37-d).

Second survey(After applying the model)

Evolution the results

ahmedbahakim@aucegypt.edu (not shared) [Switch account](#)

Name

Your answer

Job title

Your answer

Years of experience

Your answer

Project name

Your answer

Figure 37-a: First Section

Evolution the results

Photography (360-degree camera) in project progress reports

Do you think that moving from normal photography technology to 360-degree photography and integrating it into reports will help?

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Saving time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effort saving	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Resolving disputes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Following up the workflow	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving collaboration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increasing productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reducing errors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 37-b: Second Section

The obstacles

What are the difficulties and obstacles in your opinion that prevent the application of this technology?

- Unfamiliar with technology
- Difficulty using technology
- The high cost of technology
- Difficult to get a camera
- Other: _____

Figure 37-c: Third Section

Expectations and opinions of the participants

Expectations for incorporating this technology to enhance construction management in several respects

If this technique is available, to what extent do you agree to use it in the reports.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Any addition, suggestion or question by you regarding the use of 360 imaging technology in construction.

Your answer _____

Figure 37-d Fourth Section

Figure 37: Case Study Survey (After Applying the Framework)

The researcher has collected data from 33 engineers, contractors, and owners through virtual or in-person interviews. Figure 38 shows that 18.2% have less than five years of experience in the construction industry, while 81.2% have more than five years of experience. The third section is about the rate of agreement on applying the developed framework instead of conventional visualization methods in progress reports. The fourth section presents obstacles that would prevent the framework from being widely applied, as well as an open question about responses' opinions.

PERCENTAGE OF PARTICIPANTS FROM EACH PROJECT

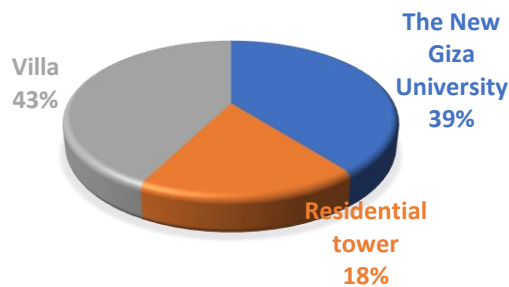


Figure 38-A

COMPOSITION OF THE RESPONDENTS

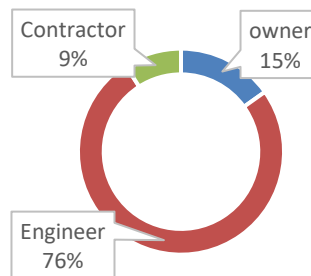


Figure 38-B

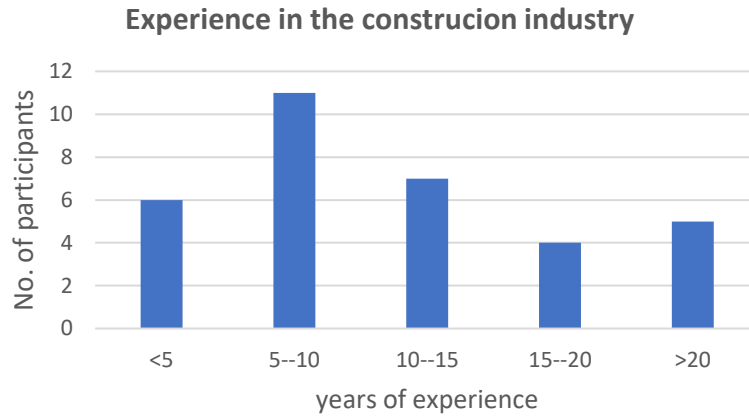


Figure 38-C

Figure 38: Basic Information for Respondents After Applying the Framework (Case Study Survey)

This survey shows the agreement of stakeholders on integrating the smart 360-degree photography framework and QR codes to enhance progress reporting instead of the usual method that is based on attaching conventional images. Figure 39 shows the eight criteria of comparison and the reasons for approval and rejection.

Figure 39 shows that the vast majority of the survey respondents are in favor of using the framework to enhance the progress reporting, while the others disagree. It is expected to see more and more 360-degree camera applications at construction sites in the future. More details in each factor will be described in dissection section Chapter 5

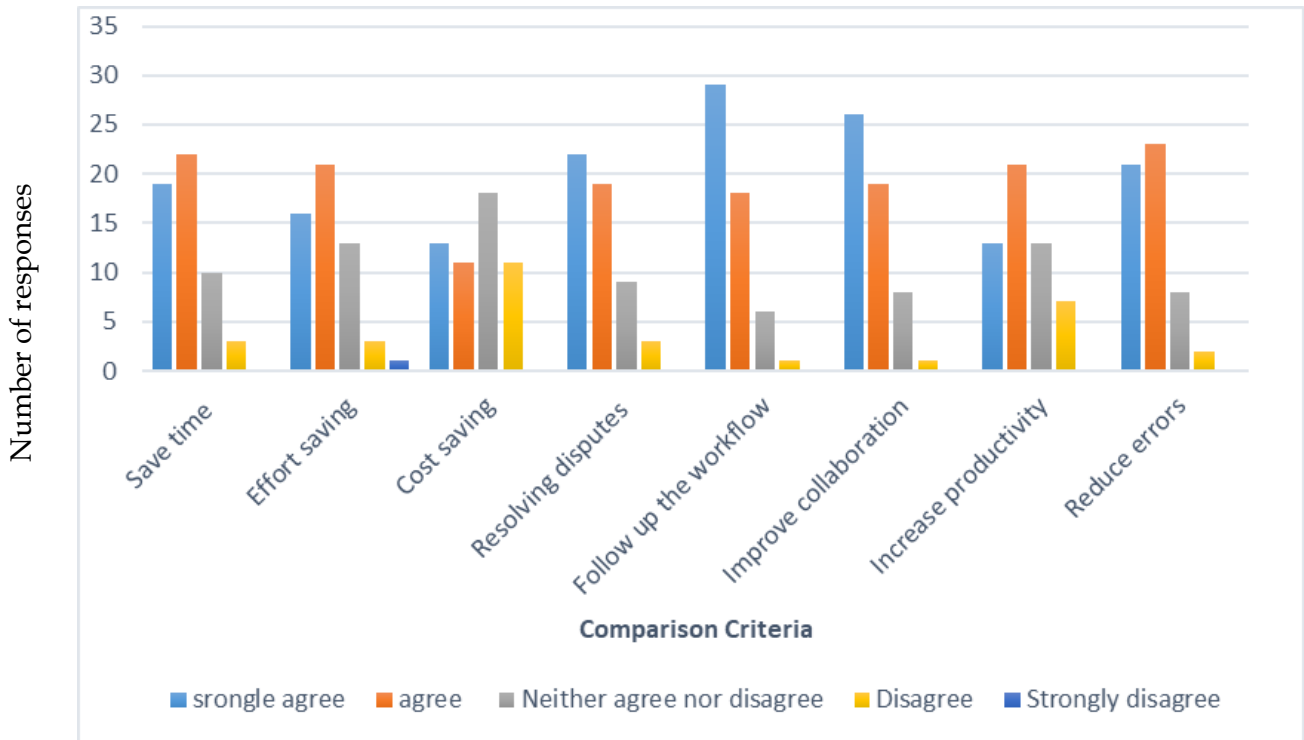


Figure 39: The Agreement of Stakeholders on Using the Framework Instead of Conventional Images

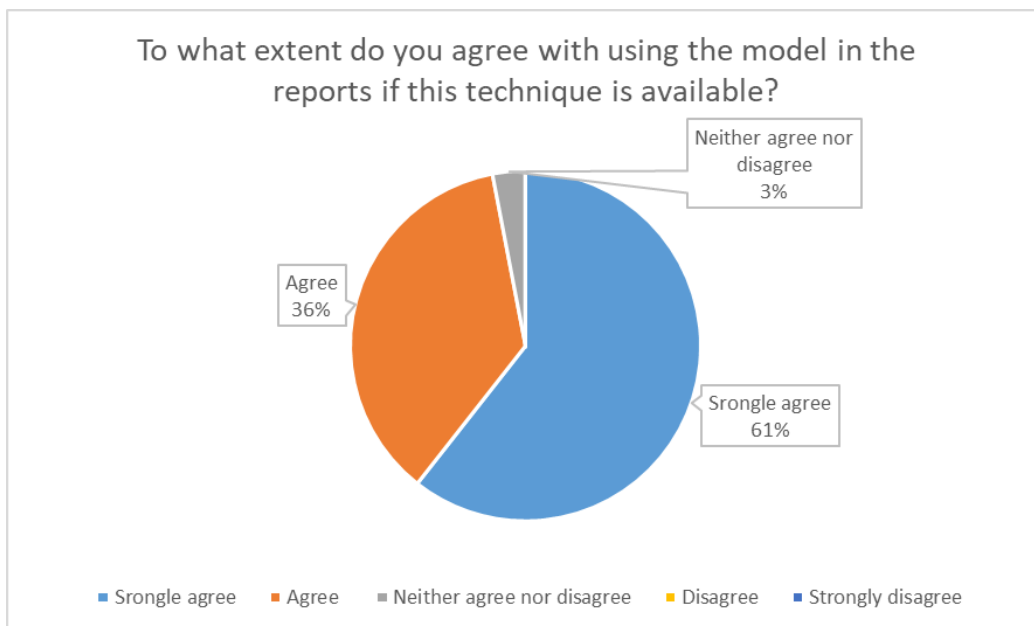


Figure 40: Measurement of the Overall Agreement on Using the Framework

In figure 40, The questions investigate the framework's effectiveness in enhancing progress reporting compared with the usual method. This pie chart shows the results of a survey in which

stakeholders' acceptance of using the framework if it is available to improve the reports. It is clear that the majority of respondents strongly agree to use the framework, with only 3% not agreeing. They also highlighted and confirmed the advantages and limitations of integrating the use of 360-degree photography and its application in construction sites which is discussed in more detail in the discussion section in Chapter 5.

CHAPTER 5: DISCUSSION

5.1 Discussion on the Use of 360-degree Photography in Progress Reporting

The results of the research and the pilot study indicate positive impacts of the integration of 360-degree photography in progress reporting. Here, we present additional discussion on the benefits of 360-degree photography in comparison to other traditional means through eight criteria, namely:

1. Time
2. Effort
3. Cost
4. Disputes
5. Follow up on workflow
6. Collaboration
7. Productivity
8. Errors

5.1.1 Time

Controlling and managing the massive amounts of paperwork and documentation needed in construction businesses' daily operations is one of the most difficult challenges and time-consuming tasks. Today, the conventional file system has been attempted to be replaced with a construction management software package, allowing for the secure management of official documents. Likewise, the development of capturing data in progress reports has been improved.

Time in this study means evaluating all stages, which include the time spent to capture the 360-degree image on a site, and the time to upload the image and attach it to the progress report

compared to the conventional construction photo documentation process.

As a matter of fact, the time spent taking 360-degree pictures is less than conventional pictures, such as those taken by phone. This was noticed during the New Giza university project because one 360-degree image equals six conventional images. But it is noticed that uploading a 360-degree photo to use in progress reports takes more time and is not easy to use because 360-degree photos need a stitching process or uploading into 360-degree platforms such as insta360 before integrating into the reports.

5.1.2 Effort

This study also focuses on how the framework affects effort saving, either directly when progress reporting is done or indirectly in certain activities. For example, the developed framework may affect rework efforts due to misinterpretation of field information. In addition, it impacts the image recapture efforts due to display limitations on a 180-degree image, which sometimes does not display the stakeholders' requirements on site.

It is worth noting that a common progress report is a content chart describing the project's progress on the first page, and then augmented by a few pages of photos to confirm what is in the chart. For instance, photographers often cannot capture all the details the team wants due to the limitations of the 180-degree image. As such, this issue often results in a double effort when submitting a progress report. The framework is based on a few labor-saving steps, so the more organized the progress report, the more time and effort it will save. Additionally, it is based on an interactive site layout in commercial applications such as OpenSpace and HoloBuilder, which means the location of images can be found quickly. In addition, using QR codes can save the effort of printing live pictures on paper. The framework is able to reduce the amount of work required by using a 360-degree camera to reveal more details through photography. This, in turn,

helps the engineer and the owner form a clear path to the places they are going to visit. This means that the framework allows viewing more than one point in the site by clicking on fixed external points surrounding the project or using the table to navigate within the project.

5.1.3 Cost

One of the most critical issues in project management is cost management. Current construction cost management methods have shortcomings, such as poor communication and stakeholder visibility. The report can be a reliable communication method between stakeholders regarding how the project is being implemented or progressing. Likewise, captured data can serve as confirmation in reports. While the project team's vision or perception is critical, the project manager's perception of the report may differ from that of line managers or stakeholders. Therefore, the framework ensures that reports can be understood at different levels and given appropriate access to enable them to make accurate decisions.

The researcher has investigated whether integrating the framework into progress reporting could result in cost savings compared to conventional methods. This factor is based on the assumption of achieving money savings, for instance, avoiding rework. To illustrate, discussions were done with contractors and subcontractors on how often you repeat work because no robust photo documentation rapidly clears up disputes such as mechanical or electrical works. They responded that there were a lot of costly mistakes during the construction work, and it is not possible to refer to the conventional pictures because they often do not cover all the details on site.

5.1.4 Disputes

Disputes appear to be synonymous with construction projects, leading to issues such as increased project costs, project delays, reduced productivity, lost profits or damaged business relationships.

As such, construction is one of the most contentious industries, sometimes leading to lengthy negotiations, broken contracts, contract amendments, design changes, and even litigation. There are several factors that can lead to conflict in the construction industry, including behavioral factors such as weaknesses in inspection clarity and integrity or poor communication between stakeholders.

As we all know, not all stakeholders can go to the job site to check on the clarity, eligibility, or progress of things. The role of image reporting also keeps stakeholders informed about projects to avoid conflicts, no matter where they are located. The advantage of 360-degree imagery is that you can create a virtual tour that shows what the site is really like from multiple directions and angles. Accordingly, the researcher has investigated if the possibility of integrating the framework into the progress report could lead to a reduction in the rate of conflict and to what extent stakeholders will agree on that.

Consequently, it is noticed that a Request for Information (RFI) during any dispute or conflict can be taken through the framework quickly and easily. That is because the framework is a visual document with many interactive advantages such as image history, image location, well-organized images, quick access to images, easy file sharing, and 360-degree image capability to provide a clear view of the place.

5.1.5 Follow up the Workflow

In general, a project workflow is a management procedure that outlines the steps that must be done to execute a task correctly and consistently. Organizations and construction companies use workflows to achieve a range of tasks by assigning tasks to workers and specifying a series of steps on how to complete them. As for workflow monitoring, as mentioned earlier, not all stakeholders have the ability to visit the site, whatever the reason. This makes the reports the

main source for monitoring and follow-up work. So, despite the enhancements to the report, whether it is a picture or a video, it still doesn't convey the full view of the site and can be accompanied by many differences in decision making.

In this framework, using a 360-degree camera instead of a traditional camera, we can rotate the image to detect surrounding content. An example can be seen in Cervo Liguria, Italy, where two buildings are adjacent. These images show how one photo is not enough to present all views of the building for follow-up or monitoring and how it affects your feedback and assessment if you look at the painted red building but on the other side see the yellow building with some painting issues.



Figure 41: Two Pictures of Different Side of Two Buildings in Cervo, Liguria, Italy

Based on this example, the framework is built to cover as much of the job site as possible by creating a virtual tour. The investigations are conducted to evaluate to what extent an integrated framework in progress reporting can improve the monitoring and tracking of workflows. The positive result indicated the importance of integrating the framework to improve monitoring in reports.

5.1.6 Collaboration

Collaboration in construction simply refers to teams working together to achieve a common project goal. This could be when everyone on the team has access to the main plans at all times

without being affected. The concept here is somewhat different from teamwork; because teamwork often involves an actual meeting to achieve something. Collaboration is when two or more people work together, by thinking and sharing ideas, to achieve a common goal through the use of modern technological advancements such as virtual meetings or cloud-based data sharing programs.

In the research, some assumptions have been made that would improve collaboration: First, the framework would give enough time for all contributors to visit the virtual worksite. It also allows moving from one fixed point to another, using a framework table to move from one floor to another at any time. Second, the framework will allow the job site to be viewed from anywhere, meaning you can be in another country and still follow the site. Third, the framework will allow us to learn from each other and reduce dependencies. Stakeholders are known to come from different backgrounds and experience levels, and they can approach the same situation from other perspectives. Therefore, sending the framework to each person and giving them the chance and time to solve a problem can lead to learning a lot from each other's perspectives without creating dependability issues in meetings or sites. Thus, based on this, the framework is recommended to be in PDF format for easy sharing. It can be sent and received using many websites, such as email or social networks like WhatsApp. In the same way, the researcher suggests adding QR to the framework if using the paper file. Also, the insta360 platform is a cloud-based software that can upload 360-degree photos to it.

5.1.7 Productivity

Construction productivity is an essential component of every construction project. Without it, deadlines are missed, and budgets sink quickly. This requires ensuring that all stakeholders work and follow the same plan sheet to ensure that the vision of the project is clear. Several issues can

affect the rate of productivity, starting from the time needed to understand the project plan and to the required time to make a decision. Whereas time is inversely related to productivity; the less time it takes to produce anything, the more productive it is.

The side effects of integrating the framework into the reports have been considered. Stakeholders' members, on-site and in the office, were informed of the most current site condition without needing a site visit by using the framework. During the New Giza university project, it was noted for the first time that all stakeholders were informed of the project condition simultaneously by sending the pdf of the framework. For instance, the CEO of Dorra and the engineers in the head offices were 15 km from the site project. Also, the project owners were almost in another city. Therefore, if the framework helps reduce travel time, it will also reduce the time for conversation and discussion among stakeholders to make a decision, which will increase the productivity rate.

Although the owners liked the framework method and its inclusion in the report, there was a great objection by some project engineers and contractors, and they argued it would lead to increased observations from many stakeholders.

5.1.8 Errors

Construction is prone to errors more than other industries. This is due to the many complex details involved. Moreover, no two projects are the same because each project faces a unique set of errors. Some construction errors are difficult to control, there is much that can be avoided. Since there are many causes for errors, we focus on errors caused by poor communication and data completion. This research will test the effectiveness of integrating framework in the progress report and the extent to which stakeholders will agree on the importance of the framework in reducing these causes of errors.

During several visits to the site, it has been noted that the reports are in a form of incomplete photo documentation. In other words, the reports are reinforced with regular pictures on the last pages. Yet, these pictures cannot convey a complete image of the work site.

By substituting the framework of several conventional images in a progress report, it has been assumed that a report with full data pictures might reduce the error rate. This is because the project can be seen from any angle. Moreover, there are several reasons that might lead to a decrease in the number of visits to the site such as the obstacles of visiting the site caused by the COVID-19 pandemic.

By discussing the differences between using the framework compared to the traditional method of integrating conventional pictures in progress reporting, we can summarize some of the results obtained in the table below.

Table 5: Summarize the comparison criteria between using the framework and the conventional pictures in the progress reports

Criteria	Unit	Framework (Using 360° photos)	Traditional means	Comments
Time				
Data Capturing Time	sec	10-15	10-12	One 360-photography equals around six conventional pictures
Data Processing Time	min	10-15	2-4	Stitching process takes time in 360° photos
Finding the location of picture in the job site	min	1-2	5-10	It is easy to use the interactive layout to framework
Cost				
Cost of camera	\$	600-900	200-400	Insta360 one x2 vs phone camera
The possibility of saving the cost of re-work to take a picture	(high/low)	High	low	Approximately, each photo documentation cost 20-50\$ per visit
The possibility of saving the cost of site visits	(high/low)	High	Low	Approximately, each site visit cost 20-50\$ per visit
Cost of training to use the camera	\$	100-150	0-50	Approximately, each training day cost 20-50\$

				per visit
Advantages				
One page of the report includes	Pictures	25-40	1-6	The framework is based on interactive site layout that mapping many pictures
Create virtual tour	(Yes/No)	Yes	No	

5.2 Obstacles of Using the 360-Photography in Progress Reporting in MENA Region

Even among large contracting companies, the lack of knowledge about 360-degree imaging technology is a barrier that explains why it is considered unpopular in the MENA region. This was apparent in the pilot study; where 89% of the respondents of the pilot study’s follow-up survey did not know about 360-photography. The same survey revealed that this lack of knowledge is the main barrier that is limiting the use of 360-photography in progress reporting, as shown in figure 42. Other barriers include the difficulty in using 360° cameras, the high cost of 360° cameras, and the expensive software packages. It is the hope that this research provides good exposure of the technology. The research also acts as guidelines to how to best utilize such technology without resorting to expensive software packages.

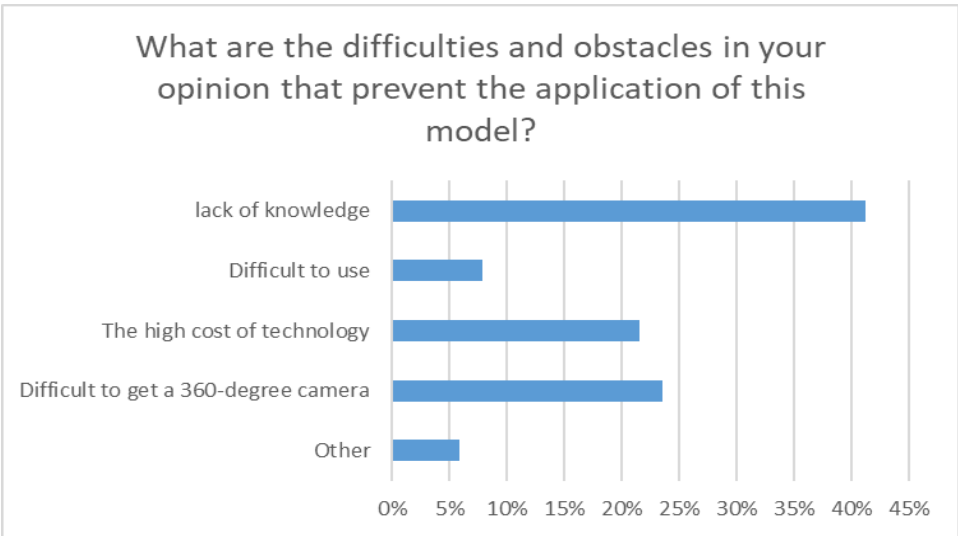


Figure 42: A question in the Case Study Survey to identify the difficulties of using the framework

5.3 Advantages of the Developed Framework

Based on the findings of this research, the advantages of the developed reporting framework can be listed as follows:

- The time taken to capture 360° photo by Insta360 one X2 is approximately the same as it takes to capture using a phone camera, but a 360° photo equals six phone photos.
- The time used to read the progress report and locate the image in the site layout by using the framework is short. For example, one page of a framework has several 360-degree photos, whereas current reports contain about 6-15 phone photos through several pages.
- The framework, in general, saves time in travel, rework, and communication because it is a complete documentation. For instance, the framework allows stakeholders to get a remote access to all the details of the project without physically visiting. Moreover, you will not need to rework capturing because one 360° shoot covers all the details around the camera.
- The framework is based on an interactive site layout, such as that in the commercial applications of OpenSpace or HoloBuilder. This means that you can find the location of the images quickly. Thus, it reduces the effort required to access the project images.
- Despite the 360-degree camera is not as available in the market as phones, the camera costs around \$600 which is not very expensive compared with laser scanning. Moreover, it takes one laborer to take pictures the same as phone photography.
- It has been observed that framework reduces the number of pages of the report which decreases the costs of printing.
- Framework's features are considered an added value to the report: picture history, image

location, well-organized photograph documentation, rapid access to images, easy file sharing, and 360-degree image capability to offer a clear view of the site project. Thus, during any dispute or conflict, the framework may be used in a quick and simple way to issue a Request for Information (RFI).

- A progress report is an essential resource for project follow-up, especially when not all stakeholders are able to visit the site. In this case, the framework plays a significant role in showing the status of the site project.
- The framework is in PDF format for an easy sharing and an increased collaboration. Similarly, QR codes can be used when using paper reports.
- It has been noticed that stakeholders agree to use the framework in reporting to increase productivity by speeding up decisions. In contrast, the current method is time-consuming for to frequently meet all the stakeholders at the site and then make a decision.
- The framework can be used as photographic documentation. It can be referenced in case a verification of something is needed such as the locations of electrical installations or air conditioning (MEP works) instead of destroying walls or ceilings

CHAPTER 6: CONCLUSION

6.1 Research Summary

Enhancing progress reports by visual documentations such as pictures or videos is essential for improving communication, transparency, and trust among stakeholders. In this research, an innovative progress reporting framework that integrates 360-degree photography was developed.

The framework's primary goal is to create a user-friendly virtual tour of the project site in different time periods (so that progress can be tracked). The framework is built through three main steps: The first step is using the 360-degree camera to capture images. The Insta360 ONE X2 camera was used in this research. The second step is uploading the 360-degree images into a platform that supports the 360-degree format. The third step is linking the photos into a pdf layout of the project site. Detailed guidelines were provided to enable users to perform those steps.

The developed framework was used for three months in a pilot study, which involved three different projects in Egypt. The first project was the New Giza University with five academic buildings. The second project was an eight-story residential structure with a 576-square-meter construction area. The third project was a two-story private villa with a 225-square-meter construction area. The results show that the proper use of 360-degree photography in progress reports positively impacts the coordination, transparency, trust, and responsibility division between the project parties.

The developed framework can be the first advantageous step for those who are interested in integrating 360-degree photos to enhance progress reporting in construction projects. Another potential advantage of this framework is that it provides actionable insights in reports whether in paper forms by using QR codes or electronic documents by using hyperlinks in multi-

disciplinary projects. The positive results obtained from the survey after applying framework in several projects give positive indicators of using 360-degree photos instead of conventional photos in progress reports.

6.2 Limitations

While the outlook for 360-degree photography in construction technology is promising, many challenges remain. Some technical limitations at this stage will be summarized based on the survey conducted and by applying the framework in three pilot case studies. To clarify the most important barriers to implementing smart 360-degree imaging technology and its applications in improving reports:

- The significant lack of knowledge about using 360-degree photograph on the construction site in the first survey - before applying framework- was also one of the main difficulties. Overall, the three pilot projects have been for the first time that a 360-degree photography has been integrated into worksites. Therefore, creating a new method in the workplace is not simple.
- Concerning the difficulties of use, despite the ease of photographing, displaying 360-degree images is complicated, especially in the so-called stitch panoramic pictures. This obstacle has been solved when using commercial applications like OpenSpace, and HoloBuilder. Moreover, attaching the 360-degree photo to the site layout needs time and practice. This means that the images are not automatically uploaded to the layout.
- Like any new technology, the cost of using commercial applications is somewhat high. For instance, the cost range typically depends on data usage and time, like \$300 per month or \$5000 per year.
- The camera is not widely available in the market; the camera has been purchased from

Amazon in Turkey. This explains the high rate of acquiring a 360-degree camera as one of the reasons for the limitations.

- Other obstacles which prevent the wide spread of such framework in Egypt and the Middle East commercial applications do not yet support these regions and lack sufficient information about the impact of these technologies.

6.3 Recommendations for Future Research

This study can be extended in the future by being implemented in other case studies of long periods and are based on the feedback obtained in the surveys. Consequently, the smart 360-degree framework is to be the next step in creating a more immersive and 360-degree realistic experiences. It is worth noting that a growing number of 360-degree camera manufacturers are incorporating 3D/volumetric capabilities into their products. Most project case studies, which are covered by the researcher in this study, create 360-degree environments that are designed to enhance reporting using frameworks or other commercial applications. An additional recommendation is the use of artificial intelligence to automatically geotag and stitch pictures, and automatically develop the progress reports. Furthermore, it is recommended to conduct research where autonomous drones could be used to capture images and videos of the construction site, then artificial intelligence could automatically generate the visual progress report and identify areas of schedule slips throughout advancements in computer vision.

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