

Exploring the Benefits of 360-Degree Panoramas for Construction Project Monitoring and Control [†]

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Abstract: In the field of technological construction tools, the 360-degree panorama provides a panoramic virtual reality capable of representing the construction environment in great detail. While there are many studies on their pedagogical and safety applications, few studies address the benefits of their use in construction monitoring and control. For this reason, the present research aims to explore its application and benefits for monitoring and control, the research for which begins with a literature review on the application of 360-degree panorama in construction, where the authors identified the main benefits. In the second stage, the authors analyzed two case studies of its application: the first is based on the construction of a retail project and the second is based on an infrastructure project. After the implementation, the researchers conducted interviews with the team members responsible for implementing the 360-degree panorama. The main benefits of the 360-degree panorama are as follows: a complete overview of the construction site situation, verification of the distribution of the space used, documentation of the current project situations, as well as progress control and quality control. The results help to improve the understanding of this tool's current state of the art in the construction field and open the door to future investigations on cost—benefit analysis that facilitate the application of this tool in construction sites.

Keywords: 360-degree panorama; benefit; construction industry; control; digital

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1. Introduction

Construction projects are complex endeavors that are constantly evolving, with the monitoring and control stage being one in which technology has been invested to improve it [1] because the information-gathering tasks inherent to this stage are often manual and arduous, supported by subjective photographic material that accumulates as waste in the project [2]. Currently, technologies used to monitor and control a project include Laser Scanning [3], Unmanned Aerial Vehicles [4], among others. However, these technologies are often time-consuming and expensive [5].

In that context, there are 360-degree panoramas that are used in construction by offering low computational, low-cost, easy-to-capture, non-computer, and true-to-reality virtual reality simulations to the user [6,7], and that allow reducing non-value-added, costly, and time-consuming activities of the monitoring and control process [5,8].

360-degree panorama is a reality-capturing technique that creates a complete view of the whole region surrounding an observer, giving a "sense of presence, of being there" [9].

Panoramic videos and photos have been used in different areas of the construction industry. In the safety field, Jeelani et al. [10] employed 360-degree panoramic images to investigate the personalized engagement experience. Accident simulation was conducted

within this panoramic vision platform, allowing workers to visualize potentially dangerous situations. As a result of a pilot study, it was concluded that this simulation generated a remarkable sense of immersion among users. Eiris et al. [7] used augmented 360-degree panoramas to represent the construction site to improve trainees' skills in hazard identification, where trainees found this format very advantageous for learning this skill.

In the field of pedagogy, Gheisari et al. [11] applied 360-degree panoramas to teach students how to make free-body diagrams of real structural elements without the need to go to the field in person, demonstrating that this technology can provide the experience of visiting a construction job site without being physically present. Eiris et al. [12] propose the use of iVisit, a platform for interactive guided site tours using 360-degree panoramas and virtual human figures, to address the obstacles of visiting the site in person. This approach was tested by visiting a masonry materials site with 10 students in introductory construction courses. The results revealed that, on average, 86% of the students found iVisit easy to use, while 68.4% perceived it as realistic. Finally, Pham et al. [13] developed a platform with 360-degree panoramas of learning safety practices, where students observed and found hazards at the construction site. They made a comparison with face-to-face and 360-degree panoramas hazard identification, finding that there is no statistical difference between the two methods.

While the most common application of 360-degree interactive panorama is to create virtual tours of complex projects [14], the ultimate goal is to use it in project monitoring and control as a method of managing documentation and assets to visualize components, monitor progress, and document defects or problems [6]. This is because they possess the potential to optimize the flow of information in terms of communication, understanding, evaluation, and implementation of corrective measures in the development of construction projects [8,15,16].

Examples in the literature include the study by Côté et al. [17], who used panoramic cameras to compare reality with a detailed 3D model of a building, obtaining as results that the system provides improved communication between the designer and builder, more accurate work planning, and a better understanding of the work to be done. On the other hand, Eiris et al. [6] detail a workflow to create a virtual panoramic environment by using 360-degree photographs. They then applied this technology to a construction site at the University of Florida cam-pus, demonstrating the technical feasibility and practical utility of generating interactive panoramic scenes of a real construction project complete for asset management and documentation.

From the above, it is understood that there are not many studies focused on the direct application of this technology in the monitoring and control of a project. Therefore, this study explores the benefits of using this technology in the monitoring and control of construction work, through the analysis of two case studies and interviews with the professionals involved.

Table 1. Benefits of 360-degree panoramas.

Benefits	References
Improve flow of communication	[8,15–17]
More accurate work planning	[17]
Better understanding of the work to be done	[17]
Feeling of immersion in the construction site	[7,9,10]
Reduce monitoring activities	[5,8]
Low cost	[7]
True to reality	[7,12]
Visualize inaccessible places	[14]

2. Materials y Methods

The following research is composed of two stages. The first stage corresponds to a review of the benefits of 360-degree panoramas in the construction sector, and the second stage explores the benefits of monitoring and control in two construction projects.

In the first stage, a review was conducted in Google Scholar and SCOPUS, using the keywords "360-degree panoramas" and "construction." SCOPUS was used because, in the construction industry, it has more comprehensive coverage than other databases [18].

In the second stage, the projects described in Table 1 were analyzed. Those in charge of implementation were asked about the benefits obtained during implementation.

Table 2. Projects considered in the research.

Project	Implementation Time	Used Camera
Construction of a retail store	6 months	Richo Theta 2
Infrastructure Project	8 months	Insta360/ Modelo: One R

3. Results and Discussion

In the present section, the benefits obtained by 360-degree panorama will be shown and their benefits will be discussed against the 360-degree panorama literature.

3.1. Project 01: Construction of a retail store

In this project, the implementation of 360° cameras was done with the help of an Insta360/ Model: One R camera and google cloud storage. Figure 01 shows a photograph and the camera used in the implementation.

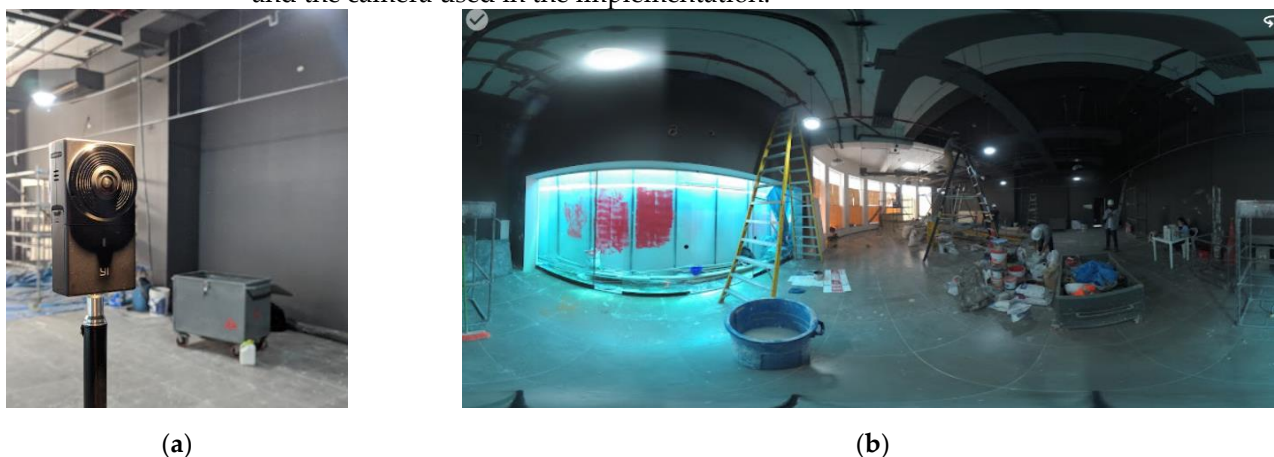


Figure 1. The figures show the implementation in the project: (a) 360° camera used in the project; (b) 360° photograph of construction.

The person responsible for implementation indicated that using 360° cameras for monitoring and control can have the following benefits:

- 360-degree panoramas can help us better understand the situation's full context, unlike traditional photographs. 360-degree panoramas have a wide range of views, allowing us to focus on different activities on the job site.
- The 360-degree panoramas help us not to take too many photos since a single photograph captured the whole environment, and it was difficult to lose the visualization of any part of the project. They also give us a complete overview of the project, which can be used for quality control verification of the space used.
- The camera could be attached to a selfie stick, making it possible to take pictures in hard-to-reach places.
- The 360-degree panoramas allow us to visualize the works that had been eliminated due to a change in the middle of the project. In addition, visualize previous works, such as electrical installations behind the walls, and compare them by different dates.

- Photographs can be shared with clients to reassure them of the progress or reduce their doubts without needing field meetings.

3.2. Project 02: Infrastructure Project

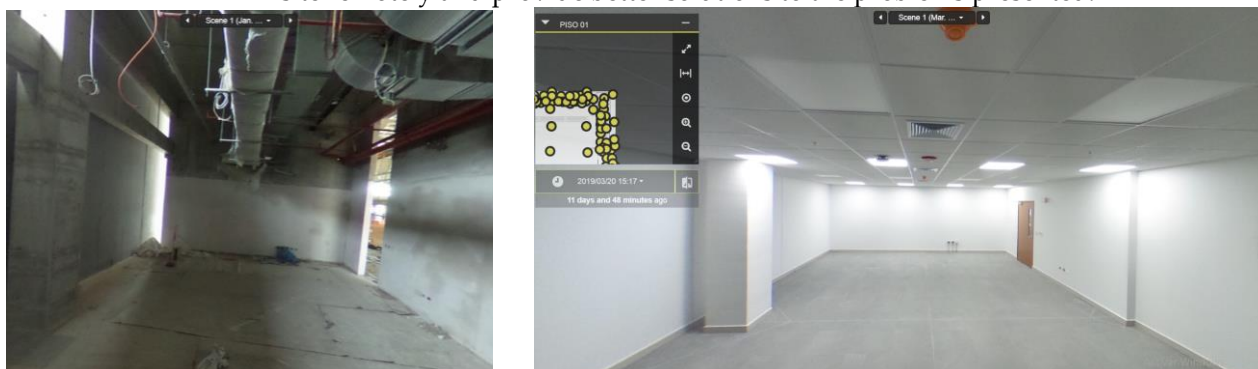
In this project, the implementation of 360-degree panoramas was done with the help of an Insta360/ Model: One R camera and Google Cloud storage. A photograph and the camera used in the implementation are shown in Figure 02.

360-degree panoramas were used to monitor daily progress, allowing for information transparency. Furthermore, the client and the general contractor had access to this information.

The photographs were used after the project for claims substantiation. The 360 photographs were considered evidence of the execution of activities and could show the project's progress, showing four to five parallel activities in a single image. This characteristic was significant in the claims stage because it was easy to locate which subcontractors had worked on a given date and to see if they had enough space to perform their activities and the conditions to perform their activities.

Another significant benefit was that the 360-degree panoramas let all stakeholders be informed about the project's progress in a simple way, without the need for them to travel to the project. In the case of the infrastructure project, they had teams in different parts of the world, and by having access to the 360 photos and project progress, they could be informed of the project's performance simply.

Cameras also promote transparency of project progress information and help improve decision-making. Occasionally, meetings were held with architectural or installation specialists away from the project. With the help of the cameras, they could access the site remotely and provide better solutions to the problems presented.



(a)

(b)

Figure 2. The figures show the implementation in the project: (a) 360° photograph during construction; (b) 360° photograph at the end of construction.

3.3. Discussion

One of the objectives of this paper is to show the application of 360-degree panoramas as a visual technological tool used in the monitoring and control stage of construction projects, as Eiris et al. [6] proposes as future research. The two projects chosen are located in Peru, and as Eiris et al. [6], show that it is feasible to make use of this technology in the monitoring and control of projects, providing multiple benefits.

The review shows that the most common benefit of applying this technology is improved communication and transparency [8,15–17], which is also observed in both projects in the study.

Project 1 explains that it is possible to use 360-degree panoramas to visualize inaccessible areas, as mentioned by Eiris & Gheisari [14]. In addition, it is exposed that there is a greater understanding of the same due to the large capture range of the 360-degree panoramas over traditional cameras, which also results in not having the need to capture a

large number of images of the site, coinciding with what is exposed in the study of Subramanian & Gheisari [5], who also propose that this point provides a reduction of the time on site to perform this activity.

The additional benefit found in this project is the ability to visualize the progress over time of the items through an orderly documentation of the photo-graphs.

In project 2, there were many professionals involved in different parts of the world, so they could not be physically on the project. In this sense, the use of 360-degree panoramas allowed them to be informed of the progress, as if they were physically present, thanks to the sense of immersion [7,9,10] and the resemblance to reality that this technology provides [7,12].

Additional benefits found in this project are improved decision making, the ability to show several activities in one photo, and the use of photos as evidence for claims.

4. Conclusions

This study presents a literature review of 360-degree panorama applications in construction, and the benefits obtained in each, followed by the analysis of two case studies in Peru, and the exploration of the benefits found in these cases.

The review demonstrates that the most common benefit of the application of this technology is improved communication and transparency. Additional benefits to literature found in the present study are the ability to visualize the progress over time of the items through an orderly documentation of the photographs, improved decision making, the ability to show several activities in one photo, and the use of the photos as evidence for claims.

Thus, important issues need to be explored more in the studies that address visual progress monitoring with the support of 360-degree panoramas. Among these, there is a need to determine through statistical tools the most important benefits of the application of this technology in Peru.

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