Application of BIM Collaborate in the Pre-Reinforced Steel System to improve the Collaborative workflow between stakeholders in the Design phase of Building projects

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***Abstract*—With the problems that appear during the coordination and collaboration throughout the building industrialization process, this article explores the functionalities and benefits offered by the BIM Collaborate platform to properly manage this type of construction projects. Since problems of visibility and traceability of engineering appear when not having accurate information, and the participation of all involved. By using the tool, it will allow storing and managing all project documents and data from design to construction, while maintaining real-time information exchange and controlled and configurable workflows for all stakeholders. This study aims to propose the implementation of this innovative platform to improve the collaborative management between client, supplier and contractor during the design stage of a Pre-reinforced Steel System building.**

Keywords—BIM Collaborate, Pre-reinforced steel, stakeholders, workflow, collaborative environment.

I. INTRODUCTION

The construction industry is booming. However, a sector as immobile as engineering and construction is still failing to improve its productivity standards. According to McKinsey, productivity globally in this sector has only increased by 1% per year since 2017, while other sectors such as manufacturing have done so at 8.6% [1].

The increase in the level of industrialization in projects allows substantial improvements in productivity in the construction sector. Nowadays, new systems are implemented in the construction of buildings allowing the prefabrication of structural steel elements outside the construction site in a long supply chain, such as beams, columns, slabs and walls. Through the industrialization of the steel part using BIM technology, the installation and implementation times of these elements are speeded up, maintaining certainty and control in construction costs [2].

As a result, designers, engineers, and workers in the precast industry must focus their attention on the management of precast components. They are associated with a critical and costly process that encompasses design, fabrication, delivery, storage, installation and inspection.

There are also some difficulties in the Prefabrication industry, in the first instance this is due to the information exchange and collaboration that is not achieved between the different parties, such as the designer, supplier, contractors and the client. The information in prefabricated construction is constantly being created and accumulated during the project phases therefore misunderstandings, misinterpretations of data and increased rework can lead to project delays attributed to ineffective collaboration practices.

In second place, according to PlanGrid and FMI's annual report, 30% of construction data is lost from early stages of the project and 52% of all rework is caused by poor data and lack of communication. These statistics demonstrate the need for a centralized communication network and information site for the collection, sharing and management of data generated throughout the project lifecycle [3].

Thirdly, the communication between client and supplier is very bureaucratic, in which there is no fluent communication. To request complementary information, doubts or clarifications of the project in any of its phases it is necessary to issue an RFI's, this process can often take some time, since the design manager can take a long time to respond. Therefore, a major issue is maintaining the integrity of the information in real time and managing its flow efficiently throughout the life of the building. In addition, change, cost and schedule information that is delivered from previous processes (i.e., design, fabrication, logistics) could be updated in a centralized platform to share information among different stakeholders [4].

Evidence shows that web-based collaboration tools and associated mobile app deployments are on the rise. The 2016 Associated General Contractors of America (AGC) and Sage Group's 2016 Business Outlook Survey indicated that 63% of construction companies are implementing cloud-based platforms to improve access to information [5].

In Ahmad and Jing's study [6], they focus on a drawing work production process for the adoption of BIM 360, currently under the name "BIM Collaborate", and improve document management as well as coordination and review of a project's

modeling progress. It concludes that, the cloud tool connects team members and significantly improves coordination and collaboration with a high level of accuracy, speed and improved communication in the process under study. This article contains very useful information for the research since it states that the platform generates benefits in terms of workflow and common data environment for stakeholders.

On the other hand, in the research of Logothetis et al. [7] a comparison is made in total of four cloud-based BIM programs, namely Autodesk BIM 360, BIMServer, Graphisoft BIMcloud and Onuma System. All programs meet the definition of a BIM, which allows the digital representation of the physical and functional characteristics of a structure and also geospatial data. It is concluded that Graphisoft BIMcloud and Autodesk BIM360 offer the most functions for data storage and exchange.

Li et al. [8] develop an IoT (Internet of Things) enabled platform in which all the information collected regarding the location of prefabricated components in real time from RFID (Radio Frequency Identification) and GPS (Global Positioning Systems) can be connected to BIM. Traceability and visibility of information, progress and cost of the physical building are available for stakeholders to monitor the entire process and make decisions when necessary. With the developed platform, the prime contractor can benefit from knowing the real-time information of the prefabrication components. Therefore, on-site data collection is proven to become effective, reliable and value-added.

Chen et al. [9] in their paper proposes a web-based BIM platform for steel structure fabrication, which aims to manage and visualize the fabrication progress in a steel structure factory in China. The proposed platform was developed and tested by using practical projects. As a result, this platform can help managers to make decisions, workers to check quality issues, and other stakeholders to understand the progress of fabrication.

Finally, Caro [10] in his research conducted a search for information on the collaborative platforms that exist in the market and developed pilot tests on 4 cloud-based platforms to compare them and know their advantages and disadvantages, which were BIM 360 TEAM, BIM 360 DOCS, BIM 360 GLUE and TRIMBLE CONNECT. In which the main result was that BIM 360 TEAM, has a higher approval due to the features and functions it offers.

With this precedent, it is concluded that cloud-based platforms resolve collaboration conflicts in projects and the flow of information exchange becomes faster and more secure by storing all information in one place which contributes to the focus of the present investigation. The highlights of Ahmad and Jing's work demonstrate that the cloud collaboration process has a significant impact as a powerful tool for transforming the fragmented method of collaboration into an efficient and highly integrated workflow.

Certainly, the use of technology could enhance this data, while facilitating the flow of information between the parties involved during project development. By having all the data, change information, 3D model updates, RFI's, cost and schedule processing on a single digital platform allows stakeholders to communicate more efficiently in a shared environment. Using the BIM Collaborate tool ensures that information reaches the client in real time, improving traceability from engineering.

II. CONTRIBUTION

A. Method of investigation

The research design was divided into two phases: Theoretical research and Application. The first phase is subdivided into two stages, which begins with the literature review, the search for existing sources related to our problem and proposed solution. A literature review was realized based on the keywords "cloud computing", "pre-reinforced steel", "collaboration" and "workflow" to see the current status of the topic using the Scopus database. We then proceed to the analysis of the information found. In the second phase, the potential functions and benefits offered by the BIM Collaborate platform are explored so that it can be implemented in projects where the pre-reinforced steel system is used. The last phase is related to the validation of the proposed solution through expert judgment.

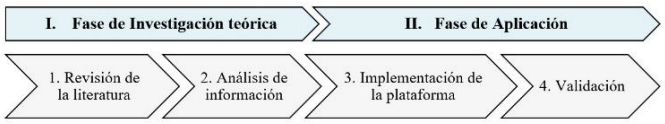

Fig. 1. Research design for the proposal development.

B. The Research Tools

In the present study, it is necessary to define some fundamental concepts, of which we have:

- Autodesk BIM Collaborate

It is a software for collaboration and coordination between different stakeholders of a project. This technology is applied in the cloud giving easy access to all collaborators anywhere in the world.

- Construction 4.0

Can be defined as the digitalization of the construction world where technologies such as robotics, cloud computing, Internet of Things, 3D printing, machine learning are being implemented with the aim of industrializing the construction sector by producing higher output.

- Cloud Computing

Cloud computing offers technological services such as: information storage, servers, databases, all through the Internet. One of the benefits is that it allows to generate backups of stored information. Another benefit is that it can be accessed from any device with an internet connection.

- Pre-reinforced Steel System

This system consists of omitting the cutting and bending parts on site. These items are outsourced by a supplier. This allows to generate a higher productivity in these pre-reinforced elements, reducing considerably the waste and labor in construction.

- Workflow

It is defined as the study of the operational aspects of a work activity in which we can identify how the tasks are structured, how the process is carried out, how it is synchronized and how the fulfillment of the tasks is followed up.

C. Methodology

The implementation of the BIM Collaborate platform is proposed to streamline design and workflow, allowing project stakeholders to review, exchange information and coordinate the same project in real time. The platform includes access to Autodesk Docs, Model Coordination, Takeoff, Build, Insight, Design Collaboration and Cost Management modules.

Since a building project in which the Pre-Reinforced Steel System is used involves the participation of a supplier that supplies the precast steel elements, continuous communication between client and supplier is essential.

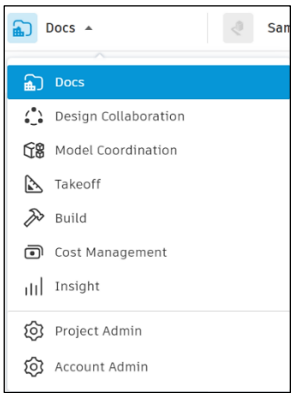

Fig 2. BIM Collaborate modules. [11]

The workflow starts with the delivery of design drawings from the customer to the supplier as shown in Fig. 11. With the cloud-based platform, the customer uploads the files to be delivered so that the other party can visualize the related information and documents. Subsequently, the supplier starts with 3D steel modeling as part of the direct digital fabrication process from the BIM model to automated machines. Similarly, the BIM specialists in charge of the modeling upload the generated files to the cloud for the customer to have greater visibility of the ongoing design work and track progress. In case there are updates to the design due to issues and/or specialties compatibilization, the Model Coordination module allows multiple models to be uploaded to create a complete master schematic with conflict detection analysis and also integrates with Navisworks Manage for additional functionality. RFI's or other records can also be stored in the platform for immediate response, as they are often requested by the supplier to correct certain errors or ask for details that are not clear. This section presents the main functions of the BIM Collaborate tool:

1) The 2D and 3D File Viewer

Allows you to view 2D and 3D files directly from the browser without the need to install additional software or download the file. The visualization is done through the Autodesk Docs module, which has multiple tools to view the model from any perspective, as well as the properties and metadata of the objects. It also allows simultaneous visualization of 2D and 3D data on a single screen. In addition, it supports desktop formats (Word, PDF, PowerPoint, etc.), multimedia formats (images, videos) and 2D and 3D design formats (AutoCAD, Revit, Navisworks, etc.).

2) Multidisciplinary design collaboration

Each project requires a unique approach and has different dynamics among the teams charged with completing the work on time and on budget. Based on this variety, Design Collaboration allows teams to choose how they collaborate with other teams. Sometimes they need to be constantly in synchronization, while in other cases they need to control the exchange of information between them (Fig 3.).

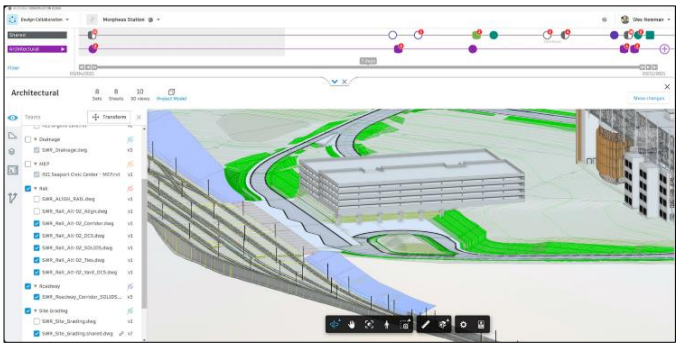

Fig 3. Automated visualization experience for all project team members.

3) Easy file sharing

The files uploaded to the platform are shared easily and quickly, by creating a link that can be sent by e-mail, chat or embedding the link in any desired site, which facilitates collaboration among users (Fig 4.). It should be noted that in order to secure the shared data, a password can be assigned if deemed convenient and also select which functions can be performed by the members, who have the access link.

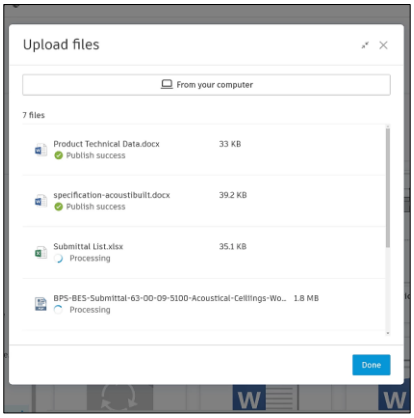

Fig 4. Shared files in the cloud.

4) Real-time file review

In the platform there are options to create work teams according to the project to be developed and thanks to its file sharing function it facilitates the accessibility of all those involved for a better review of the project and the files contained in it. It is

possible to insert comments and observations, which are visible to the entire work team.

In this way, it is possible to keep better track of progress, project changes and design updates, as well as stored documentation. All the above can be performed and visualized in real time from any device, even from a smartphone, speeding up the communication of those involved.

5) File Storage

You may upload and access files of any type, at any time and in any place. Initially, the platform provides 5GB of storage free of charge; if more capacity is required, a fee must be paid. In addition, it makes it easier for users to always work with the correct version of the file, since it allows them to upload updated versions of files so that they do not lose the sequence of work with files that already have observations.

On the other hand, the project folders are kept in order and therefore it is easier to manage the required plans and documents; it is also possible to make recoverable backup copies ensuring the protection of the files (Fig 5.).

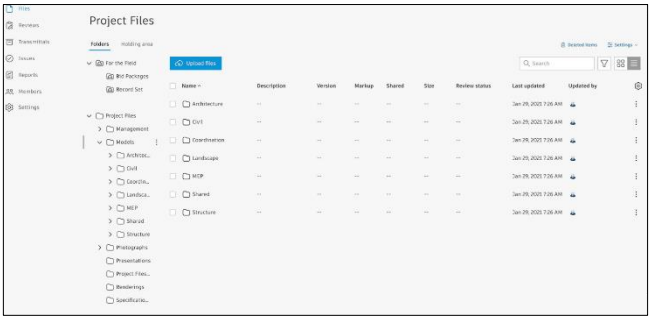

Fig 5. A unique source of information.

6) Modifications analyze

By visualizing and comparing any combination of 2D or 3D models, you can extract information on how changes in different disciplines affect the planned work, even with previous versions (Fig 6.).

In addition, monitoring groups can be set up to track and analyze changes for automated notifications. In this way, both the supplier's and the client's teams will be synchronized in the event of any eventuality to respond immediately and make timely decisions.

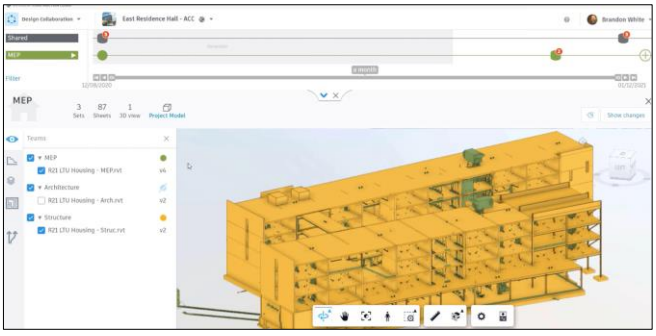

Fig 6. Visibility of any combination of 2D or 3D models in Design Collaboration.

7) Automatic conflict detection

When adding models in a coordination folder in the same way as when adding models in a coordination space, all conflicts between models are automatically detected. This is thanks to the Model Coordination feature, when loading models, conflicts can be automatically detected.

You can see the results in an intuitive matrix, conflicts are identified and grouped to prioritize the work. It allows easy access to issues in Navisworks and Revit to correct models, validate designs and close issues (Fig 7.).

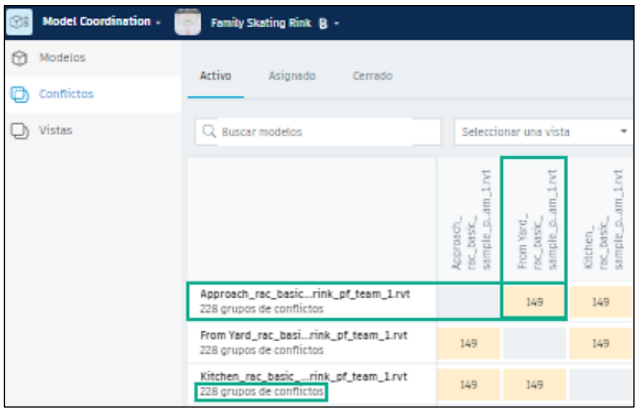

Fig 7. Conflict analysis in shared models.

8) Project Activity Tracking

The design team and other members can make use of the time sequence view to easily observe dates, data content and packages (models, views, drawing sets and supporting documentation) shared through the interface (Fig 8.).

Fig 8. The official record of the exchange of submissions throughout the project.

The use of the cloud-based tool does not require expensive devices at all, the essential thing is to be connected to the network. The basic requirements to start using it in a simple, efficient and trouble-free way are as follows:

- Internet: Es recomendable contar con buena conexión a una red de internet para visualizar sin inconvenientes los archivos más pesados como los archivos 3D.
- Navegadores: La página oficial de Autodesk recomienda utilizar las versiones más recientes de los siguientes

navegadores: Google Chrome, Mozilla Firefox, Apple Safari y Microsoft Edge.

- Hardware: Para el uso satisfactorio de la plataforma, se pueden utilizar computadoras de escritorio o laptops, tablet o un smartphone con sistema operativo Android o IOS.

- File types: The tool supports more than 50 formats. In Table 1, it presents the supported 2D and 3D design file formats, it also supports multimedia file formats and the office file formats as mentioned above. multimedia file formats and office file formats as mentioned above.

TABLE I. SUPPORTED FILE TYPES FOR 2D AND 3D DESIGN

TIPOS DE ARCHIVO DE DISEÑO 2D Y 3D						
3DM	DLV3	G	IPT	RVT	SMT	XPR
3DS	DWF	GBXML	JT	SAB	STE	X_B
ASM	DWFX	IAM	MODEL	SAT	STEP	X_T
CAM360	DWG	IDW	NEU	SESSION	STL	XAS
CATPART	DWT	IFC	NWC	SKP	STLA	
CATPRODUCT	EXP	IGE	NWD	SLDASM	STLB	
CGR	F3D	IGES	OBJ	SLDPRT	STP	
DAE	FBX	IGS	PRT	SMB	WIRE	

D. Results.

Autodesk BIM Collaborate offers the convenience of cloud computing by providing the network infrastructure to efficiently store, exchange and synchronize common data. In addition, the workflow supports three (3) main elements of design coordination, collaboration and monitoring.

A first test was carried out to learn about the options and functions of the BIM Collaborate tool and to check if it is applicable to projects with the Pre-Reinforced Steel System. It was verified that all those involved who are invited to join the platform, can visualize 3D models, 2D plans, reports, schedules or any other format, directly in the cloud and through any device or equipment without requiring knowledge for the handling of software or great technical features.

In this way, it is possible to establish automated communication on incidents, errors, queries and requests for information, without omitting the traceability of the changes made, comments and versions of the documents (Fig 9.).

The client can view the supplier's work, provide comments and annotations of the 3D model, and can be made on-site or remotely via live review (Fig 10.). All of this allows stakeholders to track comments and respond accordingly.

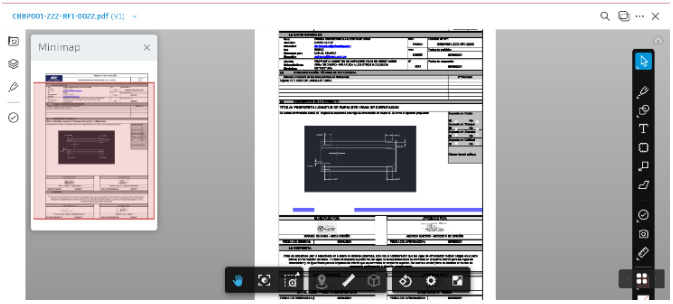

Fig 9. Viewing documents in BIM Collaborate.

In conclusion, this platform is presented as a solution to integrate the work team (client, supplier, contractor) allowing a more fluid collaboration between all involved, which is generated during the life cycle of pre-reinforced steel building projects at a single site and/or environment in real time so as to contribute to the root cause analysis of constructability problems and synchronization of the teams to improve project delivery.

Fig 10. Visualization of 3D model on the platform.

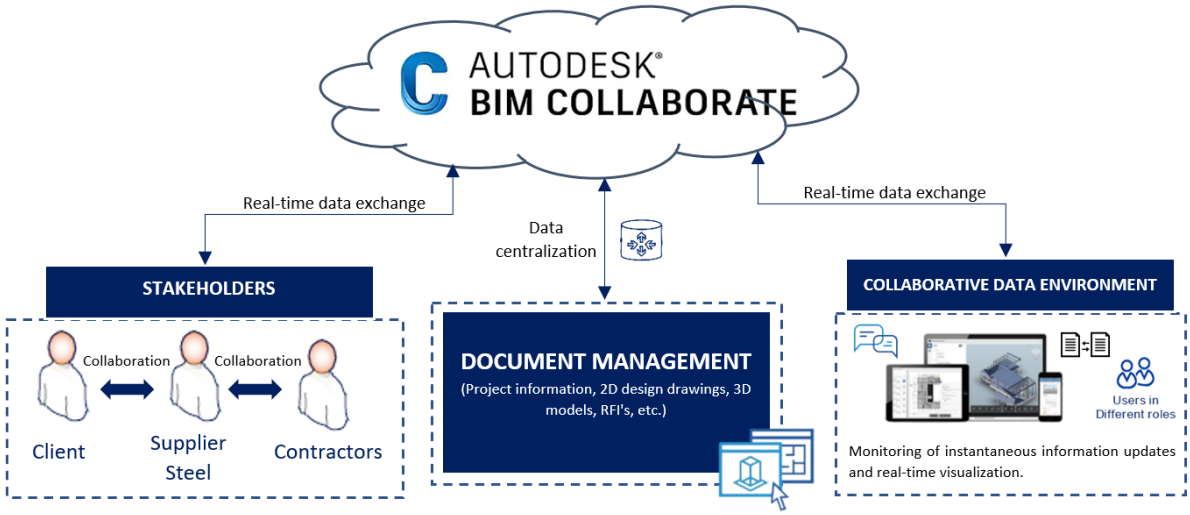

Fig. 11. Workflow with Autodesk BIM Collaborate.

III. VALIDATION

In the validation stage, it was chosen to use the expert judgment tool through the development of a survey, an essential point of this research. They were conducted online with twenty industry experts who have at least 5 years of experience to more in construction projects and topics related to the study. The interviewees are managers and/or consultants who are highly knowledgeable about digitalization in the construction industry. Therefore, due to their experience they have a better notion to answer the questions posed for the validation.

A survey consisting of 10 questions was developed, however for this research the series related to the topics of interest (Table 2) using the Likert scale is presented, which are cloud technology and pre-reinforced steel system, benefits and limitations of the cloud platform, as well as the integration of the platform in projects with pre-reinforced steel system.

TABLE II. SUMMARY OF QUESTIONS IN THE SURVEY APPLIED.

QUESTIONS
P1. How much do you know about the Pre-Reinforced Steel System?
P2. Do you know about cloud computing for project management?
P3. What do you consider to be the most relevant benefits of a cloud platform in construction projects?
P4. What would be the limitations for the integration of a cloud platform?
P5. Do you consider that a Pre-reinforced Steel System with a Cloud could be a good integration to improve collaborative work?

In the first proposed question, the subject matter experts were asked how much they know about the Pre-Reinforced Steel System in construction. According to the results obtained in the expert judgment, it can be observed that most of the respondents know or have heard about the pre-reinforced steel system. The data obtained are on a scale of 3 to 5.

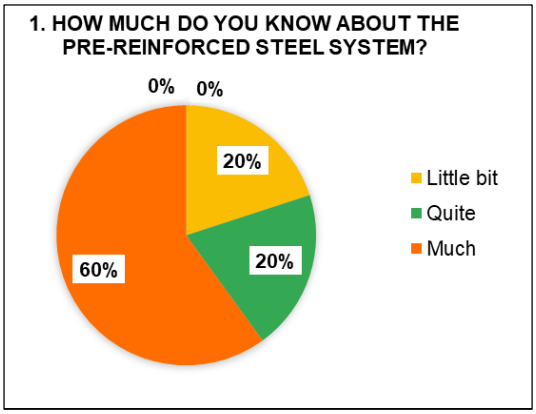

Fig 12. Question 1 for validation by expert judgment.

The next question posed, is made in order to know if the experts have knowledge or have heard about cloud computing, also the Likert scale is used from 1 meaning nothing, up to 5 which is a lot. It can be seen in the graph that a very high percentage of respondents know about this technological tool that has been implemented lately with the advent of the era of digitization in construction.

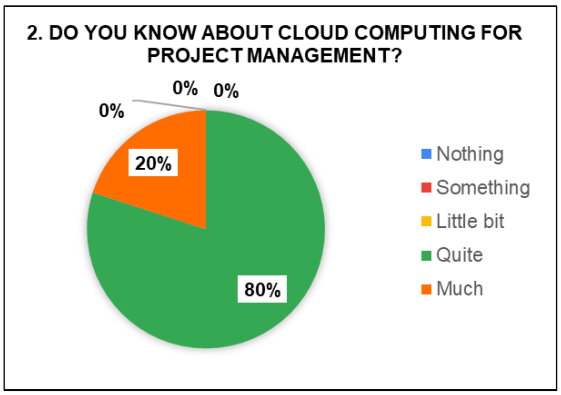

Fig 13. Results of question 2 by expert judgment.

For the third question, the main benefits offered by the platform are presented so that the experts can evaluate the level of importance of each aspect for the success of the project. It should be noted that, for the elaboration of the graph, the most incident response of each alternative was used. It can be seen that most of the experts are of the opinion that the centralization of information is the most representative benefit offered by the tool.

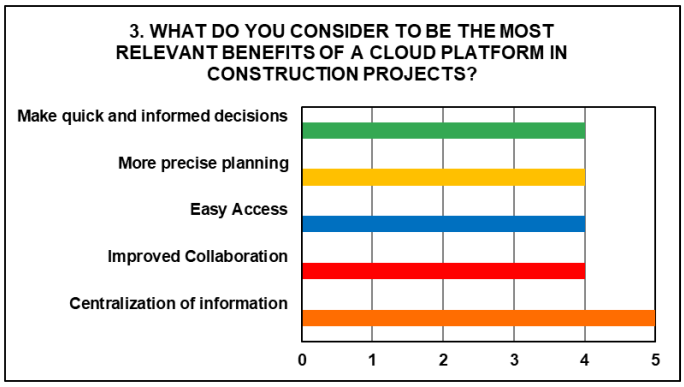

Fig 14. Results of question 3 by expert judgment.

The implementation of a new system or tool is often difficult and complicated, due to the adoption of a new methodology in the way of working. The fourth question describes some limitations that prevent the implementation of the cloud platform. One of the most incident resulting limitations is the economic aspect. Given that many of the products offered by Autodesk present high costs.

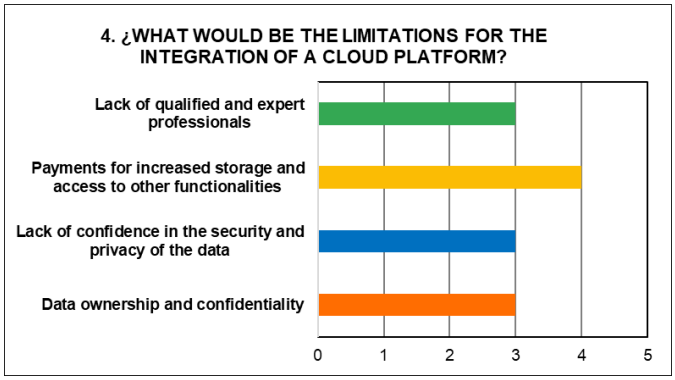

Fig 15. Results of question 4 by expert judgment.

In the fifth question, it is formulated if it would be a good integration the cloud-based tool for the improvement in the exchange of information to manage projects with the pre-assembled steel system. With the results obtained, the experts validate that the BIM Collaborate tool will be very useful and has great potential to be implemented in this type of projects as it contains several options to solve the problems related to collaboration, centralization and information exchange at any stage of the project using pre-reinforced steel, which requires constant interaction, coordination and communication between those involved (mainly between client and supplier).

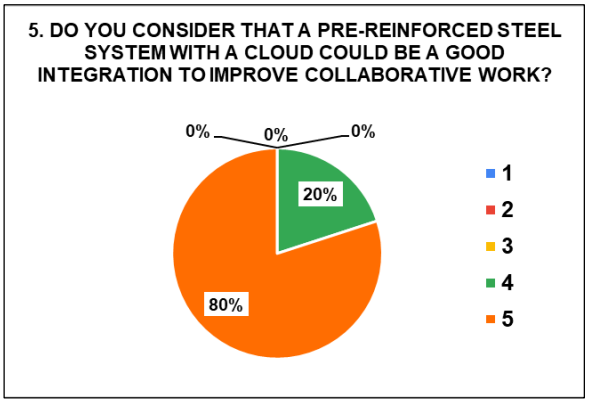

Fig 16. Results of question 5 by expert judgment.

IV. CONCLUSIONS

The use of prefabrication significantly reduces labor, execution time and considerably increases productivity and quality of deliverables. and the quality of the deliverables. However, having a poor visibility of the elements or not having an order in the information causes delays in delivery times, increasing deadlines and costs.

Several researchers have addressed this problem, agreeing that the construction with pre-reinforced steel system cannot be cultivated with an incomplete, inaccurate and untimely data exchange and lack of visibility and traceability in real time.

Digitization in the construction industry is driven by the transformation of remote collaborative workflows, with which it is possible to decrease the resources used, the time required to execute tasks and errors, resulting in cost reduction and optimization of the project lifecycle.

The implementation of the BIM Collaborate tool makes it possible to centralize information in an orderly and joint manner, since it can be viewed by any member of the project from any device (computer, laptop, tablet, mobile). In addition, it offers tools to visualize files in 2D and 3D, it is possible to interact in real time with the work team and it allows to store information with a capacity of 5GB free of charge.

In this study, a workflow is developed between the client and the supplier, where the use of the tool allows coordinating with the work teams, storing project information in a single place, and having real-time information, ensuring that managers can continuously monitor the project.

In addition, a survey of experts in the field was conducted, in which most of them (80%) validated the proposed solution, recognizing the benefits of the tool in the interaction between those involved. They also identify the limitations for the implementation of this technology in our sector. The main limitation is the economic factor, since, if the company requires a greater capacity to store data or some other specific functionality, prices depend on the number of users that will join the cloud. Finally, specialists consider the integration of BIM Collaborate with the pre-reinforced steel system as a great contribution.

After having examined different research as part of the state of the art and having used such tool, we can conclude that BIM Collaborate is a potential tool that would improve the workflow between collaborators during the whole project, storing all the data and information that is generated in projects with pre-reinforced steel system.

It is concluded that, it is feasible to use this tool in order to streamline the workflow in the design phase of projects with Pre-reinforced Steel System, reducing resources and time when interacting between stakeholders. In this sense, it also promotes collaborative work among project participants.

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