International Journal of Computing Sciences Research (ISSN print: 2546-0552; ISSN online: 2546-115X)
Vol. 8, pp. 3311-3325
doi: 10.25147/ijcsr.2017.001.1.218
https://stepacademic.net

Short Paper

Engineering and Construction: 3D Model Review and Tagging System

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Date received: May 6, 2024
Date received in revised form: July 7, 2024; July 16, 2024
Date accepted: July 17, 2024

Recommended citation:

Rosos, A. J. A. (2024). Engineering and Construction: 3D Model Review and Tagging System, *8*, 3311-3325. https://doi.org/10.25147/ijcsr.2017.001.1.218

Abstract

Purpose – To develop an application to enhance the model review process in engineering and construction projects by leveraging the functionalities of 3D design software.

Method – Rapid Application Methodology, or RAD, was mainly used in the study. Visual Studio is the main IDE used in the development of the web application and of the plugin for the 3D design software, which is Autodesk Navisworks. The backend language used was *C#*, followed by MSSQL for the database server and IIS for the web server. As for the evaluation of the functionalities of the system, forty engineers participated.

Results – In order to make decisions during the model assessment and produce real-time reports, the respondents were able to get more data from the 3D model. The web application allows for the sending of notifications or announcements, model evaluation reports, and profile administration for users. Additionally, the applications make use of an SMS module, which enables field-based engineers to get notifications even in the absence of an internet connection.

Conclusion – By integrating 3D design software and a web application, it was discovered that the designed applications could improve the 3D model review. As perceived by the respondents, the system is functionally acceptable, indicating that the study's design framework can be feasibly implemented.

Recommendations – The study focuses on two types of applications: web-based and desktop. Thus, it is recommended that a mobile application be developed as an additional platform for the engineers for easy accessibility.

Practical Implications – Though modern 3D model review tools like Autodesk Navisworks offer comprehensive review solution in engineering and construction, they are expensive for most small engineering businesses. The use of technological solution for 3D model review will benefit the various engineering organizations since it will give them the advantage of presenting the current stage of the designs to their clients in almost real-time.

Keywords – 3D, model review, design, engineering, construction

INTRODUCTION

As new technology startups emerge, the engineering and construction sectors enter a new era where project design, planning, and execution are being transformed by these new technologies. These forward-thinking software vendors are solving many of the issues that have plagued the engineering and construction industry for decades, such as challenges with evaluating, gathering, and sharing project information, by offering cutting-edge software, hardware with an emphasis on construction, and analytics capabilities. The timing of these changes could not be more ideal, as the complexity and cost of engineering and construction projects are rising, placing more and more pressure on management and clients to reduce costs and increase timeliness and efficiency. Construction management suffers many problems, and most of these problems is practical and need to be solved or better understood. As a result, the construction industry is overwhelmed by delays and has often suffered cost and time overruns because of change orders, rework, decreased constructability, and delays and claims (Rodriguez et al., 2019).

Because of the many stages that engineering projects must go through to be finished, they may be rather demanding. A construction design must use an authoring tool such as Autodesk Navisworks to be examined and approved by the appropriate authorities to comply with building codes. In engineering and construction projects, model review workflow and process may differ, and Autodesk Navisworks only supports the basic model review process which is the tagging, and it is uncapable to produce comprehensive reports in real time and approval process. Design Review is a well-established way of improving the quality of design outcomes in the built environment (Design Council, 2019). There's an increase in pressure on engineers to offer designs that

can quickly connect to clients, and 3D models and visualizations have a higher chance to succeed with this (Dean Group, 2017).

The objective of the study is to develop a 3D model review and tagging system integrated with Autodesk Navisworks that can easily generate reports after each model review and that can notify users via E-mail or SMS. Thus, the project's explicit goals were to accomplish the following:

- to provide common data environment of the model review session.
- to provide easy and secure access of the model review session file.
- to enable the creator of the model review to manage and organize the model review session online.
- to enable engineers, managers and clients to communicate their comments and to review tag status via web application or Autodesk Navisworks application.
- to provide accurate reports that can easily be access via web application.

LITERATURE REVIEW

The importance of technology adaptation in construction

It is imperative for construction businesses to digitalize the way they manage data, to unlock actionable insights that improve productivity and ultimately, the business bottom-line. Through integrated platform, we enable smarter construction by providing real-time visibility and insight into all aspects of project performance, so that construction businesses can benefit from a better control of their projects and deliver higher quality builds (Malaya Business Insight, 2022). Innovation and technological developments are integral parts of the architecture, engineering, and construction (AEC) industry (Adibfar et al., 2020). A building is an investment for decades. So, if we can adopt the right building standards we can lock in energy savings, water savings for future generations (ABS-CBN News, 2018). Building design has had a long tradition of collaborative work, however at the design stage this work is usually based on physical meetings between representatives of the different design disciplines (Cárcamo et al., 2016). Until recently, the project's stakeholders would enter information regarding their part of the project, i.e., input parameters, in data libraries (Begić & Galić, 2021).

Today, great many digital technologies are available, and more are under development. With a systematic approach to digitization based on its four technology areas (automation, digital interfaces, connectivity and data), there is great potential for streamlining value chains in the construction community (Rempling et al., 2019). Competitive pressures and client requirements are beginning to erode this entrenched culture, forcing construction firms to find efficiencies in existing processes (Stewart, 2007).

Related Studies

Engineers usually combine plan, elevation and sections to visualize (in mind) and communicate project components or projects even. Delay usually occurs in visualization and then conveying the decisions based on those visualizations to sub-ordinates. The other problem on sub-ordinate side is that sometimes it becomes difficult for them to read those visualizations or suggest their visualizations. Similarly at the assessment and review stage, measurement process, data collection and knowledge management are issues crucial to the development of an improvement plan (Robinson et al., 2005). Often, they were too expensive for low to mid-sized firms to utilize (Pinoy Builders, 2020). Published literature shows that 30% of the construction cost is attributed to rework. Moreover, change orders are considered as the largest source of construction waste (Porwal et al., 2020).

To brief how it reduces time and cost of project is that it integrates many disciplines of engineering in virtual world and creates visualization of complex project. A 3D modelling software like SketchUp, don't sacrifice usability for the sake of functionality. Just by drawing lines and shapes, push and pull surfaces to turn them into 3D forms, stretch, copy, rotate and paint to make any desirable shape. It has adopted the medium of visualization and presented physically in the form of software where communication of visualization is much simpler and cheaper and hence helps in reducing time and cost. Keeping in view that limited time and cost are the major issues of every industry specifically of construction industry, this piece of research will focus on these two factors. In the field of building construction, the implementation of Building Information Modelling (BIM) has become increasingly important in recent years (Lumbera, 2022). Substantial research efforts have thus been devoted to these topics in recent decades (Yin et al., 2019).

METHODOLOGY

Software Development

Rapid Application Development or RAD approach was used, it is an effective ally in the construction project's rapid phase when it comes to achieving faster, more effective software development.

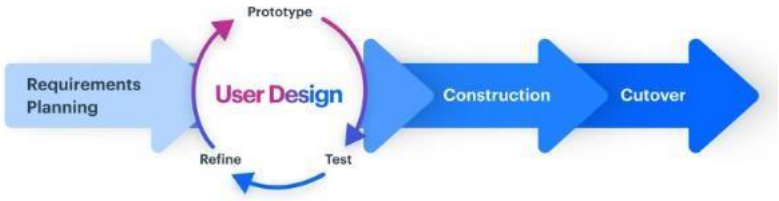

Figure 1. RAD Methodology

The application is integrated with a 3D modelling software, so it is recommended to test the functionalities from the 3D modelling software first which is required by the application. By using this methodology, the researcher can build a quickest possible functional working model for the application considering the tight deadline of the engineers and designers. Reliable feedback from trustworthy sources can be very beneficial because prototypes developed using the rapid application development paradigm rely on the engineers' and designers' input from earlier versions. Rapid prototyping and prompt feedback are given precedence over protracted development and testing cycles in this software development process.

Project Design

The project's system architecture is depicted in the diagram below, which depicts the conceptual model that defines the system's structure, behavior, and flow. The user can access the 3D model review system (website and plugin) from his or her workstation.

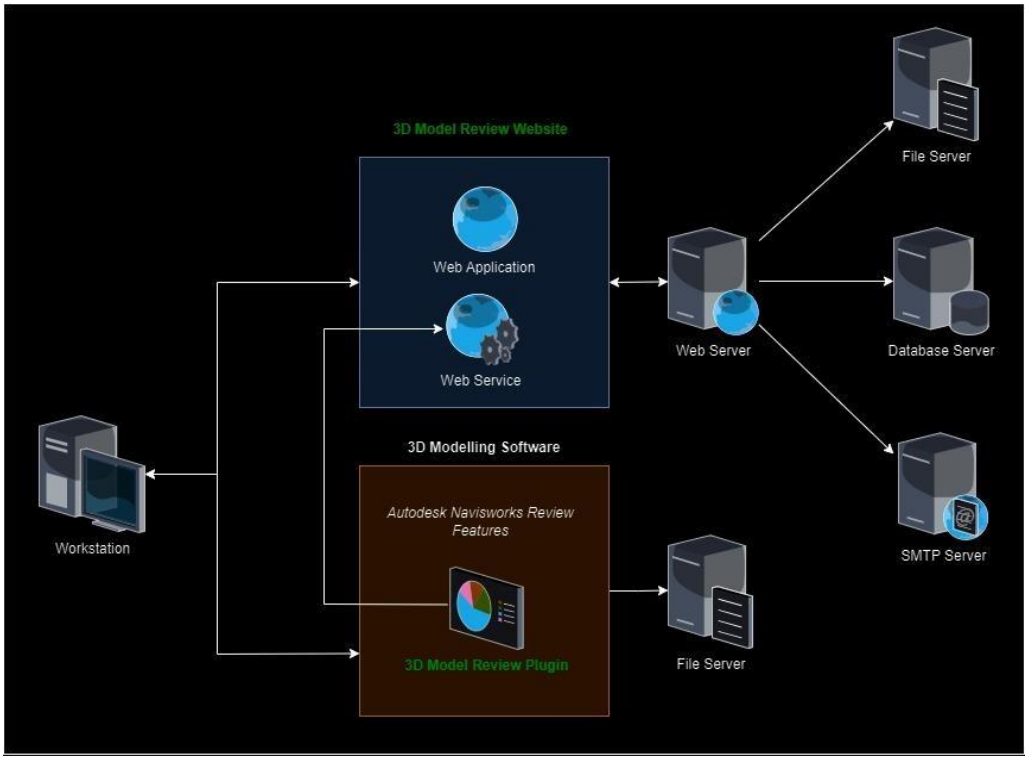

Figure 2. System Architecture of 3D Model Review System

Firstly, by opening the 3D Modelling Software which is Autodesk Navisworks. The plugin can be used to tag a model. Each tag including the snapshots, comment and the markup will be saved temporarily in the file server. Then once user ended the session, the

system will automatically save the data in the database by consuming the web service from the 3D Model Review Website. Once saved, the system will also automatically notify the designer by calling the email host from the SMTP server. Finally, by opening the 3D Model Review Website by accessing the web server. The web application is commonly stored in the file server. It also directly communicates to database server for any operation requesting by the user.

Visual Studio was used to develop the web application and the plugin of the 3D design software which is Autodesk Navisworks. The backend language used was C#, followed by MSSQL for the database server and IIS for the web server.

Use Case Diagram

The researchers used a use case methodology to show the behavior or functionality of a system. Use cases were developed as outlines of the system before delving into the details. In the early iterations, each application was described as a high-level package use case, which was considered architecturally significant. The high-level use cases were then described in detail. The detailed descriptions of the use cases were carried out in the flow of events, on which the stakeholders agreed. In this front-end activity, the use cases were used to capture what the system should do from the user's point of view.

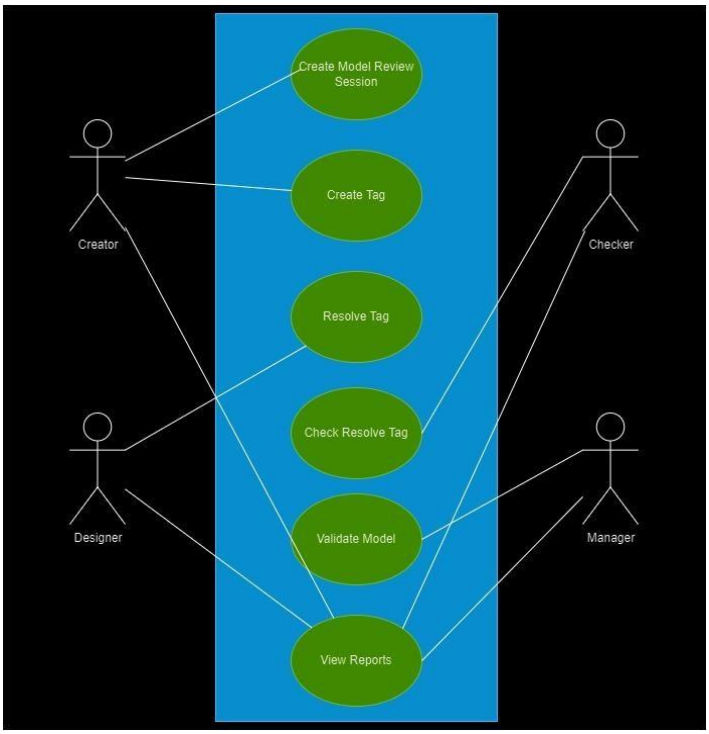

Figure 3. Use Case Diagram of 3D Model Review System

The use case diagram above illustrates and names the interactions that take place between the system and its actors. Use-case diagrams do not show how the system internally operates; instead, they describe what the system does and how the actors interact with it. Along with the six primary functions of the system, the above diagram also shows the four categories of actors: Creator, Designer, Checker, and Manager.

Software Evaluation

To ascertain the developed systems' functionality, testing and a survey were carried out. A method called purposive sampling was employed in this investigation. Forty people participated in the actual system demonstration, which was held in front of the engineers and designers.

Table 1. Likert Scale

Scale	Description	Rate
4.21 – 5.00	Very Satisfied	5
3.41 – 4.20	Satisfied	4
2.61 – 3.40	Neither Satisfied nor Dissatisfied	3
1.81 – 2.60	Dissatisfied	2
1.00 – 1.80	Very Dissatisfied	1

The table above will show the Likert scale, this displays the respondents' numerical rating for the software. It was applied to assign a functional rating to the evaluation responses. Additionally, it displays the range and the linguistic interpretation of meaning that corresponds with it. It is applied in interpreting the questionnaire's results.

RESULTS

Presentation of the System

This is the basic tagging feature of Autodesk Navisworks, as shown in Figure 4 below; only the comment field and status field are available for engineers.

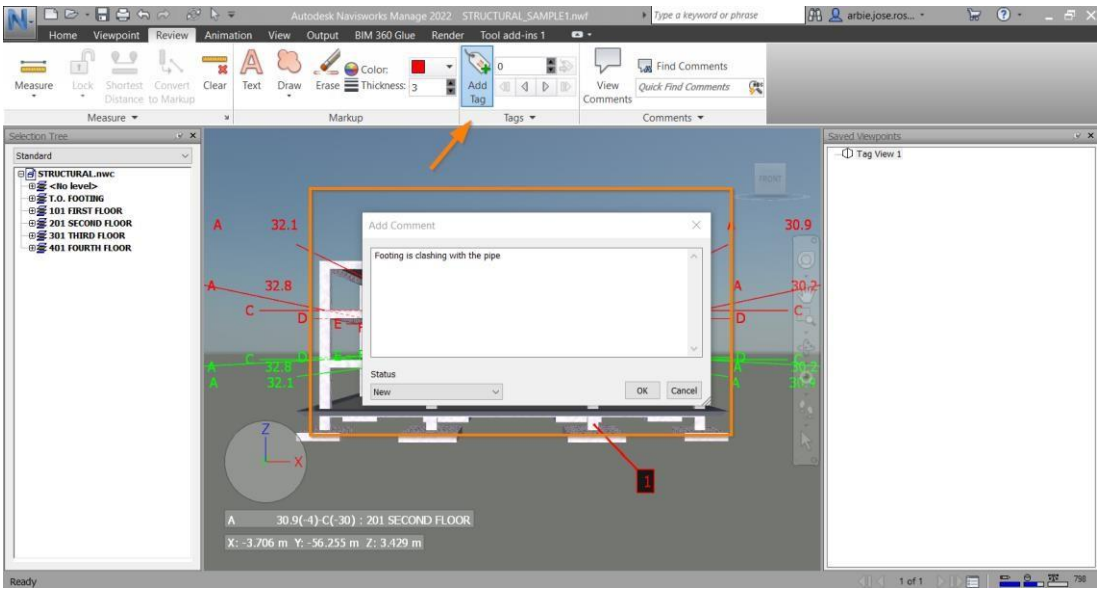

Figure 4. Creation of Tag in Autodesk Navisworks

Figure 5 below shows how to access the 3D Model Review Plugin from the Autodesk Navisworks Tool add-ins menu. The plugin window will show all the lists of tags created. The creator can add additional information about the tag by clicking the Convert tag button.

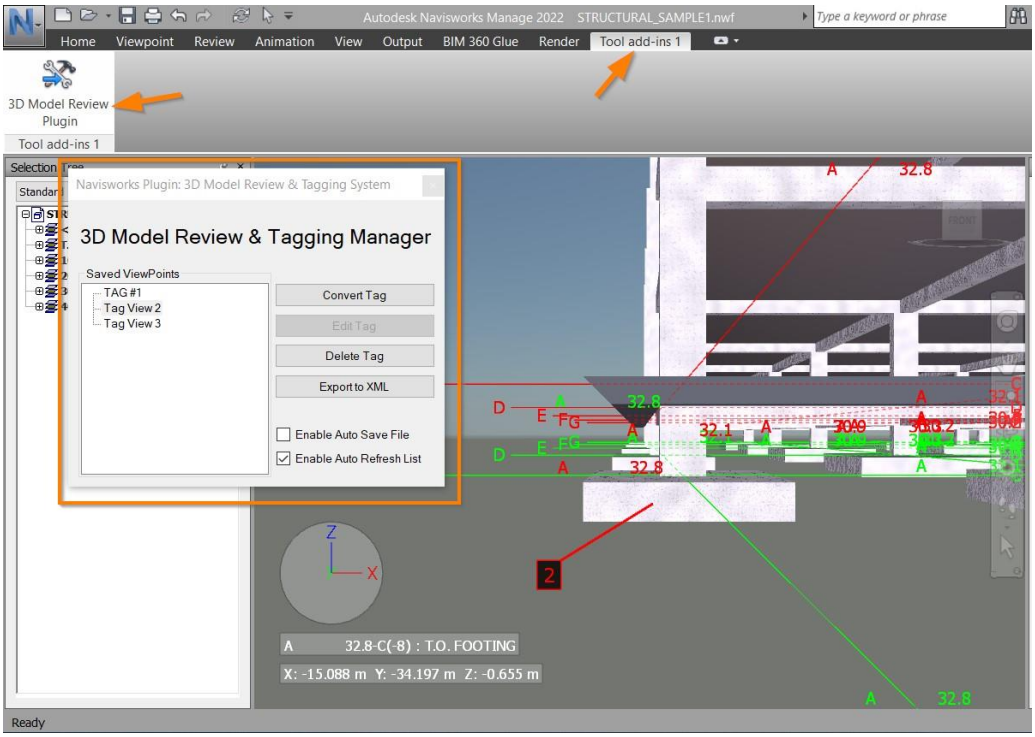

Figure 5. 3D Model Review Plugin

Once the tag is converted by the plugin, the system will capture the information and the snapshot of the model. The engineers can now view the details by clicking the Edit Tag button from the main window of the plugin, as shown in Figure 6 below.

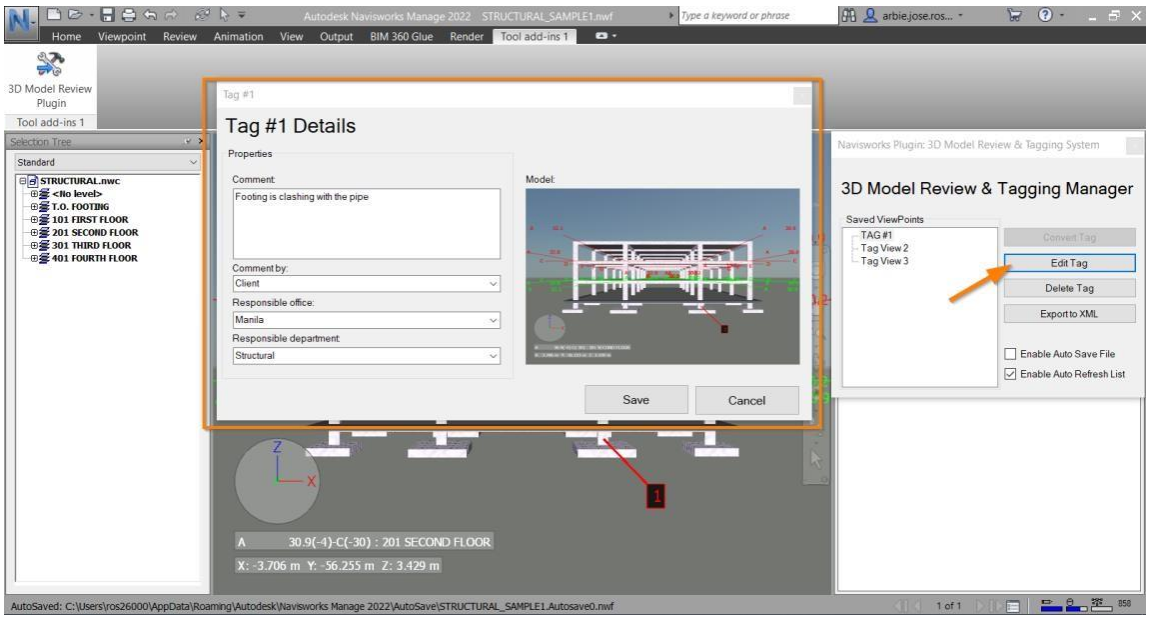

Figure 6. Tag Details Window

Figure 7 below shows the list of all the converted tags on the Tag page of the 3D Model Review & Tagging System Website. Only tags for the current session will be displayed here. The total tags assigned to each department can also be viewed on this page.

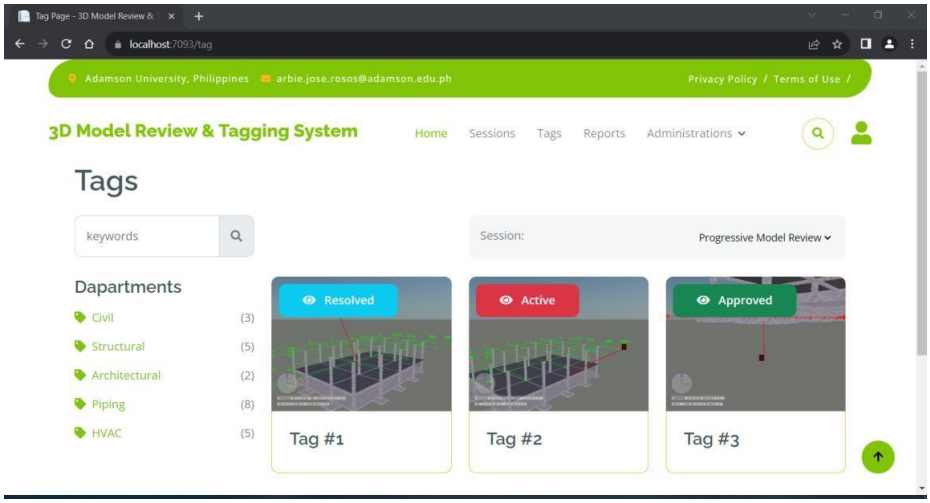

Figure 7. 3D Model Review & Tagging System Website

Figure 8 shows the details of the selected tag. The available information is the session, status, creator, checker, approver, name of the engineer who resolved the tag, and department. The status can be changed by clicking the button below the status label. Only the checker and approver can change the status. On this page, engineers can check the comments about the tag, as shown in Figure 9.

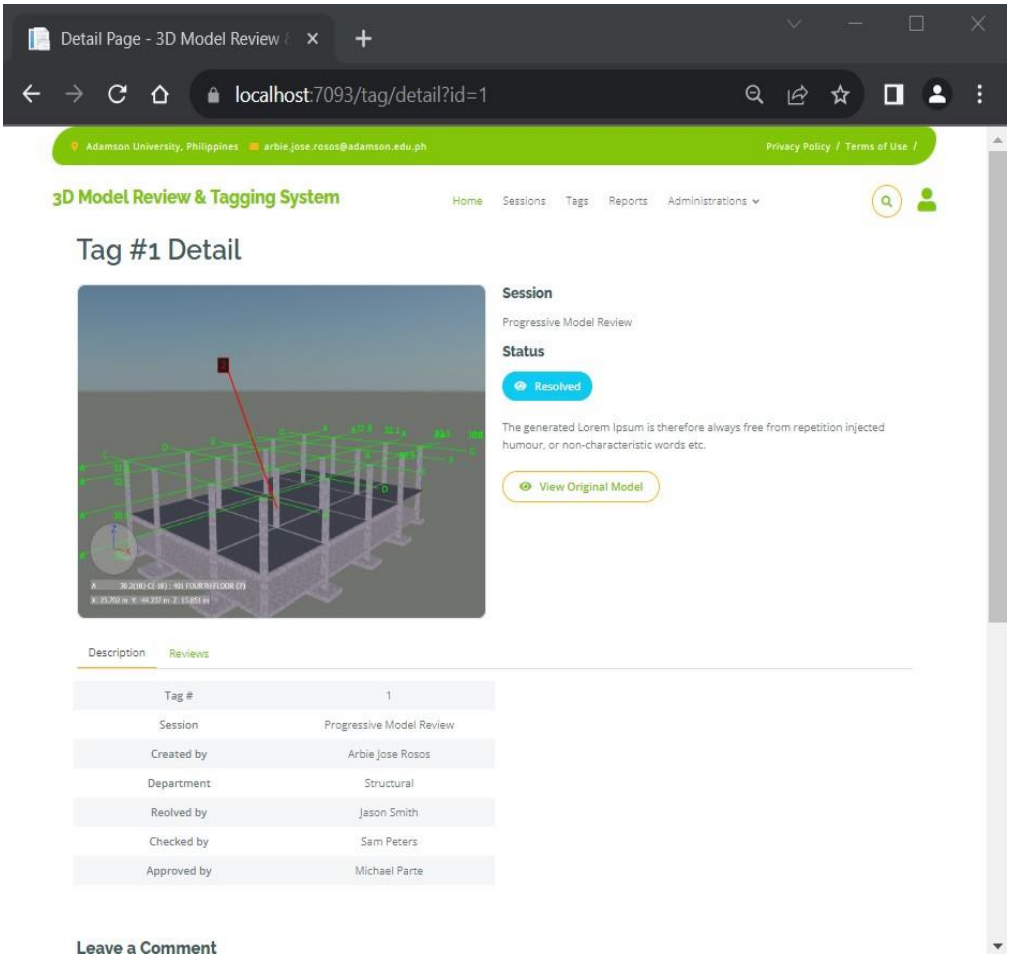

Figure 8. Tag Detail Page

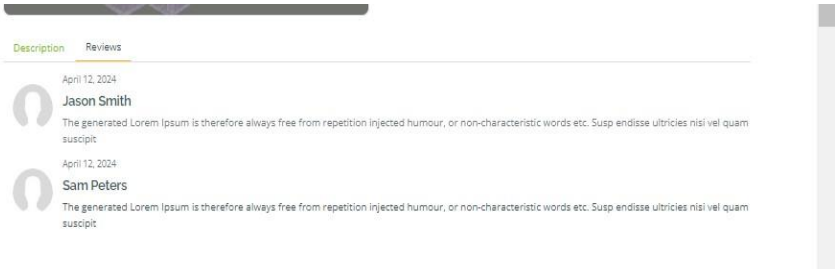

Figure 9. Tag Detail Page Review Tab

DISCUSSION

It is important to note that the term "model" frequently refers to a federated model (composed of multiple, integrated data sources), and the model is an information model, not necessarily requiring 3D information for all its components (Mitchell et al., 2022). The core of a model is the mesh which is best described as a collection of points in space (Petty, 2019).

The model review or design review process begins with the creation of a tag in Autodesk Navisworks once the model or federated model is ready. The engineers can add tags using the Tags panel located on the Review tab. Viewpoints, comments, and markups are all combined into one simple-to-use review tool by using tags. As a result, everything in the model scenario that the engineers wish to identify can be tagged. They can add a comment and status to the tag, and automatically generated viewpoint is presented to them. Once the tag is converted by the plugin, the system automatically captures the information and the snapshot of the displayed model. The list of all the converted tags can be viewed in 3D Model Review & Tagging System Website. Engineers, designers, checkers, and managers can act and change status of the reviewed model using the website.

Within the architecture, engineering and construction (AEC) industry, where the need for innovation and improved business performance requires the effective deployment and utilization of project knowledge, the need for strategic knowledge management is also being acknowledged (Kamara et al., 2002). As a result, strategies can be developed to improve workflows and mitigate rework and delays (Matthews et al., 2015). Missing or obsolete building information might result in ineffective project management, uncertain process results and time loss or cost increases in maintenance, retrofit or remediation processes (Volk et al., 2014).

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that building around the process of reviewing the engineering and construction 3D models will reduce project delays through streamlined workflows, improve the coordination process between management, engineers, and designers, and enhance coordination among various disciplines. The study also ensures that providing an efficient and on-time report of model review will lessen the work of the project members when producing the report to the client, which will lessen information discrepancies and errors that are frequently arising from manual operations. Successful outcomes of the design review process are not always immediate; indeed, success can sometimes only be judged long after completion and occupation (Designing Buildings, 2024).

The study focuses on two types of applications: web-based and desktop. Thus, it is recommended that a mobile application be developed as an additional platform for the engineers for easy accessibility. Contractors invested in IT because they perceived IT as a means of achieving efficiency and manpower saving. However, the most apparent effect of having IT was manpower saving in head office and better management of tendering data (Mak, 2001).

IMPLICATIONS

Modern 3D model review tools like Autodesk Navisworks offer versatility in handling reviews in engineering and construction phases, but they come with a price, particularly for small engineering businesses. Prompt and effective responses to incompatibilities between as-designed and as-built drawings prevent cost and time overruns and material waste (Gharouni et al., 2020). The use of combined systems for 3D model review will benefit the various engineering organizations since it will give them the advantage of presenting the current stage of the designs to their clients in almost real-time. The language model can facilitate virtual design reviews by providing real-time feedback and engaging in discussions with project stakeholders to evaluate design options and address concerns (Johannes et al., 2024). The experts' view on the emerging technologies would be useful for both managers and lenders who tend to invest in improving productivity in the construction industry (Mohamad et al., 2019). So, design control or design review is in no sense separable from other aspects of the development control process (Punter, 2017).

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to the people who have helped me complete this research paper. Dr. Jesus S. Paguigan, for his guidance which benefited me the most on completion of this study and to Dr. Leonard L. Alejandro for his encouragement and utmost support. My sincere gratitude and appreciation go to my dearest family and loved ones who are always by my side and always ready to lend their hands and give their one hundred percent support. To my Mother Mary and Father Joseph for directing me and protecting me every day. And most importantly, to my God and my Redeemer, Jesus Christ, who always gave me knowledge, wisdom, strength, and courage from the very start. I dedicated and offered this to You, my God.

Finally, I am grateful and thankful to the editorial team's and reviewers' input, which improved this research paper's coherence and clarity.

FUNDING

The study did not receive funding from any institution.

DECLARATIONS

Conflict of Interest

The researcher declares no conflict of interest in this study.

Informed Consent

This research is fully voluntary on study participants. There are no risks affiliated with this research.

Ethics Approval

The researcher makes sure that study participants are adequately informed on the specifics of the research, since participation in the study is completely voluntary. In addition, participants receive full details regarding their right to withdraw from their participation at any point.

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