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Original Article

Optimizing design efficiency : Integrating BIM technology and the dynamo plugin to improve accuracy and save time in the design phase

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Keywords:
Building information modeling (BIM), dynamo, design phase and CAD system.

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Abstract

There is a lack of consistency among design documents across various specializations, and the numerous modifications made by engineers at this stage result in significant time waste. Furthermore, numerous errors in the design can cause problems during the implementation phase. This paper introduces a framework based on Building Information Modeling (BIM) to (1) minimize conflicting information across diverse technical documents, (2) enhance coordination among various disciplines involved in the project, and (3) reduce delays in the submission of project papers. This framework creates a Dynamo tool integrated with the Revit program to reduce the time required to develop the project model. It also employs the Navisworks program to minimize conflicts. A real-life case study of a residential project of 10 buildings is analyzed to illustrate the framework's benefits and highlight its capabilities in the design stage. The results indicate that utilizing this framework in the design stage reduces the time required to produce design documents by 60% to 85% compared to the traditional CAD system.

I. INTRODUCTION

The design phase of any construction project is a critical phase where decisions have lasting impacts on the success and efficiency of the entire project and whether the project will be delivered on schedule[1]. Over the years, the traditional computer-aided design (CAD) system has been the primary tool engineers use to create and develop design documents. The first use of CAD software in construction documentation can be traced back to the development of CAD systems, such as Sketchpad, developed by Ivan Sutherland in the early 1960s[2]. Patrick Hanratty: Known as the "Father of Computer-Aided Design," he developed the first commercial CNC programming system called PRONTO while working at General Electric. His work contributed significantly to developing CAD systems that are now widely used in structural design. However, despite its success, this approach to design and all stages of construction has many drawbacks, including conflicting information across different technical documents, difficulty coordinating between different disciplines involved in the project, and delays in submitting project papers. Given these drawbacks, the need arose for an alternative system that could address these issues in a simpler and less complex manner[3,4]. Hence, a new term emerged: Building Information Modeling, first introduced by Graphisoft in 1987 with its ArchiCAD program, where the company presented a virtual building. The Building Information Model was not used until 1992, and its real spread began about 10 years later with the purchase of Autodesk, the most famous program in this field (Revit)[5]. BIM technology has greatly improved the design process and coordination between project team members and addressed many design-related issues faced by engineers, from the initial design stage to the operation and maintenance stage. For example, reduce conflicting information across different technical documents produced by disciplines such as architecture, structural engineering, and mechanical and electrical. Without a central information platform, it is easy for documents to become out of sync and contain inconsistencies[6,7]. BIM unifies all project data and drawings into a single virtual model (BIM model). All stakeholders work on this shared model, preventing conflicting information from appearing in separate documents. This can be done on a platform such as Revit[8]. This enhances the coordination among various project disciplines, including engineers, technicians, and contractors. Separate technical documents can make it challenging for teams to comprehend how their designs intersect and potentially influence other disciplines. BIM enables a collaborative process where all disciplines can visualize how their designs interact in 3D and spot coordination issues early. Teams can resolve conflicts virtually before costly construction issues arise by modeling the entire project in Revit and then importing it into NavisWorks to detect and resolve them[9,10]. Delays in delivering final construction documents, when 2D drawings need to be updated across multiple files and revisions, are time-consuming and error-prone. BIM technology has made the model-building process easier and faster by leveraging the Dynamo plugin and powerful BIM scripting capabilities to automate repetitive tasks and generate consistent, code-compliant documentation from a central model. This speeds up the document production process and helps ensure projects deliver documents on time. Introduced in 2017, Dynamo is a visual scripting plugin for Autodesk Revit[11,12]. It allows users to create custom tools and automate tasks within the Revit environment. Dynamo connects nodes in a diagram-like interface, representing functions and processes manipulating elements and data within a Revit model[13]. By creating custom scripts, architects, engineers, and designers can extend the capabilities of Revit and simplify repetitive tasks. Dynamo allows users to access and modify different aspects of a Revit model. It is accessible to users with various programming backgrounds and provides a more intuitive approach to writing than traditional text-based programming languages. BIM systems also provide advanced simulation and analysis capabilities, allowing designers to evaluate factors such as energy performance, structural integrity, and collision detection, helping to identify and resolve potential issues early in the design process[14]. Overall, adopting BIM technology in the construction industry has transformed the design phase, enabling a more integrated, collaborative, and data-rich approach that enhances project success and regulatory compliance. We can also use the Solibri model checker program, which checks the model and determines its compliance with the building code. For example, it can verify the available spaces before each door and window opening[15]. It can also determine whether the building components are fire-resistant and comply with other code provisions. The BIM model facilitates the creation of construction schedules and project timelines, which are linked to the 3D model and then converted to 4D, thereby enabling the visualization of construction sequences and the optimization of operations. Cost information provides a comprehensive understanding of the financial aspects of the project (5D), allowing for accurate quantity take-off, cost estimation, and budgeting. The BIM model also allows for better project feasibility decisions[16]. Resistance to change, lack of proper training, and insufficient software compatibility can hinder the full potential of BIM. The initial costs associated with implementing BIM technology can be prohibitive for some organizations, especially for small businesses or projects with limited budgets. We deduce that this design approach effectively addressed numerous issues, including conflicting information across diverse technical documents, challenges in coordinating various specializations involved in the project, delays in delivering project documentation, the simplicity of achieving the design, and the early identification of system collisions. Collectively, these factors contributed to the reduction of effort and costs associated with the project. Furthermore, limitations in compatibility and data exchange between different software platforms can hinder the smooth flow of information, which can impact project efficiency and coordination. Addressing these shortcomings can unlock the full potential of these technologies to enhance coordination, collaboration, and overall project success[17,18].

2. OBJECTIVE:

This research aims to explain how BIM technology can reduce the time and effort required to create plans and drawings for construction projects during the design phase by creating a framework that facilitates this process instead of traditional methods. The framework process can be summarized as follows: Phase one is converting the initial AutoCAD drawings of the project or Excel tables to BIM models through the Revit program and using Dynamo to facilitate this process. Phase two: After completing the model construction, a check is made for clashes between the systems on the NavisWorks program and the Solibri model checker program as shown in Fig1. This reduction is necessary due to several factors, including conflicting information between different technical documents, lack of coordination between the disciplines involved in the project, and delays in submitting the necessary papers. Such problems often result in design errors and necessitate repeated reviews, leading to increased project costs and extended implementation time. To address these challenges, this research focuses on taking advantage of BIM technology and highlighting its role in visualizing the virtual construction process before its implementation begins.

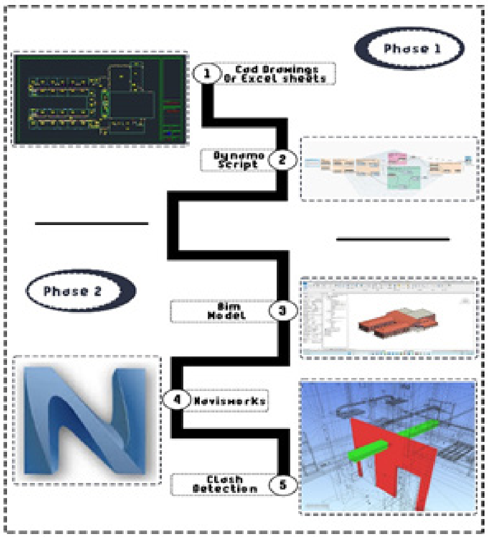


Fig. 1: Competition process in framework.

3. PHASE ONE

To create this framework, we used AutoCAD to create the initial drawings for the project and Excel to create tables, such as the levels table and the columns table, for use in the modeling phase. We then entered this data into the Revit program to create the 3D model. We then used the Revit Dynamo add-on to create scripts that aid in modeling and speed up this process, thereby saving a significant amount of time and effort. These scripts include the following:

1. Create an automatic level script: This script, as shown in Fig. 2, which works through an Excel sheet, allows levels to be created in the model faster and more accurately.
2. Auto column: This function assists in designing columns within the building by incorporating CAD drawings, as illustrated in Fig3.
3. Auto Join: This feature simplifies connecting different parts of the building, eliminating the need for individual connections, as shown in Fig 4. It can be applied to the entire building.

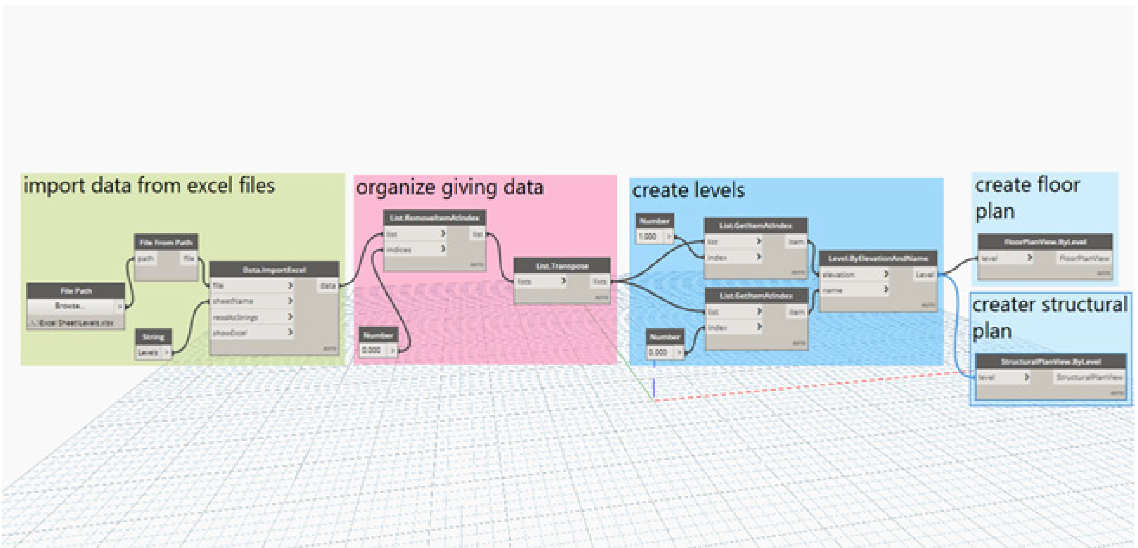


Fig. 2: Auto-level script uses an Excel sheet.

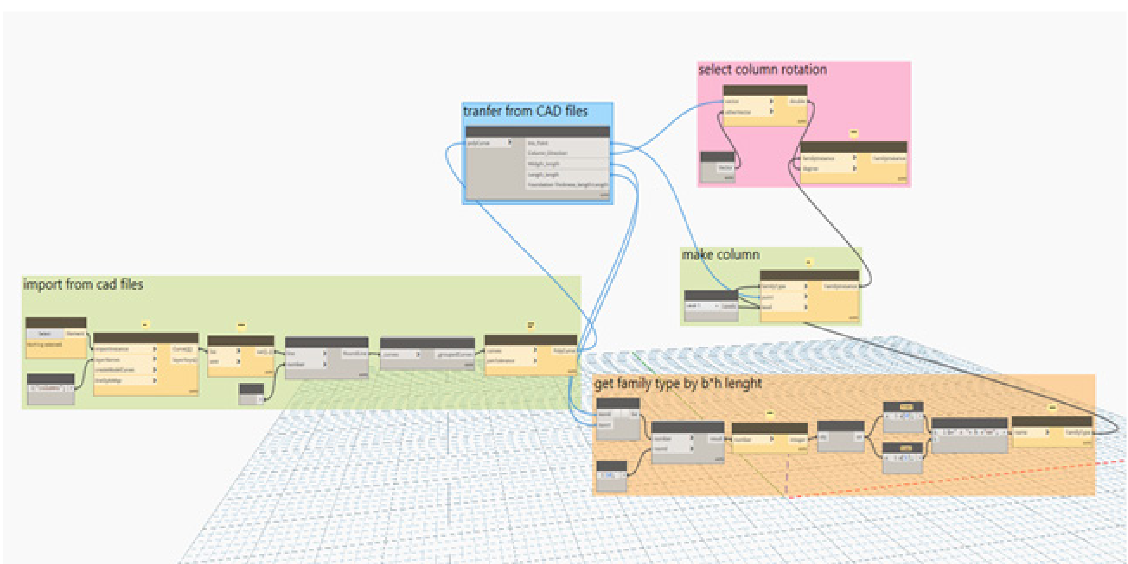


Fig. 3: Auto-column script using CAD drawings.

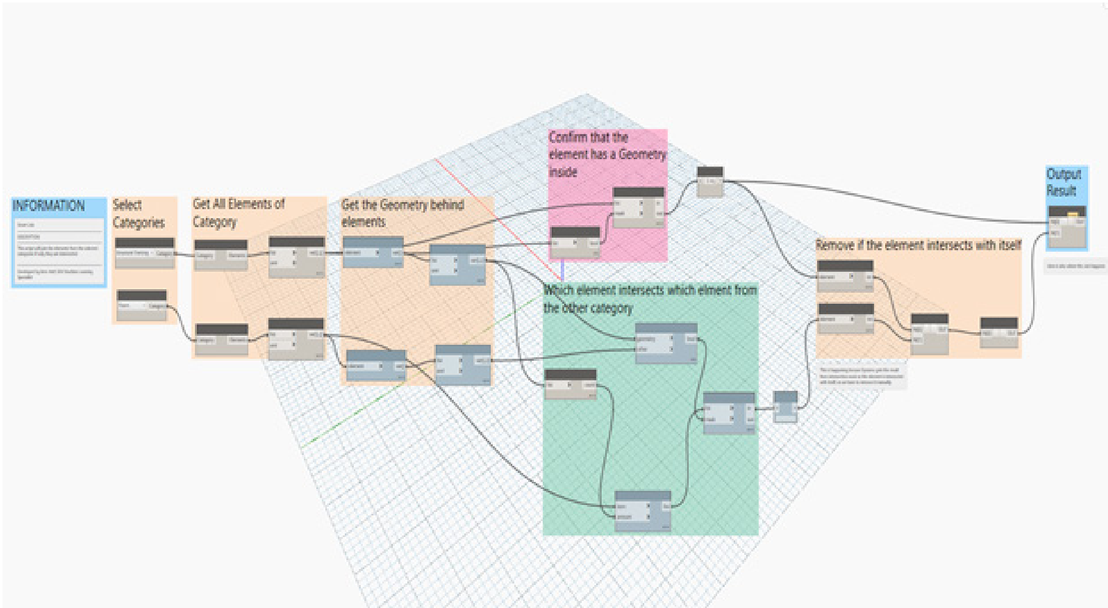
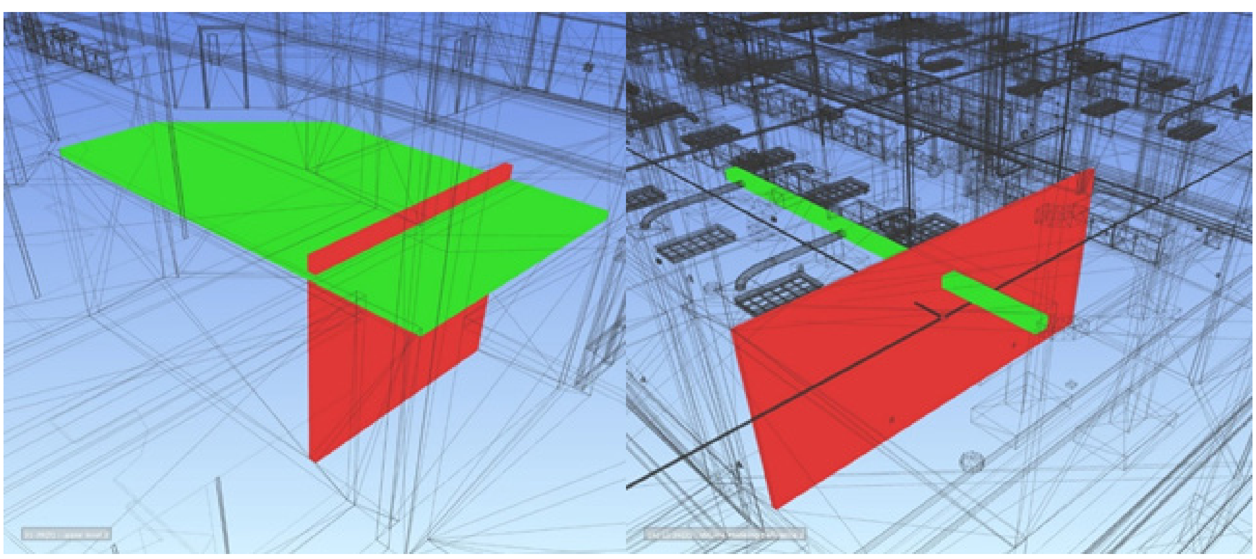


Fig. 4: Auto joins script.

4. PHASE TWO:

The model is loaded into the NavisWorks application to identify any conflicts between the various systems after completing the first step. This saves time and effort and streamlines the evaluation process, as shown in Fig 5. The Colibri Model Checker application is used to confirm whether or not this model satisfies the code requirements, Including the dimensions of the building's openings and the rooms. Are the structure and all of its parts fire-resistant? Is there enough room for windows and doors to open؟ As shown in fig 6. Does the code apply to the escape distances from the rooms. As shown in Fig 7. During the design process, all of these methods help to save time.



Clash between wall and slab

Clash between wall and air duct

Fig. 5: Clash detection from Navisworks.

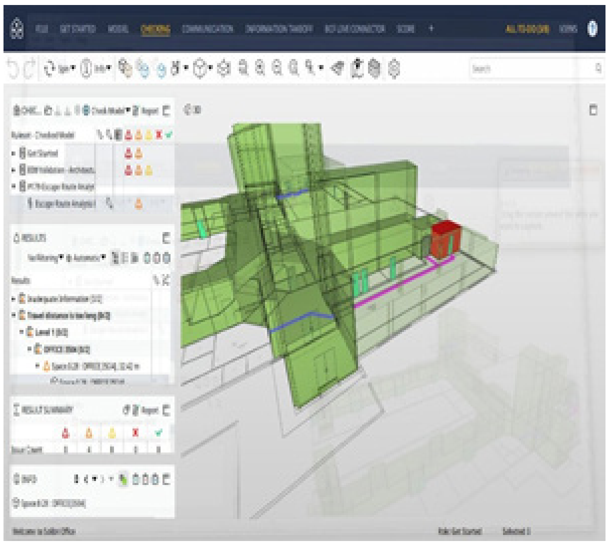


Fig. 6: The distance when opening the window is not appropriate for the sash.

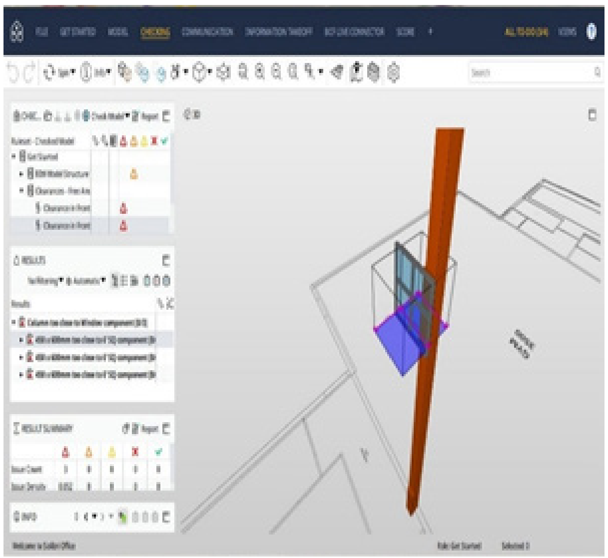


Fig. 7: Escape distances do not comply with the fire code from the program Solobri.

5. CASE STUDY

Using the above approach, several case studies focused only on the design phase of actual projects using CAD and BIM systems. The aim was to identify indicators that would provide a quantitative value for the work produced in the design process and to use these indicators to compare CAD and BIM programs. Data was collected by selecting a sample of residential building projects, totaling ten samples. Half of the projects were completed using CAD, while the other half used BIM. While it is impossible to design two identical buildings using two different systems, the study considered that the total effort required to produce design documents for both groups would be similar, given the nature of the buildings. This assumption was based on the opinion of the designers involved, and it was confirmed that the designers were equally proficient in using both systems, indicating a high level of professionalism. Information regarding this aspect was collected from the offices responsible for the design process. All approved indicators for the measurement process in each project were recorded. Subsequently, the measurement results were analyzed using computational analysis methods. The quantitative indicators in the comparative measurement process between the two systems, CAD and BIM, will be adopted to cover the main documentary outputs of the design process: plans, quantities, and specifications. Depending on the impact of technical BIM on the design process, these indicators should cover the functions of visualization and modification. Based on the previous argument, it is possible to identify the indicators through the comparison process. Table 1 presents the comparative measurement of each indicator.

Table 1: The comparative measurement of each project.

S. N	Indicator	Comparative Measurement
1	Execution of operational plans	Time to a complete executive plan
2	Quantification and cost	Quantification time and cost
3	Drafting technical specifications	Technical specification setting time
4	Better visualization and a clearer understanding	Time to complete the explanatory and marketing plans
5	Make and include modifications	Time to make adjustments

The case study was conducted on ten samples of residential buildings. Half is done according to CAD technology (using AutoCAD program) and Half to BIM technology (BIM software), as shown in Table 2

Table 2: Selected construction projects

Project name	Floor area(m2)	The design system used
Residential building in the new administrative capital	250	CAD
Residential building in the new administrative capital	250	BIM
Residential building in the new administrative capital	250	CAD
Residential building in the new administrative capital	250	BIM
Residential building in the new administrative capital	220	CAD
Residential building in the new administrative capital	220	BIM
Residential building in the new administrative capital	220	CAD
Residential buildings in the al-yasmine in the military entity, west of the new capital	180	BIM
Residential buildings in the al-yasmine in the military entity, west of the new capital	180	CAD
Residential buildings in the al-yasmine in the military entity, west of the new capital	180	BIM

The data collection method involved direct measurements of the completion times of design documents made by users of CAD and BIM systems. The design documents for each study case were categorized, followed by the comparison indicators. Table 3 shows the design process's outputs and their distribution over the comparative measurements. Table 3 displays the distribution of design documents based on the comparative measurements.

Table 3: Design documents and their distribution according to comparative measurement.

S. N	Comparative measurement	Design documents
1	Time to a complete executive plan	Plans(ground-repeated-basement-roof), sections, facades, concentration tables
2	Quantification time and cost	tables of quantities and cost
3	Technical specification setting time	Technical specifications
4	Time to complete the explanatory and marketing plans	Mass view before cladding full architectural perspective with render
5	Time to make adjustments	Documents included in the required modification

The times required to complete all documents related to each comparative measurement were summed to obtain the time required for this measurement for each case. Then, the times for the same height in all study cases belonging to one design system were calculated to obtain the total times for each comparative scale and all study cases belonging to the CAD and BIM design systems. It is worth noting here the methodology with which the comparative measurement of adjustment time was carried out. Since it is impossible to match or even converge the editing process for documents produced in both design systems, the editing times for CAD system documents were measured. Just. Each modification operation requires a specific amount of time to complete. The BIM system will estimate the time required to complete a modification on only one document among the affected documents, in accordance with the system's specifications. The rest of the documents are updated automatically.

6. RESULTS AND DISCUSSION

When comparing traditional CAD systems with BIM, previous studies have shown a reduction in the time required to complete work in the design stage by between 65% and 75%[13]. However, the use of modern BIM tools like Dynamo, a component of the Revit program and one of the most important ones, can significantly enhance this reduction. It operates by generating scripts through visual programming, which carry out various functions to streamline the process of creating the model and necessary drawings. Additionally, it utilizes the Navisworks program to identify design clashes, a feature that significantly reduces time during both the design process and the design phase. The percentage can range from 65% to 85%. It is almost done by creating scripts that work on automatic modeling directly from CAD drawings or through Excel sheets, which saves a lot of time during implementation and has many other functions. Depending on the data collection method mentioned above, we can summarize the results of the comparative measurement process applied to samples of projects studied in both CAD and BIM design systems in Table 4.

Table 4: Total time to complete the design documents for studied projects (hours).

Number	Comparative measurement	CAD (hour)	BIM (hour)	BIM with Dynamo(hour)
1	Time to a complete executive plan	68.5	24.1	12.2
2	Quantification time and cost	73.7	28.3	20.7
3	Technical specification setting time	61.5	19.3	11.3
4	Time to complete the explanatory and marketing plans	52.4	18.6	10.5
5	Time to make adjustments	27.6	11.5	5.4
6	sum	283.7	101.8	60.1

It is evident from Table 4 that the significant savings were caused by the use of BIM at the time of completion of the various design documents of the project. To shed light on the different aspects of these results, we will define a set of arithmetic factors, and we will use the following terms in this way:

CAD: Completion time according to CAD for one measurement.

BIM: Completion time according to BIM for a single measure.

BIMD: Completion time according to BIM using Dynamo and Navisworks.

BIMD/CAD: The ratio of completion time according to BIMD to completion time according to CAD for one action.

BIMG: temporal gain in the use of BIMD for a single measurement. It gives a relationship. BIMD/CAD -

1= BIMG or with the relationship: (CAD-BIMD) / CAD=BIMG.

TCAD: Total completion times according to CAD for all measurements.

TBIMD: The sum of the completion times according to BIMD for all measurements.

CAD/TCAD: The ratio of completion time according to CAD for one measurement to the total

Completion times according to CAD for all sizes.

BIMD/TCAD: The ratio of completion time according to BIM for one measurement to the total completion Times according to CAD for all sizes.

BIMPG: Time gain in using BIM for one measurement for all measurements. It is given by BIMD/TCADCAD/

TCAD=BIMPG or as related: BIMPG=BIMG.CAD/ TCAD.

Tab 5 shows the corresponding values for the data analysis process according to the previously defined mathematical factors. It notes a slight change for some deals from their mathematical equation, depending on the accuracy of the display of the results.

Table 5: Statistical analysis of the completion times of the design documents for studied projects.

Comparative measurement	CAD (hour)	BIM (hour)	BIMD (hour)	BIMD/ CAD%	BIMG %	CAD/ TCAD %	BIMD/ TCAD%	BIMPG%
Time to a complete executive plan	68.5	24.1	12.2	17.81	82.19	24.14	4.30	19.84
Quantification time and cost	73.7	28.3	20.7	28.08	71.92	25.97	7.29	18.68
Technical specification setting time	61.5	19.3	11.3	18.37	81.63	21.67	3.98	17.69
Time to complete the explanatory and marketing plans	52.4	18.6	10.5	20.03	79.97	18.47	3.70	14.77
Time to make adjustments	27.6	11.5	9.5	34.42	65.5	9.72	3.54	6.37
sum	283.7	101.8	60.1			100%	22.81%	77.35%

The computational analysis of data on completion times for design documents gives a good idea of how much the BIM system contributes to reducing the time required to produce these documents. In the following, we will highlight the picture that achieved this by creating a set of illustrative charts showing the extent of the contribution made by each element of comparative measurements.

Fig. 8 illustrates that the most significant time gain in using BIM was setting a complete executive plan, which achieved a time gain of 82.19%. As for the lowest income, it was for the time of quantification and cost estimation, which amounted to 65.50%It should be noted that part of this time is not subject to human activity in using the technology, but instead is due to the time taken by the rendering process, which is the same time required in both CAD and BIM systems.

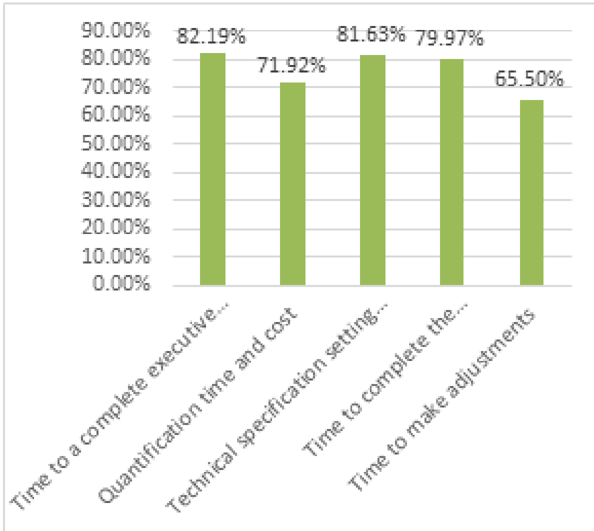


Fig. 8: Time gain in using BIM for each measurement.

According to Fig 9, the CAD system's time for calculating quantities and estimating the cost ranked first among the rest of the times, with its contribution 25.97% of the total time required to complete the design documents according to the CAD system. At the same time, the time of making the amendments ranked last, with a contribution of 9.72% of the total time.

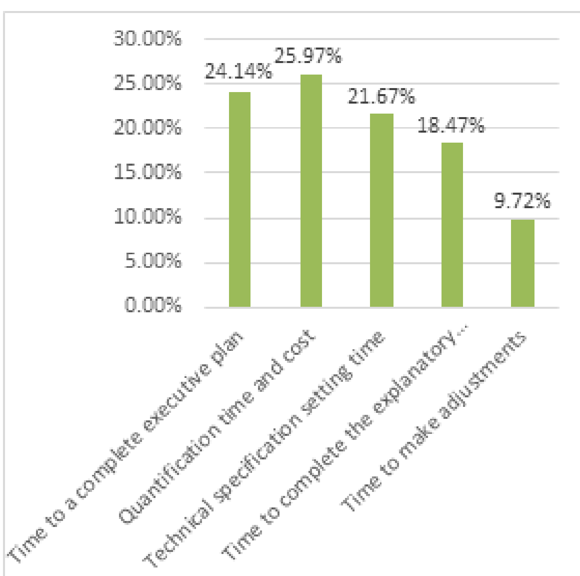


Fig. 9: Distribution of contribution percentages for each measurement.

Fig. 10 shows that calculating quantities and estimating the cost occupies the highest contribution percentage 7.29% of the total time required to complete work documents according to the CAD program. At the same time, the time of making adjustments ranked last, with a contribution of 3.54% of the traditional total time according to CAD.

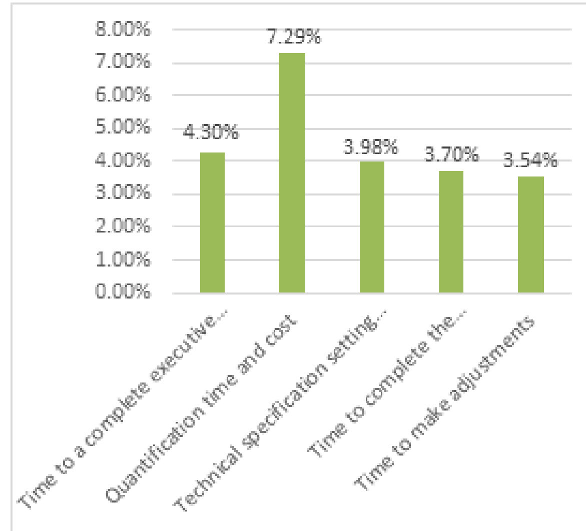


Fig.10: The BIM completion time relative to traditional CAD document production time.

Finally, Fig. 11 shows that, when using BIM, the time spent calculating quantities and estimating costs significantly reduced the overall design effort required to produce the entire set of design documents using the CAD system, reaching a percentage of 19.84%. On the other hand, the time required for making modifications was recorded. It ranks last in this disadvantage by reducing the entire design effort expended, according to the CAD system, by 6.73%. When we compile these last reductions for all times using the BIM system, we find that this technique has reduced the production time of design documents compared to traditional CAD methods by 77.35%. The total productivity gain obtained from the BIM system's contribution to producing these design documents is shown in Fig. 12 and Fig. 13.

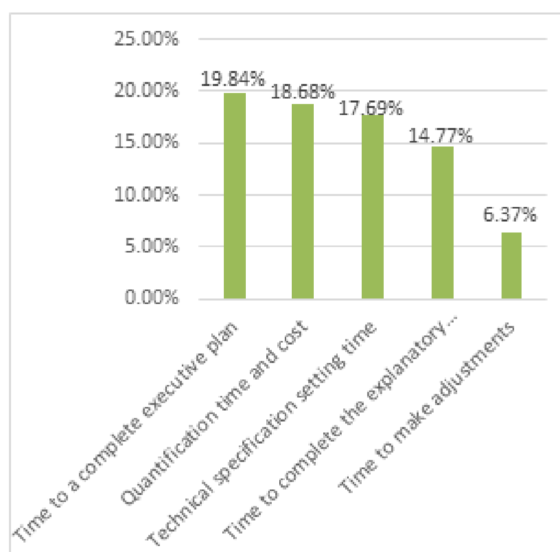


Fig. 11. BIM contributes to reducing traditional design document time according to CAD.

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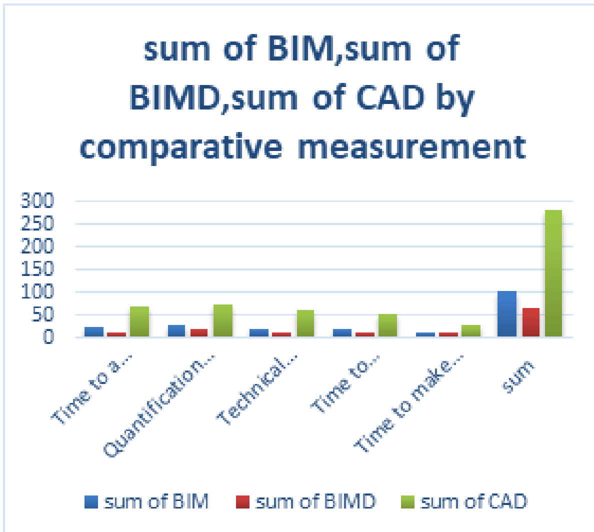

Fig. 12: Illustrates the time required to complete the process in each system.

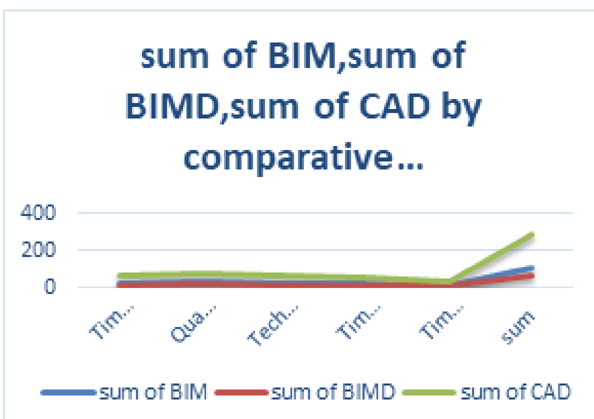

Fig. 13: The time required to complete the process in each system

Although the results we obtained were based on quantitative measurements, transparent methodology, and specific influences, several points should be noted when discussing these results. Here are the highlights:

Samples of the studied projects belong to the category of residential buildings, and the study was limited to this category for two reasons:

1. The similarity of buildings allows a fair comparison between the application of CAD and BIM systems for similar structures in terms of the design effort expended in producing documents.

2. There is a scarcity of private buildings designed using BIM due to the recent emergence of this technology in the local labor market, and its use is limited to individual initiatives.

The possibility remains that the experimental results when using BIM in projects of a unique nature differ from what was reached in this research, despite our conviction that the technical tools available in the engineering labor market currently in the use of BIM have earned a degree of maturity that eliminates concern about the difficulty of the suitability of this technique for projects of a unique nature. According to the previous

The study, the percentage that the BIM system using plugin dynamo in Revit contributes to reducing document production time, amounting to 65% to - 80 %, is an excellent incentive for any company to start adopting this technology. The degree of professionalism in using the technical tools of the BIM system plays a central role in reaping the benefits offered by this system. It controls the percentage reduction of effort involved in producing design documents that can be accessed using BIM. However, thinking that the entire design process will be reduced by such a large percentage when the BIM system is adopted is a mistake. The design process involves human activities, and the technician uses no computer system. These activities may include rudimentary paper designs or mental tests of proposed design alternatives, private discussions among team members, general meetings with management, or communication with other project stakeholders. Still, using the BIM system can positively affect even these activities. Workload shifts according to specialization and experience. The effort to produce documents using traditional CAD methods using BIM is due to the significant improvement offered by the latter system in this field. As a result, the effort will shift toward model building, which requires more design expertise than document production. This will reduce the number of less experienced crewmembers, and working in document production favors the more experienced personnel who will build the model.

7. CONCLUSIONS:

The article discusses the evolution and impact of Building Information Modelling (BIM) technology in the construction industry, particularly in the design phase. It highlights the limitations of traditional Computer-Aided Design (CAD) systems and how BIM addresses these challenges. BIM technology, including tools like Revit and NavisWorks, provides a unified platform for all project data, enhancing collaboration and reducing errors. It allows real-time updates and coordination among architects, engineers, and contractors, streamlining the design process. The Dynamo plugin for Revit automates repetitive tasks and improves document production accuracy and speed. A study comparing projects designed with CAD versus those using BIM found that BIM reduced design phase time by 65-85%, depending on the tools used. The findings indicate significant time savings with BIM, particularly when using the Dynamo plugin. Adopting BIM technology transforms the design phase of construction projects, leading to improved efficiency, reduced costs, and better

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project outcomes. The study emphasizes the importance of training and software interoperability in fully realizing BIM's potential. Overall, the article underscores the critical role of BIM in modern construction and advocates for its broader adoption to enhance project coordination and efficiency.

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