AN INTEGRATED BIM-POWER BI APPROACH FOR DATA EXTRACTION AND VISUALIZATION

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ABSTRACT:

Building Information Modeling (BIM) is one of the most promising advances in the Architecture, Engineering and Construction (AEC) industry. Even though BIM models are rich and very structured, they are not suitable for extracting information quickly and efficiently to respond to some specific queries required for making decisions. Hence, extracting information from BIM models is a very important and challenging issue. This motivated us to propose an integrated solution based on Dynamo and Power BI to allow extraction and visualization of BIM data according four relevant use cases in the AEC domain: cost extraction, clash detection, change detection and plan extraction. The research presented in this paper is based on programming algorithms on Dynamo for information extraction and creating dashboards on Power BI for the visualization of the extracted results. Additionally, we used a Revit plug-in which automates the execution of Dynamo scripts through customized buttons that correspond to each of the analyses treated in this research.

1. INTRODUCTION

BIM (Building Information Modeling)is a model-based process that provides methods and tools for creating and managing building projects faster and more economically (Sacks, et al., 2018). It allows sharing information efficiently among several stakeholders, so reducing errors and optimizing project management (Shi, et al., 2020).

BIM is becoming an important tool in civil engineering (Zhang, et al., 2017). It stores all relevant information in one integrated model that can be leveraged for many applications during the building life cycle (Kim, et al., 2013), such as clash detection, cost analysis, and energy analysis. BIM models are highly structured and contain large amounts of geometric and semantic data. However, in an unprocessed state, they are poorly suited for performing engineering tasks because the data structure is not goal-oriented. Indeed, integrating the information about a building element requires accessing several project documents and manually extracting and combining the necessary information (Niknam & Karshenas, 2017).

Data extraction from BIM models is traditionally performed by IFC (Industry Foundation Classes) and COBie (Construction-Operations Building information exchange) standards. It can also be realized by "classic raw schedules" followed by an external post-processing tool to filter the desired information. This classic method doesn’t take into consideration the user’s needs or his expertise, which restricts the possibilities of targeting the information to be extracted and reduces the reliability of the extraction process (Kim, et al., 2013).Retrieving information from a BIM model is difficult to achieve when it comes to selecting and extracting information that requires in-depth processing of the raw data and representing it according to the user's needs. For instance, clash detection requires mathematical evaluation of geometric interferences between elements in the BIM model (Andrich, et al., 2022).

Many studies have addressed the issue of data extraction and visualization from a BIM model, namely for clash detection (Caparas, 2019)(Liang, 2020); cost detection (Saridaki, et al., 2019), (Shi, et al., 2020) (Sousa, et al., 2020), and energyanalysis (Trabulci, 2020)(Gebru & Staub-French, 2019) (Asl, et al., 2014). However, these contributions mainly focused on a specific use case and don’t consider the whole extraction process.

To address this main issue about the extraction of information from BIM models, our study aims to propose a solution that allows extracting information related to four different analyses whose importance is crucial in the AEC (Architecture, Engineering, and Construction) domain, which are clash

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detection, cost analysis, plans extraction, and change detection, and to visualize the results in user-friendly dashboards.

The remainder of the present paper is structured as follows: section 2 reviews related works addressing data extraction from BIM models; section 3 presents the methodology adopted in this research; section 4 presents and discusses the results of our research. Finally, the paper ends with a conclusion in section 5.

2. RELATED WORK

Over the last few decades, the use of BIM has grown significantly in the AEC domain due to the benefits it offersin the collaboration of teams and the standardization of data through IFC models. However, the extraction of informationfrom BIM models is a cumbersome task and is subject to many errors of interpretation, especially when datais not well represented.The goal is to be able to extract only the needed data by the user and to present it in the adequate format(Kang & Choi, 2015).Many authors have addressed the issue of data extraction and visualization from BIM models. Their investigations mainly concern cost extraction(Shi, et al., 2020), clash detection(Caparas, 2019) and energy analysis(Trabulci, 2020).

2.1 Cost extraction

Cost extraction or so-called 5D BIM is a relevant BIM application used for cost management of construction projects. This simulation allows quantity surveyors to analyze different design alternatives and choose the most economically suitable one at an early stage of the project. Suchapplication requires a high accuracy for detailed quantity measurement, as this has a significant impact on the final cost of the project. In this context, (Shi, et al., 2020) used the Dynamo visual programming language of Revit to obtain a detailed quantity take-off of all the elements constituting a construction project. Then, the extracted data is exported to Excel sheetsalso using the Dynamo plug-in. The quantity surveyors are asked to enter the price per unit in order to generate a Bill of Quantity (BoQ).Furthermore, (Saridaki, et al., 2019) addressed the costing component in construction projects as part of the Life-Cycle Costing (LCC) process. The authorsalso used Dynamo to extract the quantities of the project's elements from the BIM model in Revit in order to perform the LCC analysis. Instead of Excel sheets, the results are exported to the Sigma Estimates software in the form of reports. Cost analysis has been also addressed by (Sousa, et al., 2020) who highlighted the importance of integrating BIM models in project budgeting for decision making. Thanks to Dynamo, it's possible to perform a precise and targeted extraction of quantitative data in an automatic way to a spreadsheet in which data is configured, organized, and saved in a cloud server. The visualization of the results on dashboards is possible by linking the extracted spreadsheets to the Power BI application, a Business Intelligence (BI) software provided by Microsoft which allows aggregating, analyzing, visualizing, and sharing data. This improves the understanding of information and presents it in a more organized and clearer way for the decision-making process.

2.2 Clash detection

For the visualization of clashes in construction projects, the importance of Power BI was highlighted by (Caparas, 2019)and(Liang, 2020). Power BI is best suited for this visualization task thanks to the many advantages it offers in creating reports or dashboards.(Caparas, 2019) used Navisworks software for the extraction of clash data and PowerBI software for their visualization, using Excel spreadsheets previously exported from Navisworks. In the same trend, (Liang, 2020)used Power BI visualization tool to represent the clash data. This visualization on Power BI prevents the user from being hindered by the large amount of clash data by analyzing it in an intelligent and efficient way. The Power BI dashboards are highly interactive and link intelligently to each other. The main intension of this study is to clarify the clash by object category, clash amount, yet between two documents of the coordination collection(Liang, 2020).

2.3 Energy analysis

Some researchershave addressed Facility Management (FM)and energy analysis based on BIM models. In this perspective, (Trabulci, 2020)addressed the development of BIM-FM by studying the use of lightingfixtures, which are elements present in different types of buildings. Dynamo was used to connect BIM information required for this analysisinto a SQLitedatabase to maintain the information extractedfrom the model based on the qualityassessmentsdefinedaccording to the guidelines and standards to be met. The results are thenexported to Power BI for creating dashboards to analyze all the data collected.Anotherresearch study was conducted by (Gebru & Staub-French, 2019)for the visualization of daylight and acoustic requirements using Dynamo. The importance of this studyis that daylight affects the location and orientation of rooms based on the degree of need for direct daylight, as well as the fact that buildings require an acoustical space program requirement that refers to the location of a room based on its noise and soundlevel to beproperly and evenlydistributed.In the same context, (Asl, et al., 2014)studied day lighting by calculating its values based on the LEED (Leadership in Energy and Environmental Design) Green Building Design and Construction Reference Guide, whichallows designers to optimize several energy performance objectives early in the design process. The objective of this work is to maximize the number of rooms that save energy consumption and rely primarily on natural lighting. This study requiresseveral information related to the geometry of the constructions, their locations, and the materials used. In this perspective,Dynamo was adoptedto extract all this information.

3. METHODOLOGY

The methodology developed in this research is organized in a coordinated sequence of 3 phases(Figure 1). The first step consists of the design of a BIM model of a case study building. The second step concerns the conception of the application by adopting four use cases of data extraction from the BIM model which are: cost extraction; clash detection; plans extraction and change detection. Each task was thoroughly studied in order to identify inputs and outputs. The result of this step is mandatory to precede with the development of the extraction scripts. In order to achieve a complete extraction and visualization of the data, it’s important to have the element’s 3D geometry displayed along its semantic data. For this, we opted for proving ground’s tracer plugin for the extraction of the elements’ 3D geometry and its Power BI visual for their visualization. In the third step, we examine all possible features of Power BI by looking at their requirements and attributes in order to select relevant visuals that can present the extracted data in the simplest and more explicit way.

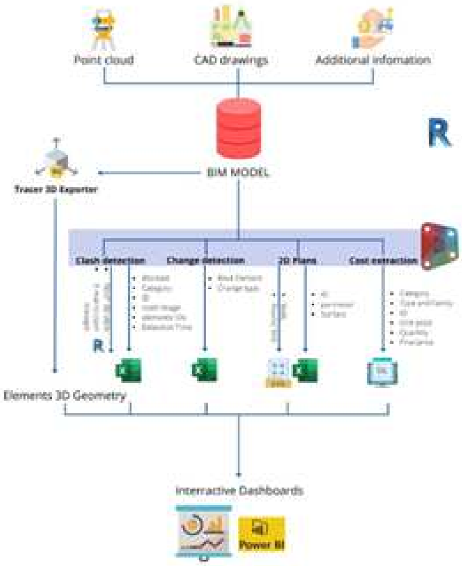


Figure 1. The workflow of our methodology.

3.1. Scan to BIM

We opted for 3D laser scanning method for data acquisition of the case study building (Figure 2). Then, a Scan to BIM process was performed to create a BIM model within Revit.

Figure 2. The case study building.

The 3D scan was accomplished using the Trimble X7 laser scanner. The cleaning and consolidation of clouds were carried out with Trimble Real Works software. The consolidated point cloud was exported in ".rcp" format so that it could be utilized in Revit for BIM modelling. The resulting BIM model is presented in Figure 3.

3.2. Data extraction and visualization

Data extraction and visualization is relevant for handling and efficiently managing building projects. Extracting information from BIM should rely on users’ needs and allow responding to some queries timely and accurately. Our solution tries to meet these requirements by designing an extraction method that isobject-based and user-oriented. It proposes some relevant use cases for the AEC community: cost extract, clash coordination, plan extraction, and change detection.

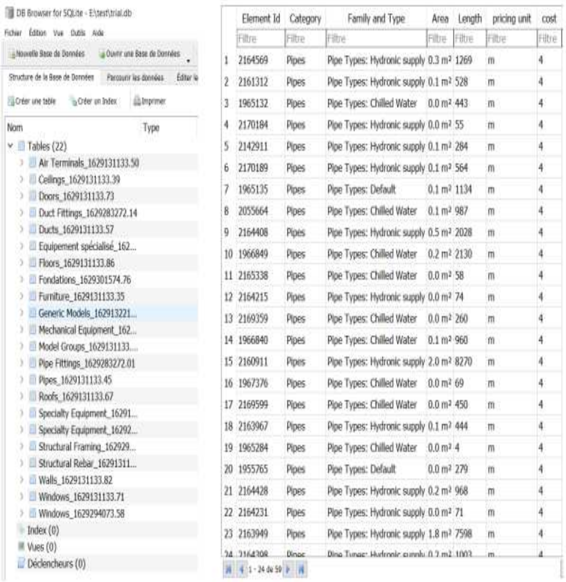
Figure 3. The BIMmodel.

3.2.1. Cost extraction

This application is based on detecting all the elements of the BIM model and targeting the cost parameter for each of them then providing the user with the cost value in an easy-to-read format. The process is carried out on Dynamo. The extracted information is stored in an SQL database. In this analysis, all categories with quantifiable elements are taken into account. The cost extraction script processes each category separately; for each item, the values of the significant parameters are extracted. A significant parameter here means any parameter that can be useful for the cost evaluation. For example, for an element of the "wall" category, the surface parameter is significant for the determination of its cost. Therefore, we extract the parameters: area, cost, unit, identifier, family type, and category.Thescript stores them into a well-structured SQLite database(Figure 4); each category is stored separately in a table.

To visualize the elements in 3D, we used the Tracer “ProvingGround” plug-in which allows exporting the 3D elements by converting them to GLTF (GL Transmission Format) binary format and storing them in the SQLite database. It is worth mentioning that the plugin also exports all the information about the element, namely its ID and all its parameters. In order to establish a link between the Dynamo

SQLite database and the Tracer one, we had to import the two databases and join them through the parameter ID.



	Element Id	Category	Family and Type	Area	Length	pricing unit	cost
	Filtre	Filtre	Filtre	Filtre	Filtre	Filtre	Filtre
1	2164569	Pipes	Pipe Types: Hydronic supply	0.3 m²	1269	m	4
2	2161312	Pipes	Pipe Types: Hydronic supply	0.1 m²	528	m	4
3	1965132	Pipes	Pipe Types: Chilled Water	0.0 m²	443	m	4
4	2170184	Pipes	Pipe Types: Hydronic supply	0.0 m²	55	m	4
5	2142911	Pipes	Pipe Types: Hydronic supply	0.1 m²	284	m	4
6	2170189	Pipes	Pipe Types: Hydronic supply	0.1 m²	564	m	4
7	1965135	Pipes	Pipe Types: Default	0.1 m²	1134	m	4
8	2055664	Pipes	Pipe Types: Chilled Water	0.1 m²	987	m	4
9	2164408	Pipes	Pipe Types: Hydronic supply	0.5 m²	2028	m	4
10	1966849	Pipes	Pipe Types: Chilled Water	0.2 m²	2130	m	4
11	2165338	Pipes	Pipe Types: Chilled Water	0.0 m²	58	m	4
12	2164215	Pipes	Pipe Types: Hydronic supply	0.0 m²	74	m	4
13	2169359	Pipes	Pipe Types: Chilled Water	0.0 m²	260	m	4
14	1966840	Pipes	Pipe Types: Chilled Water	0.1 m²	960	m	4
15	2160911	Pipes	Pipe Types: Hydronic supply	2.0 m²	8270	m	4
16	1967376	Pipes	Pipe Types: Chilled Water	0.0 m²	69	m	4
17	2169599	Pipes	Pipe Types: Chilled Water	0.0 m²	450	m	4
18	2163967	Pipes	Pipe Types: Hydronic supply	0.1 m²	444	m	4
19	1965284	Pipes	Pipe Types: Chilled Water	0.0 m²	4	m	4
20	1955765	Pipes	Pipe Types: Default	0.0 m²	279	m	4
21	2164428	Pipes	Pipe Types: Hydronic supply	0.2 m²	968	m	4
22	2164231	Pipes	Pipe Types: Hydronic supply	0.0 m²	71	m	4
23	2163949	Pipes	Pipe Types: Hydronic supply	1.8 m²	7598	m	4

Figure 4. Extraction of the cost SQLite database (category: Pipes).

3.2.2. Clash detection

The script detects clashes between disciplines that collaborate around the central model. Once executed, the user chooses the worksets to be tested. All the elements belonging to the selected worksets will then be taken into account as entries in the clash test. 3D views are generated for each detected clash to allow the user to analyse each clash separately without quitting the model's environment. Simultaneously, an image of each view is exported and an Excel table containing the following columns is created: clash number, clash name, element 1, id1, element 2, id2, workset2, date, time and image. Finally, an email is sent to the clash coordinators informing them of the new detection. The script's outputs are displayed in Figure 5.

3.2.3. Plans extraction

This application allows the extraction of 2D drawings by floor (Figure 6). For this, we used the "RoomsByPlacement" node in order to extract rooms' boundaries, after having filtered them according to the level previously chosen by the user. For the walls, since there is no custom node to extract their boundaries as is the case of rooms, we made an intersection between the plane (xOy) passing through the elevation of the level in question and all the walls. The room and wall boundaries are then attached and exported in SVG (Scalable Vector Graphic) format. The room and wall information such as element ID, area, perimeter, level, name, and category are stored in an Excel file.

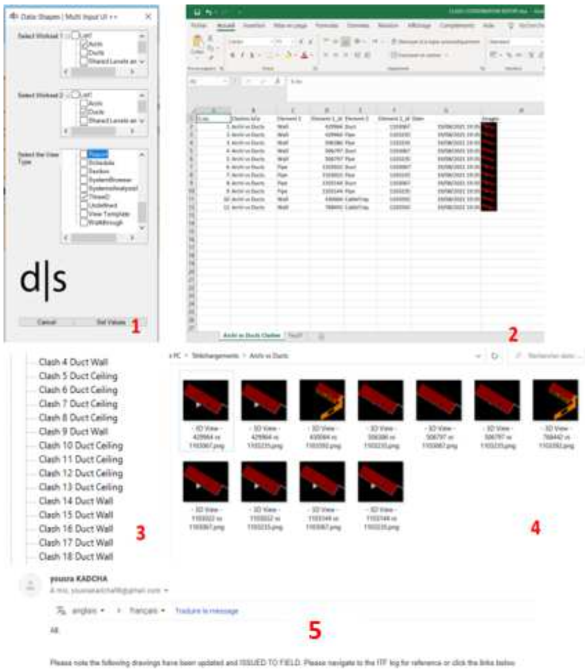


Figure 5. Outputs of the clash coordination script.
(1) Script interface;(2) Clashes' Excel table;(3) Generated 3D views;(4) Clash image folder;(5) E-mail sent to the manager.

Figure 6. Plans extraction interface.

To visualize the extracted drawing on PowerBI, we used the "Synoptic Panel" visual which allows displaying one or several images called 'maps', in which we loaded the previously generated SVG file.

3.2.4. Change detection

This analysis detects elements that have undergone changes between two versions of the BIM model. For this, we used the "ModificationTracker.ModelComparison" dynamo node that takes 3 inputs which are: document A (the current document by default); document B (the comparison model); and categories (the list of categories to be analysed).

The "ModificationTracker.ModelComparison" node script uses the GUIDs (Global Unique Identifier) of the elements to determine whether they exist, new or deleted. It returns as output a report containing lists of elements sorted according to the comparison result (existing, new, deleted). Geometry and metadata comparison are then performed between "DocumentA" and "DocumentB". This node provides four different lists as outputs depending on the type of the change.Each category of elements is then associated with a color and visualized in Revit. The different categories are also stored in an Excel file with the Id's of the Revit elements. This file is used to create dashboards on PowerBI to visualize the changes in a more explicit way.

3.3. Automation of the extraction process

In order to reduce the time needed to launch Dynamo, to install the necessary packages and to facilitate the task for the operators, we opted for the "Relay" plugin. This plugin allows to add all the scripts developed on Dynamo and to execute them in the background. It is a neat interface for users unfamiliar with Dynamo. After the scripts are executed, the results of the analysis are exported and stored automatically in the SQLite database, Excel or SVG files.

4. RESULTS AND DISCUSSION

In this section, we present and analyse the results of our extraction method with regards to the studied use cases.

4.1. Cost extraction

The result of the visualization of cost elements is an interactive dashboard(Figure 7)that can serve quantity surveyors, construction cost consultants, or sales managers in their missions of controlling and supervising the financial situation of the construction project. As each element is well defined by its cost, it's possible to control the expenses and ensure that the initial budget is not exceeded.

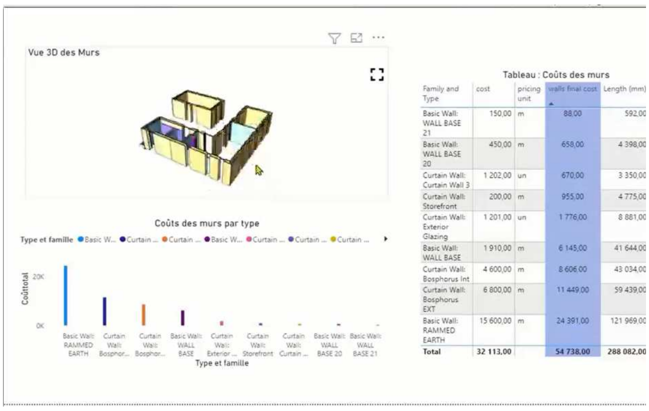


Figure 7. Cost Dashboard example.

4.2. Clash coordination

The clash coordination dashboard(Figure 9) allows highlighting physical design issues, their nature and severity. The clash detection manager can easily communicate the dashboard as a report to the project teams and use it in regular meetings to determine who is responsible for resolving each clash. This leads to good communication between the project stakeholders as they will all have the same interpretation of the problem. This quick results solution makes the clash detection work much easier since the manager will no longer need to use expensive sophisticated software nor realize time consuming conversions.

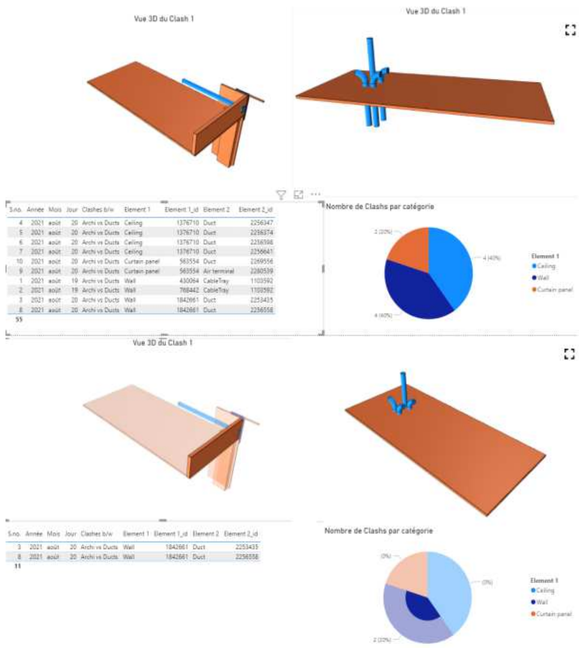


Figure 8. Clash coordination dashboard

4.3. Plans extraction

This dashboard (Figure 9) offers the possibility to analyse each spatial element along with its semantic data, which is not possible in commercial software.This allows the user to efficiently visualize the floor plans and concisely present all the spatial information related to them. The representation is clear and well targeted, which will facilitate and accelerate several tasks that require a detailed knowledge of the information of the elements of each floor. In the case of large structures, this analysis can effectively manage the number of rooms per floor, including the number of offices and provide the occupancy ratefor maintenance and management.

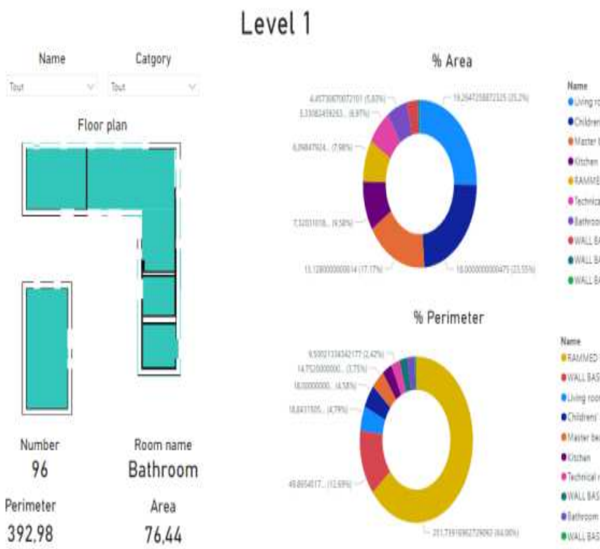


Figure 9. 2D drawings extraction dashboard

4.4. Change detection

In addition to the color-coded visual displayed on Revit, our solution also provides a simple dashboard (Figure 10) to choose which items to display based on the type of change that has occurred, while providing the user with all the related information. This comparison tool gives designers a better understanding of the changes made to the project, especially when multiple professionals are working on the model, and allows team leaders to accurately and easily visualize and identify the work progress.

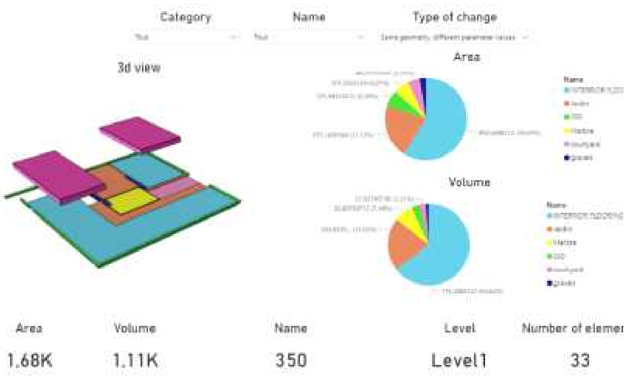


Figure 10. Change detection dashboard

Finally, the amount of data in BIM models makes it difficult to use them and extract relevant information for project management accurately and quickly.In our solution, we have used the Dynamo Revit's plugin to perform targeted analysis on the BIM model and extract relevant data, as well as the Power BI BI software for their visualization on interactive and understandable dashboards allowing a correct sharing of information between the various stakeholders of the projects and a good decision making process.

5. CONCLUSION AND FUTURE WORK

BIM is a process that is increasingly adopted in the construction sector due to the many benefits it provides and the high level of performance it allows for managing costs and quality for the building life cycle projects.However, access to BIM data is still a complex task and needs specific developments to respond to some specific needs. In this paper, four analyses have been developed to automatically extractand visualize information from a BIM model which are clash detection, cost analysis, plansextraction and change detection.

Our approach is based on two main parts. The first part concerns the extraction of information from the BIM model using the "Relay" plug-in added to Revit, which is directly linked to the algorithms implemented with the visual programming tool Dynamo. The second part concerns the visualization of the results by using the Power BI software through several dashboards. The proposed solution allows reducing time-consuming tasks and thus respecting deadlines and costs by automatically extracting information from BIM and visualizing it in form of dashboards.

As a future work, we recommend the development of a solution which allows the establishment of a direct link between Revit and Power BI.

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