JOURNAL OF APPLIED ENGINEERING SCIENCES
ISSN: 2247-3769 / e-ISSN: 2284-7197

VOL. 15(28), ISSUE 1/2025
ART.NO. 444 pp. 113-122

SEMI-AUTOMATIC RECOGNITION OF OBJECTS FROM CAD DRAWINGS FOR QUANTITY SURVEYING

T. Hassan[a*], F. Farrag [a], A. ElSonbaty [a], M. Besheer[a]

[a] Department of Civil Engineering, Assiut University, 71515, Egypt, E-mails: *tahermoh@aun.edu.eg, farag.rashwan@eng.au.edu.eg, asonbaty@aun.edu.eg, mabesheer@aun.edu.eg

Received: 22.01.2025 / Accepted: 03.02.2025 / Revised: 06.03.2025 / Available online: 31.05.2025

DOI: 10.2478/jaes-2025-0014

KEYWORDS: CAD Drawings, Supervised classification, CAD Objects Recognition, Quantity Survey

ABSTRACT:

Many engineers still utilize computer-aided design (CAD) drawings for design and then use those drawings for quantity surveys. CAD is user-friendly and easy to learn, but less powerful than Building Information Modelling (BIM). Both technologies are utilized for Bill of Quantity (BOQ). The manual technique for producing BOQ takes a lot of time and may result in errors or model shortcomings. The current study aims to present an accurate framework for object recognition from CAD drawings and convert them into intelligent drawings through which engineers can automatically count amounts. The work here is classified as supervised classification using the principles of remote sensing to identify objects in CAD drawings. This approach aims to convert engineering work into computerized tasks, as it is necessary for large projects. The proposed framework incorporates the C# programming language with Microsoft Excel and AutoCAD. The framework has been tested on over 200 layouts. Drawing faults are detected and corrected automatically or semiautomatically, yielding precise output. The current work minimizes human mistakes in quantity surveys, increases productivity, and completes project information. The study highlights the importance of using the latest technology to overcome the shortcomings in CAD drawings.

1. INTRODUCTION AND BACKGROUND

A few conditions specific to the object (e.g., vegetation, water bodies, urban areas, roads, buildings, canals) must be satisfied to identify objects in images in a remote sensing framework. When the prerequisites are met, the object is recognized as a result. In that context, these standards might serve as a reference when applying a set of conditions to AutoCAD layouts to identify elements (such beams, columns, and footings). The work here is classified as a supervised classification. A quantity surveyor's work mostly consists of computations and quantification, both of which benefit substantially from computer assistance. Nowadays, many commercially available software packages are made to facilitate the performance of quantity surveying operations. The construction sector, which employs more than 6–8% of the labor force, is crucial to economic growth worldwide (Acheng et al. 2022) (UBOS 2013). Regardless of its significance, this sector suffers from several common issues, such as ineffective procedures, inadequate training, and separation that may cause delays. Adopting Building Information Modelling (BIM) is complex due to several factors, including low awareness, expensive execution, and inadequate training (Ogwueleka AC 2017) (Newswire 2015). In Uganda, for example, BIM adoption is in its early stages, with most professionals using BIM software primarily for modeling and little use of collaboration or preconstruction software. Most engineers are familiar with modeling software, specifically AutoCAD, Revit, and ArchiCAD (Acheng et al. 2022). On the other hand, most Egyptian engineers still use CAD technology to draw constructions before manually surveying the project quantity, leading to time-consuming errors. BIM is better suited to the construction industry because it allows for real-time visualization and model analysis.

The key differences between CAD and BIM are that CAD is user-friendly and easy to learn, while BIM is powerful and can create complex models. On the contrary, BIM is not as user-friendly as CAD and is more difficult to learn, while CAD is not as powerful as BIM and cannot create complex models (Edirisinghe 2022). BIM allows architects, contractors, and engineers to collaborate on the same database and building model throughout the project, creating a digital representation of a building (Edirisinghe 2022). These differences make the BIM technology hard to use, so the current work is a trial to make the easy CAD drawings powerful and create complex models in a simple way. Quantity Survey (QS) is a critical task for both the owner and the contractor on every construction project because it helps to: (i) Determine the initial estimates of the project at various stages. (ii) Prepare a Bill of Quantity (BOQ) for contract documents as needed. (iii) Estimate the work done to pay the contractor. (iv) Determine the cost of each work item. (v) Determine the resources needed. (vi) Create a project schedule. (vii) Review and control crew production rates. All the listed tasks must be completed in a short period. As a result, it is critical to develop CAD tools to perform the intended QS tasks. Because of the continuous review of designers in our construction industry, the role of the Quantity Surveyor is critical. As a result of technological advancements that address current challenges, many software configurations have emerged in the market. Construction projects are becoming more challenging to perform QS. Also, the existing

* Corresponding author: Taher Mohamed, Assistant Lecturer, Dept. of Civil Engineering, Assiut University, 71515, Egypt,
E-mail: tahermoh@aun.edu.eg

QS software, such as Dimension X, Cost X, Prime-To, WinQS, QSPlus, Master-bill, QS Cad, Autodesk QTO…. etc., are not keeping up (Bazjanac 2006; Ken 2010). These programs are costly, complex to use with limited expert knowledge, require multiple packages to complete a task, are inaccessible, and require high computer specifications to run, which many individual quantity surveyors cannot afford, stifling technological advancements and causing project delivery delays (Mwebaze 2019).

Manual take-off from CAD software is time-consuming because it requires obtaining measurements from plans, elevations, sections, and other related documents, which takes a long time, especially if a complex project is being undertaken (Monteiro and Martins 2013)(Wijayakumar and Jayasena 2013). The process of preparing Bills of Quantities (BOQ) is significantly influenced by human errors, mainly due to the interpretation of 2D drawings. The workload assigned to the quantity surveyor substantially contributes to these errors, which in turn affect the results entered in the BOQ, ultimately impacting the contractor's pricing. (Monteiro and Martins 2013). However, all the errors can be reduced or eliminated to some extent through automation in the Quantity Surveying field (Wijayakumar and Jayasena 2013).

According to reference (Monteiro and Martins 2013) , the use of Building Information Modeling (BIM) supported software in the QS faces several challenges, including high acquisition costs, requiring extensive expertise, changing the original drawing format, and allowing multiform roof modeling. This can be problematic for QS, as it doesn't provide the necessary quantity measurement information. Modifying components like railings, steps, and landings before QS can cause issues. Furthermore, integrating design and Quantity Survey BIM software can be challenging, as modeling software focuses on the geometric aspect of the structure, while QS software focuses on the information content. The current study tries to solve this shortcoming.

Recognition methods in CAD drawings based on special symbols can be classified into structure-based and statistics-based. The structure-based recognition method extracts information from CAD vector drawings and recognizes symbols based on predefined rules. Moreover, these target symbols are usually divided into different entities based on their characteristics (Guo, Zhang, and Wen 2012). Reference [12] developed a novel descriptor based on symbol signatures to accurately filter and recognize symbols. But all the symbols should be assumed in vectorial forms at the beginning. Reference (Horna et al. 2009) developed an approach to automatically reconstruct 3D buildings from 2D vector floor plans based on the generalized maps. The resulting model could further include topology and semantics information, but the curved elements must be decomposed into several line elements in this approach. Considering the curve elements in CAD drawings, reference (Nayef and Breuel 2011) developed a grouping method according to convex-based grouping rules to classify geometric primitives from line drawings. Other works conducted in [15] were suitable with straight and circular segments. They proposed a semi-automatic detection method of floor topology based on the Wall Adjacency Graph (WAG).

To achieve effective management throughout the lifecycle of a building, especially in the Operating and Management (O&M) phase (Lu & Lee, n.d. 2017) developed a low-cost and applicable approach to assist in constructing as-is BIM objects of an existing building. Reference (Yin et al. 2019) proposed an automated layer classification method as pretreatment in transforming CAD to BIM models. It can analyze the content in each drawing layer and classify the layer into a specific category. An automated layer classification method is proposed as a pretreatment in the process of 3D reconstruction to avoid shortcomings. Reference (Lim, Janssen, and Stouffs 2018) proposed a method to semi-automate the generation of BIM models from 2D CAD drawings for existing buildings which often lack BIM models. The method has two parts: the first part, 2D CAD drawing preparation, involves cleaning the drawings to obtain simplified 2D input geometry, and the second, 3D BIM model generation, involves generating and extracting parameters to generate 3D BIM components. The research focused on the semi-automation of the second part. The model is generated story by story, with each building element type being processed.

2. PROBLEM STATEMENT

Most engineers in Egypt still use CAD technology for drawing constructions, and the project quantity surveying is performed manually (Wang 2012). This led to many errors and was more time-consuming. On the other hand, BIM offers a more complete representation of a building's design. It takes more than the building's core components into account. Many in architecture and engineering industries have not yet adopted BIM. As a result, there is a lack of experts in BIM. This becomes obvious in the extra training that must be undertaken to understand the model. It is not easy to locate suitable professionals for BIM training. The BIM methodology will pay back its initial outlay over time, so the initial investment may be too large (Wang 2012) (Elyamany 2016). China is one example of a developing nation still using CAD drawings as delivery for construction projects (Yin et al. 2019).

In Nigeria, a questionnaire survey is performed with respondents comprising architects, builders, engineers, surveyors, and quantity surveyors. The study discovered that AutoCAD is the most popular software at 87.7% for Architectural/ Engineering design and drawing. Another study in (Edirisinghe 2022) found that MS Excel and AutoCAD are the most often used software by quantity surveyors in Sri Lanka. In recent years, reference (Su et al. 2020) has done much fruitful research on converting CAD and GIS data, but these studies have certain limitations and rarely involve converting remote sensing image data to CAD.

CAD programs are currently the most widely used tools in the construction sector. Developing it to be a powerful tool, the same as BIM software, is a severe need. Additionally, errors in the drawing affect the accuracy of the QS, so minimizing human mistakes in drawings is essential to increase productivity.

3. OBJECTIVES OF THE STUDY

The objective of the current work is to convert engineering work to computerized work for several purposes, including saving time/effort, increasing accuracy, and reducing human error, which is required for large projects.

The main goal is to create a tool that can automatically take-off quantities of structural and architectural elements from CAD drawings into Excel. Moreover, to develop an efficient and dependable framework for identifying elements in CAD drawings and converting them into intelligent drawings from which quantities are automatically assessed or measured. A novel approach that incorporates the C# programming language with Microsoft Excel and AutoCAD will be introduced. Another objective of the current study is to test the framework presented by a group of engineers with extensive experience in the field of civil and architectural engineering. The last objective is getting feedback from the involved engineers to discover and minimize mistakes in drawings and get accurate information for QS.

4. RESEARCH TOOLS

The research is built mainly on four tools. The first tool is the C# programming language, which is utilized to develop the introduced framework as it is a general-purpose, high-level programming language developed by Microsoft that runs on the .NET Framework. Also, C# is used to create web apps, desktop apps, mobile apps, and much more, which are familiar to the engineering community. The second tool is AutoCAD, Autodesk's Computer Aided Design (CAD) software application, which is used in a variety of industries by graphic designers, engineers, project managers, architects, and other professionals. AutoCAD is the most used, cost-effective, and easy-to-access software in construction work and has been taken up as a base software (Saleh 1999). The third tool is Microsoft Excel, a client program that hosts the object application and is widely utilized for final calculations. This primarily included the research processes, such as developing a link between AutoCAD and Excel, designing a simple drawing in AutoCAD, and extracting drawing data from AutoCAD into Excel. Primary data, the main source used in the research through programming, was obtained as discussed below. In this study, some features of the drawings are made manually, and the remaining work is done automatically, so there is a need for supervised and unsupervised algorithms.

5. SUPERVISED AND UNSUPERVISED LEARNING ALGORITHMS

Supervised and unsupervised learning algorithms have demonstrated significant promise in the acquisition of knowledge from large data sets. Supervised learning refers to an algorithm's ability to apply general knowledge from available data with the target or marked cases for the algorithm to predict new (unlabeled) cases. Particularly, supervised algorithms perform analytical tasks using training data first, then construct contingent functions for mapping new attribute instances. As previously stated, the algorithms necessitate pre-specifying maximum settings for the desired outcome and performance levels (Alloghani et al. 2020).

Unsupervised learning refers to the process of grouping data into clusters using automated methods or algorithms on data that has not been classified or categorized (Alloghani et al. 2020). In this situation, algorithms must "learn" the underlying relationships or features. From the available data, group cases with similar features or characteristics. When small amounts of labeled data are available, the learning is specified as "semi-supervised". Unsupervised data learning involves pattern recognition without the involvement of a target attribute. That is, all the variables used in the analysis are used as inputs, and because of the approach, the techniques are suitable for clustering and association mining techniques. According to Hofmann (Alloghani et al. 2020), unsupervised learning algorithms are suitable for creating labels in the data that are subsequently used to implement supervised learning tasks.

Unsupervised clustering algorithms identify inherent groupings within the unlabeled data and subsequently assign a label to each data value. The work provides both foundational knowledge for novice or beginning researchers in machine learning and new techniques for improving both the accuracy and computational complexity of supervised and unsupervised learning in the context of relevant and practical applications. Techniques like deep learning-based object detection networks are used to locate and classify objects (e.g., buildings, roads, vehicles) in images. AutoCAD is used to create detailed plans for roads, buildings, utilities, and other infrastructure. Remote sensing data enhances these designs(Zhang, Lu, and Zhang 2019). The synergy between remote sensing and AutoCAD enhances our ability to create accurate, context-aware designs while considering environmental factors and real-world conditions (Li et al. 2022).

The current study's work is classified as supervised classification or deterministic supervised learning (computer vision), as the user has to change layer names to check unidentified properties. This step is very necessary and helps the work to be precise, so putting in less effort at the beginning of the work will save a lot of time in the end.

6. RESEARCH METHODOLOGY

In the field of remote sensing, to identify objects in images, a set of conditions which describe the specific object must be met (e.g., vegetation, water bodies, urban areas, roads, buildings, waterways). Thus, when the conditions are met, the object is identified. Guided by these criteria, a set of conditions is applied to AutoCAD panels, and elements (e.g., beams, columns, footings) are identified. The introduced framework interacts with drawings in two ways. The first one is done manually, such as changing the name of the drawing layers, fixing some errors, and comparing the resulting drawings with the original ones. The second way is automatic interaction through the other parts of the framework. Thus, the current work is classified as deterministic supervised learning or computer vision. **Error! Reference source not found.** demonstrates the proposed f ramework's methodology steps for object identification from CAD drawings. The introduced framework reads the CAD file with invented code, and the data is extracted from the drawings. These data are created in an overall matrix that includes all the properties of lines, arcs, text, points, polylines, circles, blocks, etc.

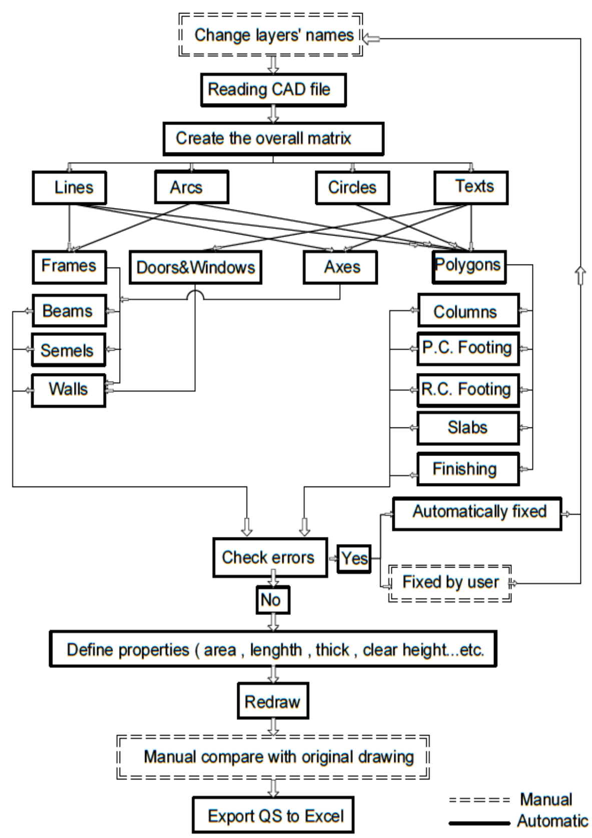


Figure 1. Steps of the introduced methodology for object identification from CAD drawings

All the elements in the CAD drawings are classified through submatrices which are extracted from the overall one. All these matrices are checked separately in an automatic sequence. Among all the data, only four concerning: lines, arcs, circles, and texts are used in the framework. Every one of these four may be categorized as one or more of the four main groups: (i) Frames, (ii) Doors &windows, (iii) Axis, and (iv) Polygons. For example, a line may be a frame, an axis, or a polygon.

Likewise, arcs may be a frame or, a polygon, and so on. Frames are beams, semels, or walls, while polygons are columns, plain concrete (P.C.) footings, reinforced concrete (R.C). footings, slabs, and finishing. All the properties of objects are identified automatically, and the errors are checked. An error in the drawings is dealt with in two ways according to the existing situation: automatically or manually. After performing the necessary modifications, the process is repeated, and all the properties are identified and defined accurately. Using the framework, the user can automatically redraw the plan to compare it with the original drawings to be confident that what was drawn is the same as what will be in the quantity survey. After that, all the quantities can be calculated to get a complete Quantity survey for the project. The main processes involved in the research are developing a link between AutoCAD and Excel, designing a simple drawing using AutoCAD, and extracting drawing data from AutoCAD into Excel.

Two types of errors can be found in the project drawings. **Error! Reference source not found.** introduces some examples of errors that can be fixed automatically and other examples that the user should fix. The first one has only one fixation probability, such as an intersection between frames and columns, two lines overlaying above each other, an open polygon with lines opposite each other, etc. These types of errors can be fixed automatically by the introduced framework without interfering with the user. The second type of error is which has more than one probability of fixation, such as missing symbols, single lines, unparallel lines, open polygon with lines non-opposite to each other's, etc. The framework makes a sign for the user to indicate that there is an error in that location. The user should fix these types of errors because of the possibility of making many decisions based on the situation.

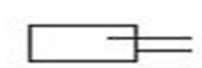
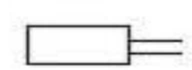
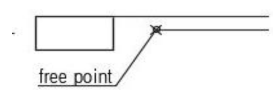
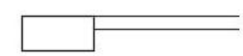
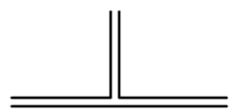
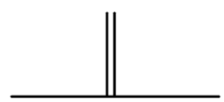
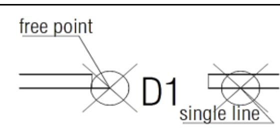
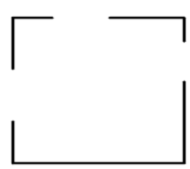
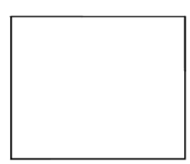
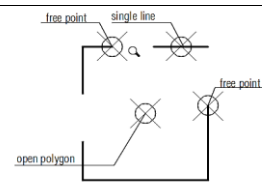
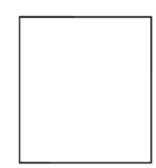
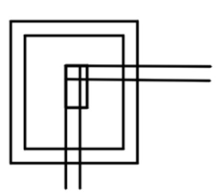
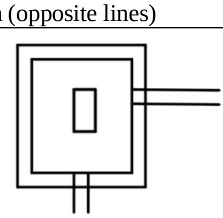
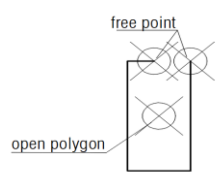
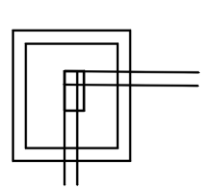
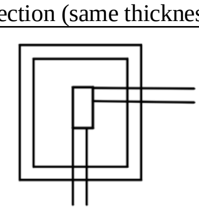
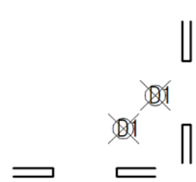
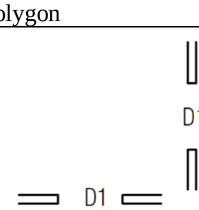
Examples of errors can be fixed automatically		**Examples of errors should be fixed by the user**	
Before	**After**	**Before**	**After**
			
Beam line inside column polygon		Free beam line	
			
Two beams intersection		Door intersection	
			
Opened footing polygon (opposite lines)		Opened footing polygon (un opposite lines)	
			
Column, footing and Semel intersection (same thickness)		Column open polygon	
			
Column, footing and Semel intersection (different thickness)		Far door symbols	

Table 1. Some examples of discovered errors by the introduced framework

7. EXPLEMENTARY EXAMPLE AND DISCUSSION OF QUANTITY SURVEY RESULTS

A layout in **Error! Reference source not found.** is used as an e xample to show the steps of the introduced framework.

The work steps on the framework are as follows:

1. The layer's names are changed to names that are identified in the framework code. If the objects in a layer have different names, they should be changed as listed in **Error! Reference source n ot found.**:
2. The three layouts (Columns and footings, Structural and Architecture) are put on each other with the same coordinates so that the net heights of the walls and columns can be calculated.
3. The project drawings and tables are exported to the framework.
4. Through the invented code, the matrix of overall properties of lines, arcs, circles, and text can be created, and the properties of each of them are shown from Table 3 to Table 6 as examples.

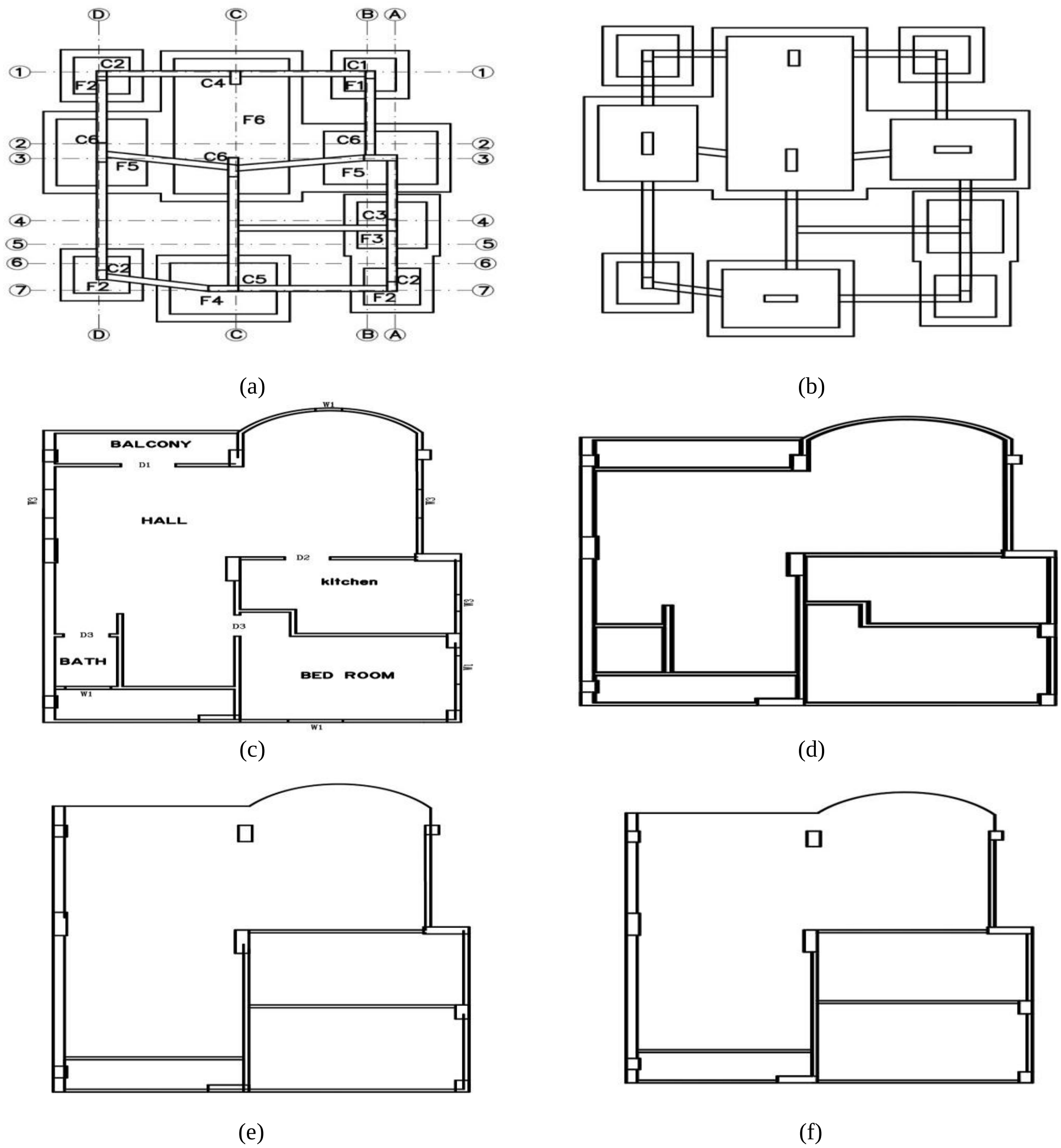


Figure 1. Example for identifying and fixing CAD drawings errors a) Columns and footings before; b) Columns and footings after; c) Architectural layout before; d) Architectural layout after; e) Structural layout before; f) Structural layout after

* Corresponding author: Taher Mohamed, Assistant Lecturer, Dept. of Civil Engineering, Assiut University, 71515, Egypt,
E-mail: tahermoh@aun.edu.eg

Object	New layer name	Object	New layer name
Semel	Semel - Semel thickness	Door &Window	Door &Window
Footing Symbols	Footing	Finishings*	Finishing- Floor Height
Columns Symbols	Column-Floor Height	Out Finishing*	Finishing- Floor Height -Out
Axis	Axis	Finishings Openings*	Finishing- Floor Height- Open
Beams**	Beam- thickness		

* Inserted as polygons. ** Inserted as a frame.

Table 2. Changing the names of the layers

Layer Name	**Length**	**Angle**	**End X**	**End Y**	**Start X**	**Start Y**
wall-3	3.553706	270	15847.86	4723.368	15847.86447001	4726.921
P.C. footing	1.3	270	15840.14	4733.106	15840.14	4734.406
Semel -0.6	4.52915	180	15843.04	4726.687	15847.56	4726.687
R.C. footing	0.701131	180	15838.04	4733.506	15838.74	4733.506
⋮	⋮	⋮	⋮	⋮	⋮	⋮
Door & Window	0.12	180	15846.9	4733.045	15847.02	4733.045

Table 3. The most important properties of lines for the overall matrix

Area	**Center X**	**Center Y**	**Center Z**	**Layer**	**Radius**	**Circumference**	**Diameter**
0.317	15847.804	4720.993	0.000	axis	0.318	1.995	0.635
0.317	15838.798	4720.993	0.000	axis	0.318	1.995	0.635
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
0.283	15842.953	4734.356	0.000	column-3	0.300	1.885	0.600

Table 4. The most important properties of circles for the overall matrix

Arc Area	**Center X**	**Center Y**	**Layer**	**Length**	**Radius**	**Start Angle**	**Total Angle**
2.911	15845.002	4733.983	wall-3	4.705	2.494	35.954	108.091
2.519	15845.002	4733.983	wall-3	4.402	2.374	36.885	106.230
0.008	15842.953	4734.356	finishing-3	0.314	0.300	0.000	60.003
0.002	15842.953	4734.356	finishing-3	0.181	0.300	180.000	34.510
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
0.030	15842.953	4734.356	finishing-3	0.501	0.300	84.255	95.745

Table 5. The most important properties of arcs for the overall matrix

Text Layer	**Position X**	**Position Y**
Door & Window	15847.11	4732.724
finishing-3	15842.31	4731.868
footing	15839.27	4723.401
⋮	⋮	⋮
column-3	15839.53	4724.397

Table 6. The most important properties of text for the overall matrix

5. The project checked to make sure that there were no drawing errors that could affect the accuracy of the QS (see **Error! Reference source not found.** a, b, c, d, e, and f).
6. After correcting these errors either automatically by the framework or manually by the user, the project is exported to the framework again to extract the results.

7. The framework can automatically redraw all the elements taken to check the layout in detail and compare it with the original drawings. This makes the user confident that what was drawn is the same as what will be in the QS as seen in **Error! R f ource not found.**.
118
8. The QS results are exported to Excel format. The outp **Error! Reference source not found.** to **Error! Reference source not found.** as examples. The outputs are categorized as follows: 1) Plain concrete footings, 2) Reinforced concrete footings, 3) Columns, 4) Slabs, 5) Beams, 6) Semels, 7) Thresholds, 8) Doors and Windows, 9) Paintings, 10) Floors, 11) Skirting, 12) Cornices, and 13) walls.

Item No.	Item Description	unit	NO	Dimensions: Length / Area	Dimensions: width	Dimensions: Hight	cubes & Areas: Add	cubes & Areas: Reduction	Total	Notes
						Total of P.C			45.91	m^3
1	F1	m3	1.00	2.50	2.35	0.40	2.35	0.00	2.35	m^3
	F2	m3	2.00	2.70	2.50	0.40	5.40	0.00	5.40	m^3
	F3-F2	m3	1.00	16.62	0.00	0.40	6.65	0.00	6.65	m^3
	F4	m3	1.00	4.05	3.45	0.40	5.59	0.00	5.59	m^3
	F5-F5-F6	m3	1.00	64.80	0.00	0.40	25.92	0.00	25.92	m^3

Table 7. Quantities of plain concrete footings

BOQ Item Description :											Reinforcement					
Item NO	Item Description	Unit	NO	Dimensions: Length	Dimensions: width	Dimensions: Hight	cubes & Areas: Add	cubes & Areas: Reduction	Total	Notes	Direction In X: Bar No	Direction In X: Diam	Direction In Y: Bar No	Direction In Y: Diam	Col . Neck: Length	Col . Neck: Width
					Total of R.C				44.28	m^3						
2	F1	m3	1.00	1.70	1.55	0.50	1.32	0.00	1.32	m^3	11.00	12.00	12.00	12.00	0.30	0.40
	F2	m3	3.00	1.90	1.70	0.50	4.85	0.00	4.85	m^3	14.00	12.00	15.00	12.00	0.30	0.50
	F3	m3	1.00	2.40	2.10	0.50	2.52	0.00	2.52	m^3	24.00	12.00	27.00	12.00	0.30	0.60
	F4	m3	1.00	3.25	2.65	0.60	5.17	0.00	5.17	m^3	21.00	16.00	25.00	16.00	0.30	0.90
	F5	m3	2.00	3.45	2.75	0.70	13.28	0.00	13.28	m^3	21.00	16.00	26.00	16.00	0.30	1.00
	F6	m3	1.00	7.00	3.50	0.70	17.15	0.00	17.15	m^3	28.00	16.00	42.00	16.00		

Table 8. Quantities of Reinforced Concrete Footings

BOQ Item Description											Reinforcement				
Item NO	Item Description	Unit	NO	Dimensions: Length	Dimensions: width	Dimensions: Hight	Areas & cubes: Add	Areas & cubes: Reduction	Total	Notes	No. of Columns	No. of Bars	Diameter	Hight of column+ thickness of slab	Thickness of R.C
					Total Of Columns				6.29	m^3					
3	C1	m3	1.00	0.30	0.40	3.20	0.38	0.00	0.38	m^3	1.00	6.00	16.00	3.20	0.50
	C2	m3	2.00	0.30	0.50	3.00	0.90	0.00	0.90	m^3	2.00	8.00	16.00	3.20	0.50
	C2	m3	1.00	0.30	0.50	3.08	0.46	0.00	0.46	m^3	1.00	8.00	16.00	3.20	0.50
	C3	m3	1.00	0.30	0.60	3.08	0.55	0.00	0.55	m^3	1.00	10.00	16.00	3.20	0.50
	C4	m3	1.00	0.30	0.70	2.80	0.59	0.00	0.59	m^3	1.00	10.00	16.00	3.00	0.70
	C5	m3	1.00	0.30	0.90	3.10	0.84	0.00	0.84	m^3	1.00	14.00	16.00	3.10	0.60
	C6	m3	2.00	0.30	1.00	2.88	1.73	0.00	1.73	m^3	2.00	16.00	16.00	3.00	0.70
	C6	m3	1.00	0.30	1.00	2.80	0.84	0.00	0.84	m^3	1.00	16.00	16.00	3.00	0.70

Table 9. Quantities of Columns

Item NO	Description Item	Type	Numbering	NO	Dimensions: Length	Dimensions: width	Dimensions: Hight	Add / Reduction	cubes & Areas: Add	cubes & Areas: Reduction	Total	Notes
									Total Of Beams		2.96	m^3
								Horizontal				
4	on Axis 7	beam	b1	1	3.27	0.12	0.400	Add	0.16	0.00	0.16	m^3
	on Axis 7	beam	b2	1	4.53	0.12	0.480	Add	0.26	0.00	0.26	m^3

on Axis 6	beam	b3	1	3.93	0.12	0.400	Add	0.19	0.00	0.19	m^3
on Axis 4	beam	b4	1	4.53	0.12	0.480	Add	0.26	0.00	0.26	m^3
on Axis 3	beam	b5	1	3.83	0.12	0.480	Add	0.22	0.00	0.22	m^3
					Vertical Axis						
on Axis C	beam	b6	1.00	5.66	0.12	0.48	Add	0.33	0.00	0.33	m^3
on Axis B	beam	b7	1.00	3.97	0.12	0.40	Add	0.19	0.00	0.19	m^3
on Axis A	beam	b8	1.00	3.05	0.12	0.48	Add	0.18	0.00	0.18	m^3
on Axis A	beam	b9	1.00	2.64	0.12	0.48	Add	0.15	0.00	0.15	m^3
on Axis D	beam	b10	1.00	5.61	0.25	0.40	Add	0.56	0.00	0.56	m^3
on Axis D	beam	b11	1.00	0.61	0.25	0.40	Add	0.06	0.00	0.06	m^3
on Axis D	beam	b12	1.00	3.24	0.25	0.40	Add	0.32	0.00	0.32	m^3
on Axis D	beam	b13	1.00	0.82	0.25	0.40	Add	0.08	0.00	0.08	m^3
					Oblique						
Oblique Axis	beam	b14	1.00	0.82	0.25	0.40	Add	0.00	0.00	0.00	m^3
					Arcs						
Arcs	beam	b15	1.00	0.82	0.25	0.40	Add	0.00	0.00	0.00	m^3

Table 10. Quantities of beams

Item NO	Item Description			No	Dimensions		Areas & cubes & Numbers		Total	Notes
					Width	Hight	Add	Reduction		
	Doors & Windows						Doors	4.00	9.90	
							Windows	7.00	6.80	
								Total Numbers	Total Areas / m^2	
	door - D1	Wooden Door	0.00	1.00	1.00	2.20	2.20	0.00	2.20	door
6	door - D2	Wooden Door	0.00	1.00	1.10	2.20	2.42	0.00	2.42	door
	door - D3	Aluminum	0.00	2.00	1.20	2.20	5.28	0.00	5.28	door
	window - W1	Aluminum	0.00	4.00	1.00	0.80	3.20	0.00	3.20	window
	window - W3	Aluminum	0.00	3.00	1.20	1.00	3.60	0.00	3.60	window

Table 11. Quantities of Doors & Windows

.Item NO	Item Description	Numbering	NO	Dimensions			Add / Reduction	Areas & cubes		Total	Notes
				Length	width	Hight		Add	Reduction		
							Total of Semel			4.77	m^3
					Horizontal Axis						
	on Axis 7	m1	1	2.65	0.30	0.600	Add	0.48	0.00	0.48	m^3
	on Axis 7	m2	1	0.70	0.30	0.100	Add	0.02	0.00	0.02	m^3
	Between Axis 4&5	m3	1	3.63	0.30	0.600	Add	0.65	0.00	0.65	m^3
	Between Axis 4&5	m4	1	0.90	0.30	0.100	Add	0.03	0.00	0.03	m^3
	on Axis 1	m5	1	0.70	0.30	0.100	Add	0.02	0.00	0.02	m^3
	on Axis 1	m6	1	1.35	0.30	0.600	Add	0.24	0.00	0.24	m^3
	on Axis 1	m7	1	1.69	0.30	0.600	Add	0.30	0.00	0.30	m^3
	on Axis 1	m8	1	0.62	0.30	0.100	Add	0.02	0.00	0.02	m^3
					Vertical Axis						
	on Axis D	m9	1	0.70	0.30	0.100	Add	0.02	0.00	0.02	m^3
	on Axis D	m10	1	0.70	0.30	0.100	Add	0.02	0.00	0.02	m^3
5	on Axis D	m11	1	3.69	0.30	0.600	Add	0.66	0.00	0.66	m^3
	on Axis D	m12	1	1.31	0.30	0.600	Add	0.24	0.00	0.24	m^3
	on Axis C	m13	1	3.60	0.30	0.600	Add	0.65	0.00	0.65	m^3
	on Axis B	m14	1	0.65	0.30	0.100	Add	0.02	0.00	0.02	m^3
	on Axis B	m15	1	2.09	0.30	0.600	Add	0.38	0.00	0.38	m^3
	on Axis A	m16	1	0.90	0.30	0.100	Add	0.03	0.00	0.03	m^3
	on Axis A	m17	1	0.90	0.30	0.100	Add	0.03	0.00	0.03	m^3
	on Axis A	m18	1	0.70	0.30	0.100	Add	0.02	0.00	0.02	m^3
					Oblique Axis						
	No Axis	m21	1	1.24	0.30	0.600	Add	0.22	0.00	0.22	m^3
	No Axis	m22	1	0.71	0.30	0.100	Add	0.02	0.00	0.02	m^3
	No Axis	m23	1	1.06	0.30	0.600	Add	0.19	0.00	0.19	m^3
	No Axis	m24	1	0.83	0.30	0.600	Add	0.15	0.00	0.15	m^3

Table 12. Quantities of Semel

Item NO	Item Description	Place	type	NO	Dimensions Length	Dimensions Hight	Add or Reduction	Areas & cubes Add	Areas & cubes Reduction	Total	Notes
	-							Total Length Skirting		6.71	
						Level					
	No2	BEDROOM	0.00	1.00	18.20	0.10	Add	1.82	0.00	1.82	m. run
	No2-Subtract door-D3	BEDROOM	0.00	1.00	1.20	0.10	Subtract	0.00	0.12	0.12-	m. run
	No3	BATH	0.00	1.00	6.67	0.10	Add	0.67	0.00	0.67	m. run
	No3-Subtract door-D3	BATH	0.00	1.00	1.20	0.10	Subtract	0.00	0.12	0.12-	m. run
7	No5	HALL	0.00	1.00	39.68	0.10	Add	3.97	0.00	3.97	m. run
	No5-Subtract door-D3	HALL	0.00	1.00	1.20	0.10	Subtract	0.00	0.12	0.12-	m. run
	No5-Subtract door-D3	HALL	0.00	1.00	1.20	0.10	Subtract	0.00	0.12	0.12-	m. run
	No5-Subtract door-D2	HALL	0.00	1.00	1.10	0.10	Subtract	0.00	0.11	0.11-	m. run
	No5-Subtract door-D1	HALL	0.00	1.00	1.00	0.10	Subtract	0.00	0.10	0.10-	m. run
	No6	BALCONY	0.00	1.00	10.41	0.10	Add	1.04	0.00	1.04	m. run
	No6-Subtract door-D1	BALCONY	0.00	1.00	1.00	0.10	Subtract	0.00	0.10	0.10-	m. run

Table 13. Quantities of Skirting

The framework is written in C# and compatible with operating systems that designers or contractors possess. The introduced framework can perform the automated quantity survey. It should be remembered that other frameworks like rivet are very expensive and are used by fewer people than AutoCAD, which is used very widely. The preparation of a complete and concise project document is a critical issue facing professionals, developers, and contractors working in the building industry. The lack of an accurate, fast, and effective framework for estimating the bill of quantities creates problems during the design, tender, and construction supervision of construction projects for designers and contractors. The introduced framework shows simplification of measurements and cost calculations through automated quantities from CAD files, Enhanced project predictability due to reduced variations, Improved design quality, Low financial risks due to reliable cost estimates, Improved construction planning leading to increased speed and reduced overall project durations, financial constraints for upfront costs for software, hardware upgrades, training, and support.

8. FRAMEWORK TESTING

The presented framework is tested by a group of engineers with extensive experience through a questionnaire distributed among 28 technical office/site civil and architectural engineers. More than 200 plans, including residential and university places, with sizes ranging from 100 to 7000 m^2, have been tested using the suggested framework. A total of 443 structural plans and 337 architectural plans were included in the study; each participant typically completed between 13 and 17 drawings. Respondents to a questionnaire stated that using the new suggested framework saved 77% of the time for a detailed quantity survey, while 73% of the time was saved for the total survey. Also, about 96% of participants rated their ability to identify errors in drawings as excellent or acceptable.

9. CONCLUSIONS

Engineers often use CAD drawings for design and quantity surveys due to limited BIM development knowledge. A new framework aims to convert engineering work to computerized work, saving time, effort, accuracy, and reducing human error. Tested on over 200 plans, it offers a comprehensive representation of building design, reduces document searching, and allows prefabrication of crucial components. The model updates constantly, allowing clients to check in anytime, and resource tracking ensures efficient project development. The most important outputs of the present research can be briefly summarized as follows:

(1) An efficient and dependable framework for recognizing the elements in CAD drawings and turning them into intelligent drawings is presented in the current study.
(2) CAD technology is still widely used by engineers to draw construction projects, so the framework that has been provided will automatically perform quantity surveying.
(3) An automated system for identifying and handling drawing shortcomings in CAD drawings has been developed. It also provides error positions that cannot be fixed, resulting in highly accurate quantity calculations.
(4) The new framework automates CAD file quantities, simplifies measurements, and calculates costs, reducing project durations and financial constraints for owners and contractors while ensuring reliable cost estimates.
(5) The introduced framework aids in project estimation, contract preparation, contractor payments, resource pricing, project scheduling, resource review, and production rate control for crews.
(6) An alternative tool has been introduced that is compatible with computers, has high capabilities, and is easy to use.

Notation

2D = Two Dimensional
3D = Three Dimensional
BIM = Building Information Modelling
BOQ = Bill of Quantity
CAD = Computer Aided Design
O&M = Operating and Management
QS = Quantity Surveyor
QTO = Quantity Take Off
WAG = Wall Adjacency Graph

References

Acheng, Pamela O., Nathan Kibwami, Tom J. Mukasa, Brian B. Odongkara, Rachel Birungi, Julius Semanda, and Musa Manga. 2022.

"Building Information Modelling Adoption in Uganda's Construction Industry." International Journal of Construction Management. https://doi.org/10.1080/15623599.2022.2047278.

Alloghani, Mohamed, Dhiya Al-Jumeily, Jamila Mustafina, Abir Hussain, and Ahmed J Aljaaf. 2020. "Supervised and Unsupervised Learning for Data Science." Supervised and Unsupervised Learning for Data Science.

Bazjanac, V. 2006. Applying Information Modelling to Buildings.

Edirisinghe, T. V., & Bandara, K. P. S. P. K. 2022. "Specialized Software Usage among Quantity Surveyors in Sri Lanka." Built Environment & Spatial Sciences.

Elyamany, Ahmed H. 2016. "Current Practices of Building Information Modelling in Egypt." International Journal of Engineering Management and Economics 6 (1). https://doi.org/10.1504/ijeme.2016.079836.

Guo, Tiantian, Hui Zhang, and Yamei Wen. 2012. "An Improved Example-Driven Symbol Recognition Approach in Engineering Drawings." In Computers and Graphics (Pergamon). Vol. 36. https://doi.org/10.1016/j.cag.2012.06.001.

Horna, S., D. Meneveaux, G. Damiand, and Y. Bertrand. 2009. "Consistency Constraints and 3D Building Reconstruction." CAD Computer Aided Design 41 (1). https://doi.org/10.1016/j.cad.2008.11.006.

Ken, D. 2010. "Autodesk Quantity Take-off. Germany: Saunders Construction."

Li, Zheng, Yongcheng Wang, Ning Zhang, Yuxi Zhang, Zhikang Zhao, Dongdong Xu, Guangli Ben, and Yunxiao Gao. 2022. "Deep Learning-Based Object Detection Techniques for Remote Sensing Images: A Survey." Remote Sensing. MDPI. https://doi.org/10.3390/rs14102385.

Lim, Joie, Patrick Janssen, and Rudi Stouffs. 2018. "Automated Generation Of Bim Models From 2d Cad Drawings."

Lu, Qiuchen, and Sanghoon Lee. 2017. "A Semi-Automatic Approach to Detect Structural Components from CAD Drawings for Constructing As-Is BIM Objects."

Monteiro, André, and João Poças Martins. 2013. "Automation in Construction A Survey on Modeling Guidelines for Quantity Takeoff-Oriented BIM-Based Design." Automation in Construction 35.

Mwebaze, N. 2019. "Developing a Quantity Surveying Tool for Automatically Taking off Quantities from AUTOCARD into EXCEL (Doctoral Dissertation)." MAKERERE UNIVERSITY.

Nayef, Nibal, and Thomas M. Breuel. 2011. "Statistical Grouping for Segmenting Symbols Parts from Line Drawings, with Application to Symbol Spotting." In Proceedings of the International Conference on Document Analysis and Recognition, ICDAR. https://doi.org/10.1109/ICDAR.2011.81.

Newswire, P R. 2015. "Global Building Information Modelling Market - By Products, Regions and Vendors - Market Trends and Forecasts (2015 - 2020) - Reportlinker Review." NY-Reportlinker.

Ogwueleka AC, Ikediashi DI. 2017. "The Future of BIM Technologies in Africa: Prospects and Challenges." In Integrated Building Information Modelling. https://doi.org/10.2174/9781681084572117010016.

Saleh, Mohammed Abdullah Eben. 1999. "Automation of Quantity Surveying in Construction Projects." Journal of Architectural Engineering 5 (4). https://doi.org/10.1061/(asce)1076-0431(1999)5:4(141).

Su, Jinya, Matthew Coombes, Cunjia Liu, Yongchao Zhu, Xingyang Song, Shibo Fang, Lei Guo, and Wen Hua Chen. 2020. "Machine Learning-Based Crop Drought Mapping System by UAV Remote Sensing RGB Imagery." Unmanned Systems 8 (1). https://doi.org/10.1142/S2301385020500053.

UBOS. 2013. "The National Labour Force and Child Activities Survey." Uganda Bureau of Statistics Statistics and United Nations, no. July.

Wang, Xiangyu. 2012. "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors." Construction Economics and Building 12 (3). https://doi.org/10.5130/ajceb.v12i3.2749.

Wijayakumar, Mayouran, and Himal Suranga Jayasena. 2013. "Automation of BIM Quantity Take-Off to Suit QS's Requirements." In The Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction.

Yin, Mengtian, Zihao Ye, Llewellyn Tang, and Shuhong Li. 2019. "An Automated Layer Classification Method for Converting CAD Drawings to 3D BIM Models." In Advances in Informatics and Computing in Civil and Construction Engineering, 67–76. Springer International Publishing. https://doi.org/10.1007/978-3-030-00220-6_9.

Zhang, Gongjie, Shijian Lu, and Wei Zhang. 2019. "CAD-Net: A Context-Aware Detection Network for Objects in Remote Sensing Imagery." IEEE Transactions on Geoscience and Remote Sensing 57 (12): 10015–24. https://doi.org/10.1109/TGRS.2019.2930982.