

Cloud-Based System for Pre-Tender Drawing Revision Management

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ABSTRACT

The construction industry still relies heavily on manual systems to manage updated drawings during the pretender stage, particularly among smaller Quantity Surveying firms. This reliance leads to fragmented document management, unreliable version control, excessive remeasurement effort, and an increased risk of human error. This study proposes a cloud-based knowledge management framework incorporating Artificial Intelligence (AI) to address these operational inefficiencies. This paper presents a hybrid solution that integrates cloud storage with an AI-powered drawing comparison system, leveraging the Systems Development Life Cycle (SDLC) paradigm. To examine the system's ability to identify changes and speed up quantity updates prototype testing was conducted using representative architectural and structural drawing samples. The prototype observations suggest that cloud integration enhances accessibility and creates a single, reliable source of information. At the same time, OpenCV is able to identify changes in drawings, reducing the need for human comparison. The integrated system, in general, enhances Quantity Surveyors' efficiency, reinforces traceability, and improves information retention.

Keywords: Cloud-based drawing management; AI-assisted quantity take-off; OpenCV revision detection; Pretender decision making, Built-Environment, Construction Information Technology

INTRODUCTION

Advancements in digital technologies have transformed construction project delivery and Quantity Surveying (QS)-related activities, particularly measurement, documentation, and cost planning, where accuracy is critical (Ashworth & Perera, 2018). In this context, the discussion focuses on the pre-tender process in a small QS firms undertaking quantity take-off, cost planning, and tender document preparation while working with architects and engineers during the design development stage (Cartlidge, 2020). Especially since several projects are often treated simultaneously, efficient control over drawing revisions is necessary to preserve consistent tender information and reduce unnecessary duplication of measurement tasks (Smith, 2016).

In a conventional QS team, project QS staff interpret drawings, review revisions, and amend measurements to ensure the cost data is up to date (Cartlidge, 2020). However, numerous small QS firms continue to use non-integrated solutions for tender information (e.g., email exchanges, WhatsApp groups, shared folders, PDF/DWG files vs. Excel for documents) (Oyedele, 2015). Although basic sharing and exploration of the models are possible, these tools typically do not offer a well-structured revision history (change logs/approval records/quantity updates), leading to decreased traceability and the utilization of out-of-date drawings (Arayici et al., 2011).

These situations are exacerbated for tenders, with changes to the design so often occurring during the pre-tender period, QS staff are left trying to cross-reference revised drawings against earlier drawings and measurements within tight tender timeframes (Smith 2016). These errors can lead to a lack of cost certainty and impact tender decision-making, which may, in turn, contribute to post-contract variations and claims (Assaad & El-adaway, 2020). While such cloud storage enhances file accessibility and sharing, it does not automatically recognize relationships across different drawing versions or organize revision-related knowledge. Therefore, this study proposes a cloud-based knowledge management workflow combined with OpenCV-based drawing comparison

for revision tracking, automatic change identification, and improved traceability during the precontract stage (Zhang et al., 2020).

Problem Solution

During the pre-tender stage, Qs are responsible for reviewing revised construction drawings and remeasuring quantities in accordance with design changes issued by the architects and engineers. Although construction technologies have improved, work is mostly done by hand, especially in small QS companies. These frequent revisions to drawings require repeated visual checks and manual rechecks, making design changes difficult to detect and increasing the likelihood of human error.

Furthermore, small QS firms commonly experience weak version control and fragmented document management systems, where multiple revisions are dispersed across different devices or shared through informal communication channels. This practice often creates uncertainty regarding the latest approved drawings and disrupts information consistency (Waidyasekara et al., 2025). Previous studies have also identified that conventional QS practices are characterized by fragmented workflows and limited integration systems, which constrain effective change management (Zainon et al., 2018). The lack of structured change-tracking mechanisms further heightens the risk of overlooked design amendments (Muhamad & Mohammad, 2018). Collectively, these challenges contribute to increased rework, repeated quantity take-offs, delay in completing pre-tender measurement tasks and inconsistencies in quantity outputs. All these challenges may adversely affect tender pricing accuracy and elevate tender-related risks.

Thus, there is a crucial need for a digital platform that integrates cloud-based document management with Artificial Intelligence (AI) driven drawing comparison to enhance measurement accuracy, workflow efficiency and knowledge sharing among construction consultants. Although construction workflows are increasingly digitalised, there is limited research on integrating image-based revision detection with quantity estimation logic tailored to small QS firms.

Current Approach

The current process for handling drawing revisions is inefficient, leading to unnecessary delays, misunderstandings, and redundant work. What follows are some of the primary reasons why such deficiencies are creating problems.

Firstly, inconsistently named files make it more difficult to locate the latest version of a drawing quickly. Drawings are stored in several shared folders, such as cloud-based (Google Drive, OneDrive) and server-based storage, but they are not organized by version as much as by discipline or date (Cao, Li & Liang, 2005). Staff members can spend hours sifting through files or requests to find the most up-to-date components, slowing down work. Moreover, even if the correct drawing is located, it is not always clear that it's the most current version of a design, and mistakes that must then be reworked can ensue.

Moreover, the existing non-standardized naming convention causes misnaming and confusion with files. Archivists who catalogue drawings often need to recall from memory how they should be categorized or named, and not infrequently a drawing is given the wrong name or is at least misplaced in a given collection (Pasalski, Owerko, Kasznia & Wrzosek 2025). This can lead to the wrong versions being used, delaying approval and causing miscommunication with consultants.

Furthermore, the drawings are manually checked by the Engineers and Quantity Surveyors for differences between versions. Typically, they need to do so by opening two files side by side in software such as Adobe Acrobat, AutoCAD, or a PDF viewer. This approach is mentally taxing and time-consuming. Small changes, down to slight alterations in dimensions or where the walls are placed, can make a big difference in the project, and it is easy to miss them. If such details are ignored, this could lead to errors and a greater investment in cleaning them up (Choudhry & Iyer, 2017).

On the other hand, changes to the drawing are made and communicated informally via email or WhatsApp, typically accompanied by pictures or a brief note. Without a formal process for capturing these changes, key pieces of information, such as why updates were made or what problems led to them, frequently fall through the cracks. This lack of information causes confusion among the team. Without a complete understanding of the amendment, there is a chance they will carry out the work incorrectly or miss it altogether, leading to additional delays or rework (Fong & Yip, 2006).

Besides, staff have to manually enter the information into two different Excel sheets once it is noted. Eventually, those sheets get copied, rewritten, or outdated. As a result, the organisation may struggle to trace previously implemented changes. This cycle is inefficient and error-prone, and can introduce errors into project specs and coordination, ultimately affecting project progress.

Technological Solution and Available Tools

In this section, the available technological tools will be reviewed to support drawing revision management in the pre-tender stage. The comparison is made to determine a solution that is feasible for small QS firms. The outcome of this comparison is used to justify the selected hybrid solution, which is the integration of cloud storage and OpenCV-based drawing comparison.

Overview of Available Technologies

The lack of proper version control, reliable change detection, and transparency to handle pre-tender drawing revisions will increase the risk of outdated information and unnecessary remeasuring. Digital tools have been shown to improve information accuracy and reduce coordination errors in construction workflows, particularly cloud platforms and AI-based automation (Nguyen et al., 2021).

In practice, storage platforms primarily aim to mitigate the effects of file storage fragmentation and unreliable version control by providing a central repository and limiting access to the latest set of drawings

(Björk B-C, 2003). AI- and computer-vision-based tools also focus on detecting differences between drawing versions, minimizing the need for manual verification and helping locate areas that need remeasurement (DiBeneditto & Webster, 2018). Documentation traceability and knowledge retention management systems improve the systematic organization of the revision records, decisions, and other ancillary information. BIMbased solutions offer more advanced, model-based coordination and change tracking, but their implementation is typically more expensive and requires greater organizational preparedness. This can limit their feasibility in small QS firms (Bamgbose, Ogunbayo, & Aigbavboa, 2024).

Comparison of Available Technologies

Table 1 lists the available technologies that may be used to manage pre-tender drawing revision in small QS firms. The selection of the comparison criteria was based on cost, complexity, strength and weakness. A suitability measure was added to indicate the likelihood that a technology will be adopted by small QS firms due to limited budgets, skills, and time.

Table 1: Comparison of Available Technologies

Technology	Cost	Strength	Weaknesses	Suitability for Small QS Firm	Sources
Manual Process	Free	No setup needed	Slow, error-prone, and cannot track changes	Low	(Fung et al., 2014 ; Love et al., 2022)

Cloud Storage	Low	Accessible, prevents file loss	No auto comparison	High	(Bello et al., 2021 ; Quickbase, 2024)
AI (OpenCV)	Free	Fast, accurate, and reduces human error	Needs setup & calibration	High	(Radke et al., 2005 ; OpenCV Documentation)
Document	Very High	Powerful & professional	Expensive, overkill for SME	Low	(Bluebeam, n.d. ; G2, 2025)
BIM	Very High	Automated & precise	Requires BIM models, not common in pre-tender	Low	(Rashidi et al., 2024 ; Altaf, O. 2023 ; RSI International, 2024)

As Table 1 shows, the manual procedure is low-cost but slow and error-prone, and it does not systematically track changes; it is not the optimal procedure for repeated drawing revisions. Document management systems and BIM-based solutions offer greater control and complexity coordination, but at a higher cost and with a more complex implementation process, which reduces their practicability in small QS firms at the pre-tender stage. On the other hand, cloud storage is highly appropriate because it provides centralized storage, offers easier access to the latest drawings, and reduces the risk of file loss with minimal setup requirements. Comparison using OpenCV is also considered appropriate, since it can automate the process of detecting differences between drawing versions and, hence, reduce visual verification and allow remeasuring the difference only in affected areas. Therefore, cloud storage and OpenCV-based drawing comparison are selected as the core hybrid solution to achieve feasible revision control and change detection for small QS firms.

Comparison of Current Approach vs Proposed Technology

Table 2 directly addresses the major issues highlighted during the pre-tender stage: diffuse document storage and poor version control, which can increase the risk of outdated drawings and result in different quantities. By moving drawing storage for email and personal devices to a centralized cloud server, the suggested solution will reduce uncertainty about the latest approved revision and enhance information consistency, a common drawback of small QS firm workflows. The OpenCV-based drawing comparison also aims to mitigate the risk of missed amendments by automatically highlighting changed regions, reducing the effort of repeated full-sheet visual inspection and requiring only remeasuring effort in areas where changes have occurred.

Table 2: Comparison of Current Approach vs Proposed Technology

Work Description	Current Approach (Manual)	Proposed Technology (Cloud + AI OpenCV)
Drawing Storage	Email, Personal Laptop (multiple folders)	Centralized Cloud Server with controlled access and automatic versioning

Drawing Comparison	Manually check the PDF drawing	AI OpenCV detects all changes automatically and highlights modifications
Quantity Take-off Update	Remeasures manually	AI auto-generates a revised quantity that QS can modify
Speed of Workflow	Slow	Fast
Accuracy	Depends on human observation	High detection accuracy, reducing human mistakes
Team Communication	Shared late or duplicated in email	Cloud platform ensures everyone uses the latest revision immediately
Tracking Revision History	Hard to trace which drawing was used for which measurement	Cloud stores all versions, timestamps and comparison reports

Notably, the decision point is in the OpenCV comparison output generation, where the QS decides whether the highlighted changes affect measurement items and subsequently sets the extent of remeasurement and quantity take-off updates. By doing so, the workflow can be tracked more effectively, as revision history, timestamps, and comparison reports provide an audit trail that helps with change tracking and minimizes coordination errors. Despite the suggested technology enhancing the speed and organization of revision processing, quantity takeoff updates have yet to be verified by QS, especially when dealing with complex details, drawing quality, or alterations that cannot be accurately viewed due to geometric discrepancies. Overall, the comparison reveals that the cloud + OpenCV solution meets the requirements for an integrated platform that improves measurement accuracy, minimizes redundant work, and provides more consistent tender documentation in small QS companies.

Selected Technological Architecture

Based on the comparative analysis above, the chosen technological architecture combines a cloud storage solution, an OpenCV-based drawing comparison, and a proposed AI-assisted quantity update module. According to this, the desired solution must be cost-effective, have an easy implementation process, integrate with the SME workflows, and support both revision control and change detection. Cloud storage is the foundation of the system, as it centralizes all updated drawings and related quantity changes in a single repository. In practice, sketches are often scattered across WhatsApp and email, increasing the risk of accidentally using the wrong ones. In turn, cloud storage helps reduce this risk by ensuring access to the most recent drawing version and updated quantity record (Alaloul et al., 2020), and by maintaining a history.

OpenCV-based drawing comparison is then used to identify differences between the original and modified drawings. OpenCV also performs basic computer-vision tasks, such as image preprocessing and change detection, which identify regions that have changed, thus eliminating the need to review drawings line by line (OpenCV Documentation, 2023). The key benefit of the visual demarcation of modified zones (e.g., bounding boxes) in the context of quantity surveying practice is that surveyors can focus their verification and remeasurement on the altered areas, rather than the drawing as a whole. Indicatively, Figure 1 shows that OpenCV detects new structural components and outlines the altered area, thus demonstrating its potential to reduce time spent on manual tracing of detailed drawings. The outcome of the detection, however, can depend on the quality of drawn lines, the richness of linework, or scanned pictures, and thus the output needs to be taken as a decision support, not as a conclusive one.

OpenCV Image Processing Configuration

The proposed system utilises OpenCV as its image-processing engine to identify the revisions between the original and updated pre-tender drawings. The detection model is structured as a pipeline, multi-stage system that consists of image pre-processing, difference detection, contour extraction, parameter filtering and visual annotation, thereby enhancing methodological reproducibility and ensuring systematic revision identification (Bradski & Kaehler, 2008). i. Image Pre-Processing

The original and the re-drawn images are then transformed into a grayscale format so as to simplify calculation and standardise pixel-intensity comparisons. Contrast differentiation between the structures and the background layers is enhanced by conversion to gray scale. Then the Gaussian blur filter is used to ensure the reduction of small scanning noise and irregularities of pixels that can disrupt contour detection. It is then followed by an adaptive thresholding to separate the foreground drawing elements and the background artefacts. Such methods are widely used in the image vision processes in order to enhance image stability and feature extraction (Szeliski, 2022).

Change Detection Mechanism

The pixel-based absolute differencing of similar grayscale images is used to determine the revision. The difference map produced reveals areas that there is a significant variation in pixel intensity that is above a specified threshold. These variations in pixels are then grouped through contour detection into recognizable modification areas. This method allows the system to determine structural modifications, including added walls, eliminated partitions or changed annotations. Image differencing techniques are widely applied to identify structural changes between layered technical drawings (Gonzalez, 2009).

Noise Filtering and Parameter configuration

To remove small artefacts like printing marks or noises of annotations a minimum contour area threshold (e.g., 150 pixels) is used. The contours with the value less than this are automatically eliminated to eliminate false positives. The threshold parameter can be adjusted by drawing scale and resolution. Sensitivity calibration can also be set to reflect the various drawing disciplines (architectural, structural, MEP) hence enhancing detection stability on various technical documents. iv. Error Control and Operational Limitations.

A possible cause of detection error could be variations in the scale of drawing, scanning distortion, overlapping annotations, and the low-quality of files. The system has sought to reduce these risks by ensuring that there is resolution normalisation and by providing the mechanism of manually verifying the system before confirmation of the quantity update. The result of the OpenCV detection process is therefore seen to be decision support information and not a complete substitute for professional judgement.

In this design, detection transparency and ability to control parameters and methodological reproducibility are enhanced, and the computational efficiency is maintained on the scale of the requirements of small-to-medium enterprise quantity surveying practice.

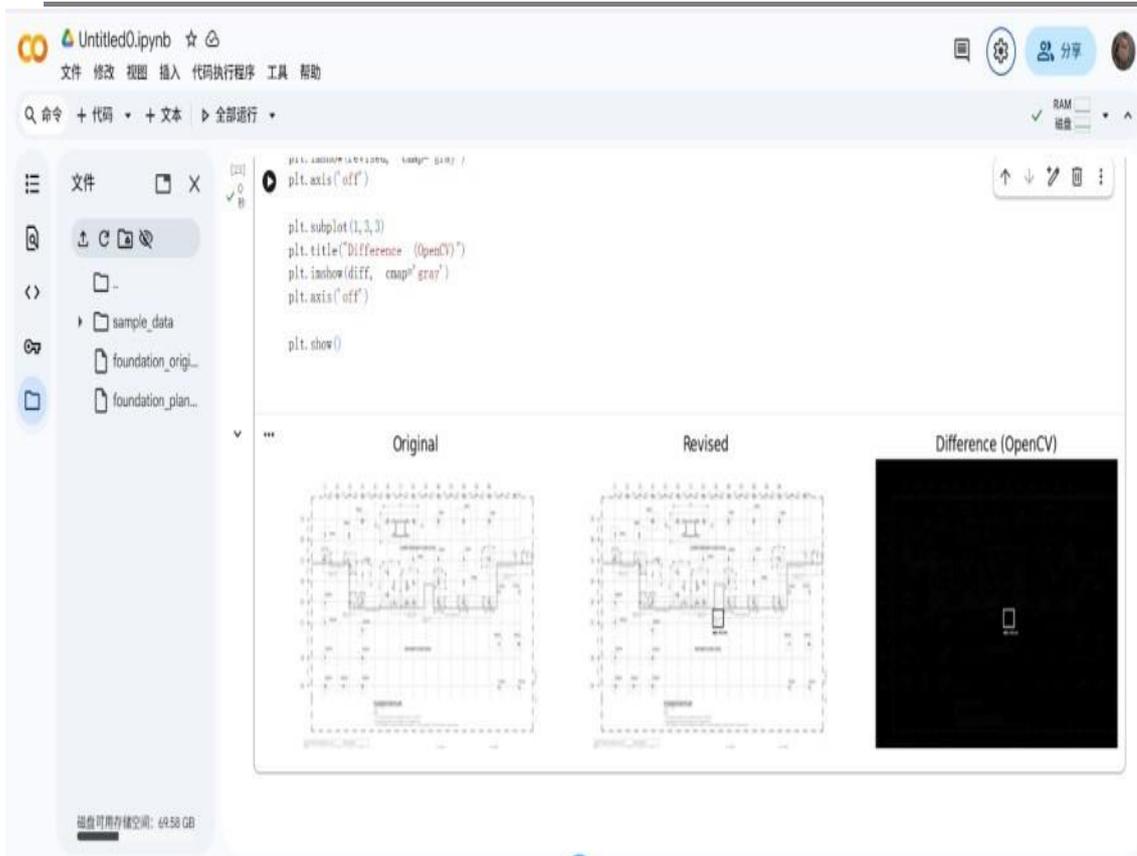


Figure 1 : OpenCV-Based Revision Detection Output Highlighting Identified Contours and Bounding Regions

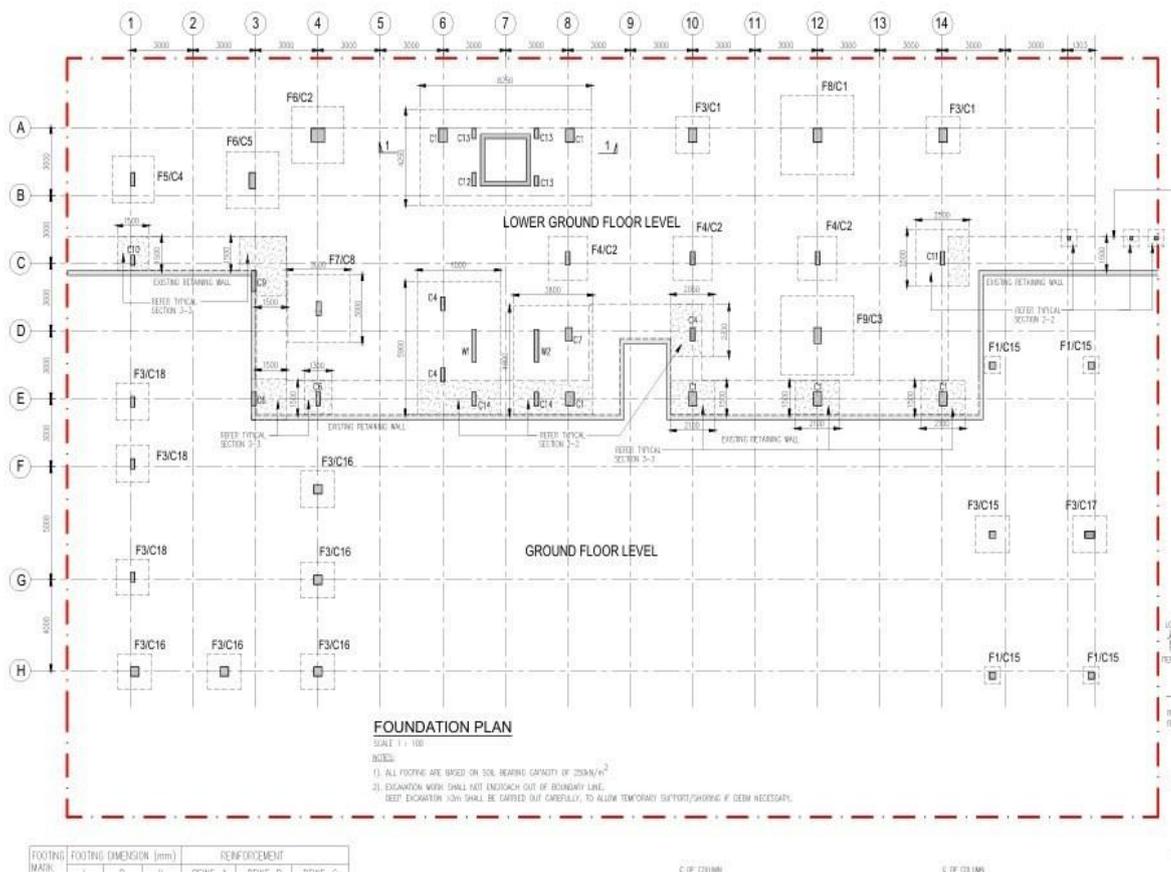


Figure 2: Original Drawing

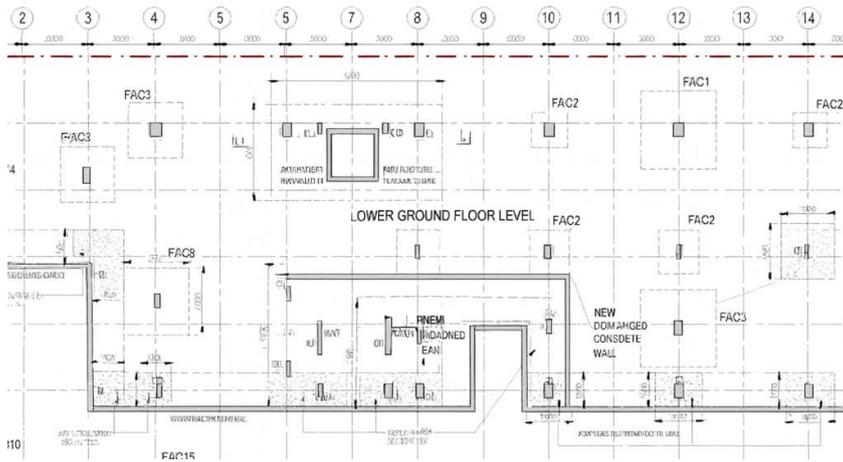


Figure 3: Revised Drawing

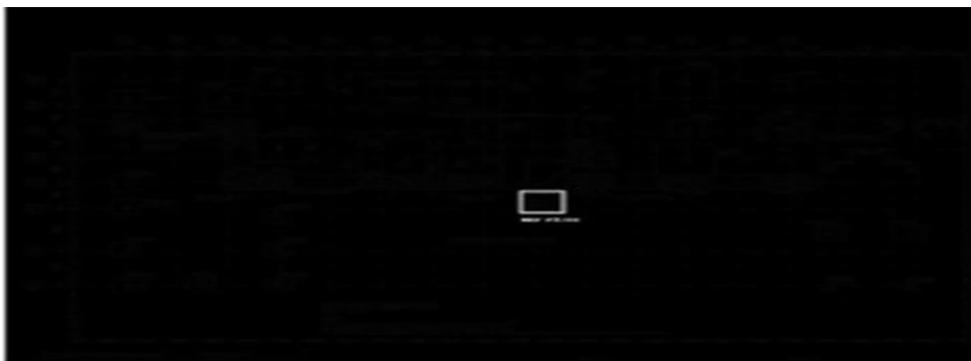


Figure 4: Result Difference of Original and Revised Drawing

AI-Assisted Quantity Estimation Logic

The given system, in turn, involves a rule-based quantity estimation module following the identification of revised zones by OpenCV that produces preliminary changes in quantities. The module is not a fully autonomous artificial intelligence system, but a structured computational logic in accordance with the Standard Method of Measurement (SMM) to help the Quantity Surveyor identify any possible quantity variations.

The detected altered regions of the image are initially converted to pixel dimensions into real measurements according to the scale on which the drawing is made (e.g., 1:100). Given a wall extension detected to be 50 pixels in length, assuming one pixel represents 10 mm, the difference in length in the real world is determined as such. The pixel to scale conversion guarantees the dimensional consistency before the computation of the quantity.

After obtaining differences in dimensions in the real world, standard measurement equations are used. In order to illustrate, when there is a gain in 0.5m of wall length but no changes in standard storey height that is 3.0m then the updated area of the walls can be given as:

$$\text{Area} = \text{Length} \times \text{Height}$$

$$\text{Area} = 0.5\text{m} \times 3.0\text{m} = 1.5 \text{ m}^2$$

The increment in the resulting area is then attributed to the relevant Bill of Quantities (BQ) item which could be brickwork or partition works. In case of reinforced concrete elements, slab thickness differences or beam depth differences might require the recalculation of volume of concrete. This can be expressed, say, by:

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Thickness}$$

These calculations align with established digital quantity extraction principles (Eastman et al., 2011).

The system incorporates rule-based referencing aligned with the principles of the Standard Method of Measurement (SMM) in order to classify identified changes into respective trade items (e.g., concrete, reinforcement, formwork). Rules of deduction can also be introduced on opening and structural adjustments depending on the predefined parameters of measurements.

It is necessary to highlight that the results produced by the AI-assisted module are preliminary estimations of the final result. The system provides decision-support data without replacing professional judgement highlighting the possible quantity implications arising from drawing revisions. Confirmation of final quantities is open to professional view and interpretation of contract.

Cybersecurity and Data Protection Framework

Since the proposed system will be placed in a cloud-based environment and will store updated drawings along with documentation associated with the tender, the aspects of cybersecurity and data protection will be part of the architectural design. The information used in construction projects, especially the pre-tender drawings and the cost, is quite commercial and hence liable to illegal access or data loss or alteration of the documents. To address such risks, the system employs a security-by-design methodology that implements the access governance, data encryption, audit-traceability, and recovery functionalities into the general technological environment, per the accepted information security management principles, including ISO/IEC 27001 (ISO, 2022).

The cloud repository has user access organized in terms of role-based permissions such that only individuals are allowed to access the repository with the degree of access required to meet the operational tasks. This approach will reduce chances of over-exposure of data and assist in accountability by keeping records of activities. In more sensitive positions, further authentication measures can be put in place to minimize the chances of losing credential. The information transmitted between users and the cloud environment is secured by encrypted communication protocols and the stored documents are ensured by encryption at rest to secure confidentiality. The integrity of the documents is also enhanced by version control and revision tracking mechanisms which allows easy determination of approved revisions reduce the risk of unnoticed alteration of records. These are the kinds of controls that are in line with the well-known security and privacy control frameworks (NIST, 2020).

Scheduled automatic backup and structured retention policies help in operational resiliency. Backup processes address the risk of unwanted deletion or intentional interference, and retention policies assist in the prevention of storing project documentation and related personal information far beyond the reasonable scope of its purpose. Such actions are conceptually consistent with the Security and Storage (Retention) principles of the Malaysian Personal Data Protection act (Personal Data Protection Department, 2010). All these combined with governance, encryption, auditability and recovery mechanisms lead to an increased level of confidentiality, integrity and availability of project information, and, thus, secure digital collaboration within project environments.

Proposed Technology Enhances Decision Making

The combination of cloud-based storage, automated image comparison using OpenCV, and an AI-assisted quantity module will enhance decision-making during the pre-tender stage. This integration will enhance quantity surveyors' capacity to determine the need to remeasure, the affected Bill of Quantities (BQ) items, and the clarification inquiries that should be directed to design consultants. Cloud storage also reduces the possibility of using old drawings. Empirical evidence indicates that cloud-based systems contribute to information consistency and mitigate coordination errors in the construction process, thereby enabling faster, more transparent revision decisions (Nguyen et al., 2021).

The identified altered areas, as identified by OpenCV, are then followed by the proposed quantity update module, which produces a draft of the changed quantities to enable the surveyor to examine the changes. The Standard Method of Measurement (SMM) is used to inform the draft estimation of items such as concrete, formwork, and

reinforcement, and the system makes suggestions for probable changes in the quantities of the relevant elements based on changes detected. This approach can reduce the frequency of repetitive remeasurement efforts and help surveyors quickly identify the items of measurement affected, but it does not eliminate the need to exercise professional judgement. The recommended amount of amendment is still to be surveyor-checked and modified, especially when the observed change does not fully capture the design intent or when the measurement assumptions need to be explained. This is supported by evidence that AI in quantity surveying is more likely to redirect the surveyor's functions, serving as a manual scanner, to the verification and confirmation of propositions generated by computers (Opoku et al., 2022). Every confirmed change could then be stored in the cloud as a record of the revision, further strengthening future traceability and knowledge retention.

From a decision-making perspective, the OpenCV output further supports targeted verification by automatically recognizing changes in edited drawings, thereby alleviating the inefficiencies of manual decisionmaking and the tendency to miss minor variations in thick schematics. An example of this is when updating a structural plan includes a line of extra beams. OpenCV can outline all changed areas in bounding boxes, so the quantity surveyor can constrain remeasuring to the specific parts of concrete, formwork, and reinforcement that have already changed, instead of having to remeasure the entire diagram. This increases the speed at which cost adjustment points are identified and reduces the uncertainty associated with manual inspection of pure visual material. Despite these benefits, the accuracy of the comparison will depend on the quality of the input; scanned PDFs, overlapping linework, or low-quality drawings will often result in false positives, and the Quantity Surveyor will need to verify the results before making final measurement decisions.

Finally, the AI-assisted quantity update module enhances decision consistency, providing a rough quantity update that satisfies the Standard Method of Measurement (SMM), and integrating the changes found by OpenCV and, by doing so, avoids the situation where the quantity surveyors will need to restart the work on the quantity update every time it is necessary. The shift to operational practice involves verifying and refining AI-generated quantities, which can reduce the revision cycle and decrease repetitive work, without compromising professional judgement (Opoku et al., 2022). To enhance traceability, the system can record critical revision metadata in the cloud, including the revision date, the person who edited the quantity, notes associated with a change in quantity, and the final verified value. The repository of accumulated revision records can provide a knowledge resource for similar future revisions over time; however, meaningful enhancement is possible only under conditions of continuous data collection across several projects and regular inspection by quantity surveyors.

Proposed System Development

The development of the Cloud-Based Knowledge Management Strategy Integrating AI for Revised Drawing Management System is organized using the Systems Development Life Cycle (SDLC). The system development followed a structured SDLC framework comprising feasibility analysis, system design, prototype implementation, and iterative refinement. During the stage of system analysis, functional and non-functional requirements are outlined. It involves AI-based revision detection, QS verification, cloud-based version control, and knowledge storage. These requirements are then translated into a proposed system workflow and a list of the input, process, and output structures at the system design stage. After that, during the implementation stage, the prototype of the system based on cloud storage and a comparison tool based on OpenCV were created, and some basic testing was performed using sample revised drawings to ensure the system works and the workflow logic. Lastly, the maintenance phase defines future enhancements, system upgrades, and security management to support continuous use and further modification.

Since this proposal presents a prototype system rather than a fully-fledged business solution, a prototype-based evaluation is conducted to examine its technical feasibility. Simulation of pre-tender drawing revisions is carried out using representative architectural drawings in PDF format. The original and revised drawings are uploaded to the cloud repository, and the OpenCV comparison utility is invoked to automatically identify changes. Preliminary quantity adjustments are generated before the Quantity Surveyor reviews and approves the revised Bill of Quantities (BQ) prior to export. The evaluation remains limited to simulated scenarios, and full field implementation is recommended in future research to assess long-term performance and operational reliability. A structured pilot test within a QS firm is therefore recommended to validate usability, time efficiency, and workflow integration under live pre-tender conditions.

Comparison Between the Current Process and The New Process

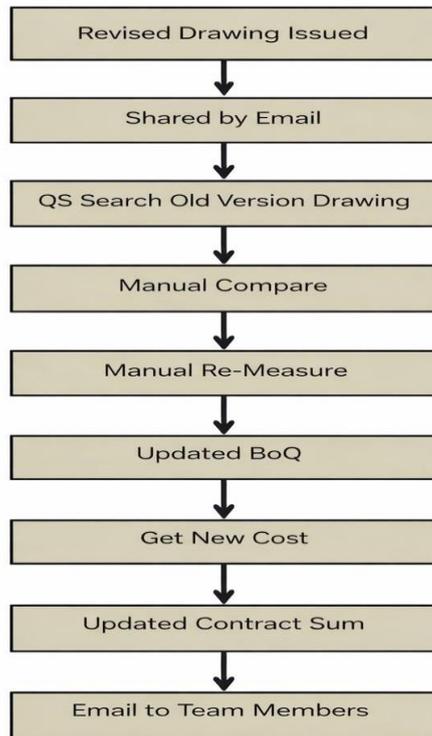
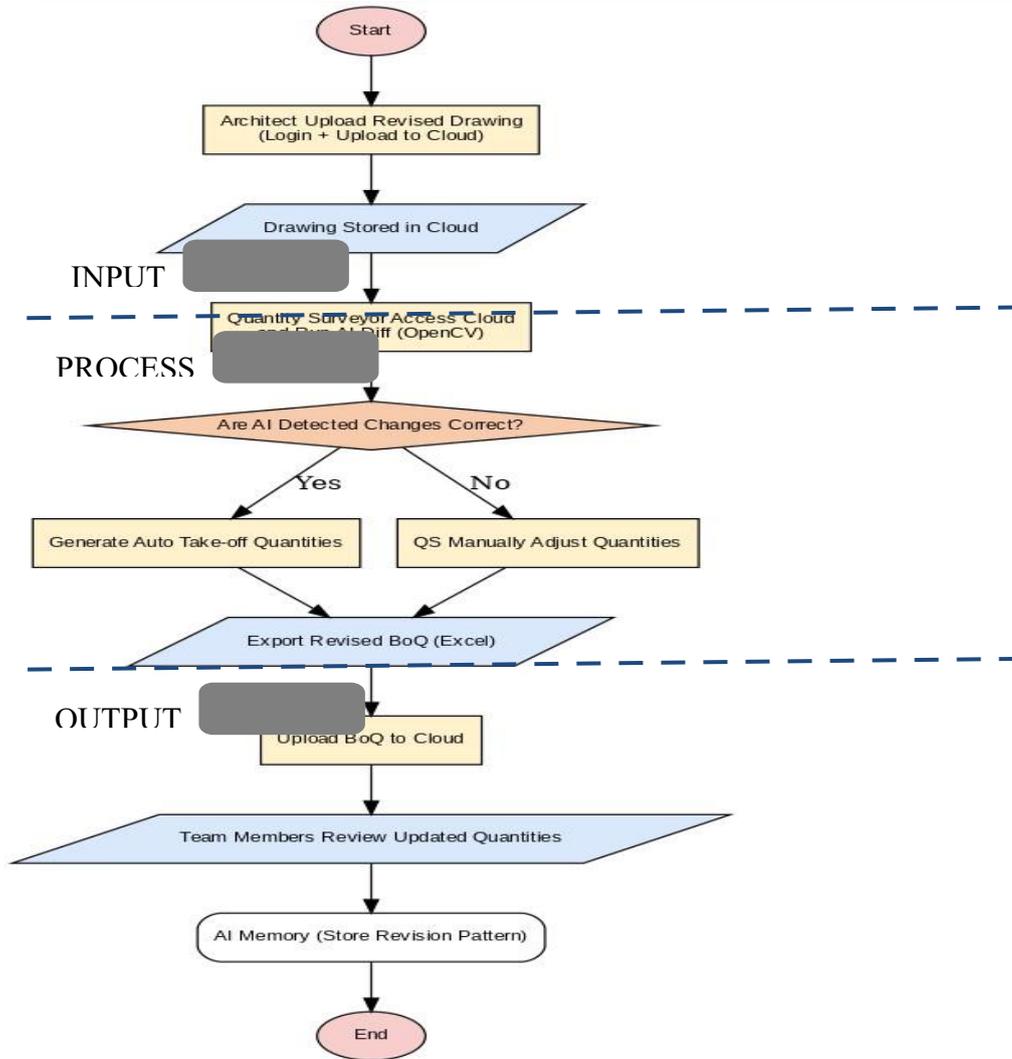


Figure 5 : Current System Workflow

The company's current workflow for processing revised drawings is entirely manual, causing delays for QS departments and potential inaccuracies. When distributing a revised drawing from the architect or engineer's side for comparison, these drawings are typically sent via email without being stored at a central location. Then, each person receives a copy via official company email, meaning the QS manually retrieves it from their mail or files for comparison purposes to identify any past differences in drawings. Once both the old and new drawings are located, the QS manually compares them to highlight any differences. This is done by scanning both drawings to identify differences, which is rather laborious and may lead to errors, especially when floor plans or construction details are complex. This is followed by the QS manually measuring all items affected by the identified differences. These changes are incorporated into the BQ, and a new cost is calculated based on the new measurements. This new cost information is then used to adjust the contract sum. Finally, the QS manually emails this new BQ or cost to all team members for approval.

Figure 6 shows that the new workflow also proposes adopting a digital, centralized, AI-assisted approach to managing the revised drawings, improving efficiency and effectiveness. The new workflow is initiated when the architect uploads the revised drawings to the cloud via a user login system for security. This is the key input to the entire system, ensuring that all team members work from a single, centralised, revised drawing file. After uploading the file into their cloud repository, the QS accesses the system to use the AI Diff Function provided by OpenCV. At this point in the processing step, the system automatically compares the modified drawing to its preceding version and highlights any differences in drawing elements identified by the AI. The system can automatically identify changes in drawings and present them visually, reducing the need for manual human monitoring when comparing drawings. The QS is only required to determine if changes identified by the AI are indeed correct. So, if the AI correctly identifies all changes, this system can generate a preliminary draft new take-off quantities. Upon verification, the system exports the finalised BQ in Excel format to facilitate standardisation of QS documentation for tender costing or contract variations. A finalised BQ is uploaded to cloud-based storage for assessment by all stakeholders, including architects, engineers, contractors, and clients, to enable real-time modification observations. The system also captures changes and stores them directly in its feedback repository to support future calibration, facilitating a complete feedback cycle and enhancing knowledge through greater efficiency.



OpenCV Revision Detection Process (within the workflow)

In the suggested workflow, the OpenCV revision detection module will service the process step when an architect uploads a new drawing into the cloud repository. The system recalls the old version and drawing that has been changed to compare the previous one with the new one. To ensure that the images are standardised and reduce the background noise the initial step entails converting the drawings into grayscale images. The system then matches the two drawings to make the two images to have the same scale and orientation. Image subtraction is done after alignment to determine visual changes between the two original and revised drawings. Secondly, geometric change is detected by use of contour detection methods. The system brings out the differences that are detected by surrounding the modified regions with bounding boxes. These areas that are in bold show the possible design changes like altering walls, openings, columns, beams or structural elements.

The Quantity Surveyor examines the identified areas to determine the detected differences as actual design changes. In case changes are found to be valid, the system automatically generates new take-off quantities. In case of an inaccurate detection, the Quantity Surveyor will correct the quantities manually, and the finalisation of the measurement will be made. As such, OpenCV module is not a substitute of professional judgement but a decision support tool. It helps the quantity surveyors to recognize updated areas and still ensures that the measurements are checked by humans.

Performance Comparison Between Manual and Proposed System (table 和解释) To further explain the practical effect of the proposed system, a comparative performance analysis of the traditional manual workflow and the proposed cloud-based AI-assisted workflow is shown in Table 3

Table 3 - Performance Comparison Between Manual and Proposed System

Criteria	Manual Comparison	Proposed System
Average review time per drawing	Approximately 30 minutes	Automated processing (timing not benchmarked; prototype demonstration)
Risk of human oversight	High, dependent on individual reviewer	Reduced through systematic detection
Traceability of revisions	Manual documentation	Cloud-based revision log
Knowledge retention	Individual experience-based	Organisational digital repository
Workflow efficiency	Repeated remeasurement required	Focused remeasurement on affected areas

Note: Time values are indicative estimates used to illustrate workflow differences; formal benchmarking was not conducted in this study.

The comparison shows that the proposed system will enhance efficiency in the workflow and minimize the chances of human error. Under the traditional approach, quantity surveyors will need to physically make comparisons of drawings and they can miss minor amendments. The computerized detection identifies modified regions and enables the surveyor to only remeasure modified parts and not the whole drawing. In addition, the centralised cloud storage guarantees the availability of the latest version of the drawing to all team members and a revision history that may be used in the future. This helps in enhancing coordination of project stakeholders and decision making in the pre-tender stage.

Benefit of The Proposed System

Firstly, OpenCV does not require high-performance servers or special hardware. Since the system supports file formats such as PDF and DWG, it easily fits into the current digital ecology of QS work. The system helps minimise costs while maximising operational efficiency. It avoids the expensive investment in certain proprietary software by using free or low-cost technologies such as OpenCV, standard office laptops, and cloud storage. On the other hand, technology greatly reduces labour hours and minimises the risk of costly mistakes through automation, which compares drawing changes to minimise recurrent manual remeasurement. The same conclusion was drawn in past research, which found that automation and AI-supported drawing comparison reduced repetitive manual tasks and facilitated more accurate measurements in construction cost management (Alaloul et al., 2020). For small and medium-sized construction companies, the solution is economically justified because the potential savings in time, rework, and erroneous amounts exceed the low implementation costs.

Secondly, the system enhances operational performance because it closely aligns with QS's current workflow and requires only minimal behavioural change. The QS would only need to upload new drawings, review AI-detected modifications, and export updated quantities. As suggested by previous studies, systems that align with current work processes and do not require excessive behavioural adaptation have a higher potential to be endorsed by construction professionals and successfully incorporated into practice (Sacks et al., 2020). This makes those tasks easy to understand and do. The system allows QS teams, engineers, and architects to adopt it without changing their roles much, as it augments instead of replacing existing methods. In addition, the technology facilitates better team coordination by centralising drawing versions and enhancing knowledge sharing.

Thirdly, the system is efficient in project timelines due to the lightweight, well-documented, and easy-to-integrate technology it uses. Thus, a functional prototype could be developed, tested, and refined within a short period. Future implementation may involve pilot testing in a real project before full adoption, and training sessions for

QS employees can be finished in a few hours. Hence, project development, testing, and deployment can be accomplished within the beginning stages of a construction project cycle. This is in line with past research, which has shown that lightweight and modular digital systems can be developed in a short development cycle, especially when the open-source technologies are embraced (Love et al., 2019).

Limitations of The Proposed System

Firstly, the drawing quality is highly dependent on the uploaded drawings. To achieve efficiency, low-quality scanned drawings or drawings with inconsistent line widths and poor image resolution may adversely affect OpenCV's revision detection efficiency. Then, OpenCV is solely responsible for geometric comparison and is incapable of identifying design concepts or ideas, or of reading any meaning from structurally designed buildings or their material components. Hence, Quantity Surveyors must still manually check and modify quantities to achieve a measure of accuracy. Thus, revision detection based on AI is highly dependent on the contrast and consistency of the inputs, which are drawings.

Secondly, it is important to note that this system involves initial setup processes such as cloud configuration, standardisation of folders, and linking of the AI comparison script. However, small companies may encounter some difficulties with initial setup and onboarding processes, as they may lack adequate IT support services. In addition, personnel training is required to teach QS personnel how to upload drawings and validate AI outcomes for effective BQ file generation. Such requirements can increase the cost and time of the initial implementation, as well as the time required to adapt the system fully.

Thirdly, cloud storage depends on internet access and raises cybersecurity and privacy concerns. This is to say the sensitive and confidential data is contained in revised drawings, BoQ information and project records. In the absence of proper access control, encryption, and password management, the system can face threats of unauthorised access or data breaches. Hence, system updates and regular security monitoring are required to ensure that the data remains intact and that users have confidence.

Lastly, even though the system has an in-built feedback repository that identifies revision patterns, it has limited autonomous learning ability. The model is not based on self-training, so the input of the structured data and professional verification by Quantity Surveyors is obligatory to achieve the refined results to the detection. Furthermore, one should mention that the system is largely tested by way of prototype demonstrations using sample sets of drawings. The evaluation was conducted at conceptual and workflow-design level instead of conducting a pre-tender environment which is functioning fully. Therefore, further empirical confirmation in real-life construction projects is needed to assess robustness and scalability of operations performed and the possibility of supplementing the system into the industry processes. Future studies may incorporate quantitative performance benchmarking such as detection accuracy rates and time-efficiency comparisons.

CONCLUSION

This paper suggests a cloud-based knowledge management system combining an OpenCV-based comparison of drawings with a rule-based, SMM-congruent quantity estimation system to assist the pre-tender drawing revision management in small and medium-sized quantity surveying practice. The paper illustrates a logical hybrid model where cloud storage supplements version-controlling and traceability and OpenCV-based visual alteration detection allow focused verification and remeasurement. The suggested quantity update module also converts identified geometric alterations into initial quantity implications to aid decision-making, and maintain the professional judgment by using a check of quantity surveyors.

Despite the contributions that were made to methodology, the system test has been prototype-based and has been tested using simulated conditions using representative drawing samples. Therefore, formal field-based validation and quantitative benchmarking of performance, i.e., accuracy of detection, time savings and cost-effectiveness, was not done. Pilot testing specifically in a live quantity surveying pre-tender workflow should therefore be given priority in future research to determine the reliability in operation, usability, and quantifiable performance indicators. Further enhancements on governance of cybersecurity and the calibration dataset can add more robustness and scalability to it, thus enabling industry adoption.

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REFERENCES

1. Ashworth, A., & Perera, S. (2018). *Cost studies of building* (6th ed.). Routledge.
2. Alaloul, W. S., Liew, M. S., Zawawi, N. A., & Kennedy, I. B. (2020). Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for cloud-based collaboration. *Journal of Construction Engineering and Management*, 146(6), 04020058.
3. Altaf, O. (2023). A review of BIM adoption and barriers to BIM adoption in quantity surveying practice. (PDF).
4. Arayici, Y., Egbu, C., & Coates, P. (2011). Building Information Modelling (BIM) implementation and remote construction projects; Issues, challenges, and critique. *Journal of Information Technology in Construction*, 16, 75-92.
5. Bamgbose, O. A., Ogunbayo, B. F., & Aigbavboa, C. O. (2024). Barriers to building information modelling adoption in small and medium enterprises: Nigerian construction industry perspectives. *Buildings*, 14(2), 538.
6. Bello, S. A., Oyedele, L. O., Akinade, O. O., et al. (2021). Cloud computing in construction industry: Use cases, benefits and challenges. *Automation in Construction*, 122, 103441.
7. Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors* (2nd ed.). John Wiley & Sons.
8. Bluebeam. (n.d.). Document Comparison (Compare Documents). Bluebeam Revu Online Help.
10. Björk, B.-C. (2003). Electronic document management in construction—Research issues and results. *Journal of Information Technology in Construction (ITcon)*, 8, 105–117
11. Bradski, G., & Kaehler, A. (2008). *Learning OpenCV: Computer vision with the OpenCV library*. "O'Reilly Media, Inc."
12. Cao, Y., Li, H., & Liang, Y. (2005). Using engineering drawing interpretation for automatic detection of version information in CADD engineering drawing. *Automation in Construction*, 14(3), 361–367.
13. Cartlidge, D. (2020). *New Aspects of Quantity Surveying Practice* (5th ed.). Routledge.
14. Choudhry, R. M., Iyer, K. C., & Kumaraswamy, M. (2017). Causes of Discrepancies between Design and Construction. *Journal of Construction in Developing Countries*, 22(2).
15. DiBeneditto, L. W., & Webster, R. (2018, June). CADcompare™: A web-based application that compares PDF CAD drawings. In *Proceedings of the American Society for Engineering Education (ASEE) Annual Conference & Exposition* (Salt Lake City, UT).
16. Efficient File-Naming Convention for data exchange in the construction industry. (2025). In *GEOMATICS AND ENVIRONMENTAL ENGINEERING* (No. 2; Vol. 19, p. 99). <https://doi.org/10.7494/geom.2025.19.2.99>
18. Fong, S. W., & Yip, J. C. H. (2006). An investigative study of the application of lessons learned systems in construction projects. *The Journal for Education in the Built Environment*, 1(2), 27–38.
19. Fung, W. P., Salleh, H., & Rahim, F. A. M. (2014). BIM application capability in quantity surveying practice.
20. G2. (2025, November 28). Best construction management software (user reviews noting "expensive/overkill" for small projects).
22. Gonzalez, R. C. (2009). *Digital image processing*. Pearson education india.
23. International Organization for Standardization. (2022). *ISO/IEC 27001:2022 — Information security management systems — Requirements*. ISO.
24. Lo, T. K., & Fong, S. W. (2009, December 1). Capturing, sharing and re-using lessons to improve learning in construction projects. PolyU Scholars Hub.

- <https://research.polyu.edu.hk/en/publications/capturingsharing-and-re-using-lessons-to-improve-learning-in-con/>
25. Love, P. E. D., Matthews, J., Simpson, I., Hill, A., & Olatunji, O. (2019). A benefits realization management building information modeling framework for asset owners. *Automation in Construction*, 104, 1–10.
 26. Love, P. E. D., Sing, C.-P., Wang, X., Edwards, D. J., & Irani, Z. (2022). Why does rework occur in construction and engineering projects? *Journal of King Saud University – Engineering Sciences*.
 27. Muhamad, N. H., & Mohammad, F. F. (2018). Impact of design changes in construction projects. *Malaysian Journal of Sustainable Environment*, 4(1), 1–18.
 28. National Institute of Standards and Technology (NIST) (2020). Security and privacy controls for information systems and organizations (No. NIST Special Publication (SP) 800-53 Rev. 5 (Withdrawn)). National Institute of Standards and Technology.
 29. Olantunji, O. A. (2011). Modelling the costs of corporate electronic tendering implementation. *Journal of financial management of property and construction*, 16(3), 211-230.
 30. OpenCV Documentation. (n.d.). Template Matching.
 31. OpenCV Documentation. (n.d.). Feature Matching.
 32. OpenCV Documentation. (2023). OpenCV: Open Source Computer Vision Library. Retrieved from <https://docs.opencv.org/>
 33. Opoku, D., Perera, S., & Osei-Kyei, R. (2022). The role of artificial intelligence in quantity surveying practice: Current applications and future opportunities. *Automation in Construction*, 140, 104373.
 34. Personal Data Protection Department, Malaysia. (2010). Principles of personal data protection https://www.pdp.gov.my/ppdpv1/en/principles-of-personal-data-protection/?utm_source=chatgpt.com
 35. Quickbase. (2024, May 20). Benefits of cloud-based document management systems.
 36. Radke, R. J., Andra, S., Al-Kofahi, O., & Roysam, B. (2005). Image change detection algorithms: A systematic survey.
 37. Rashidi, A., et al. (2024). Applying BIM technology in the pre-tender cost estimating process (limitations due to model availability/quality; higher precision when feasible). *Buildings*, 14(5), 1260.
 38. RSI International. (2024). Breaking the Barriers: BIM adoption challenges in quantity surveying firms of Northern Malaysia (high cost of BIM software + training as key barriers).
 39. Sacks, R., Girolami, M., & Brilakis, I. (2020). Digital transformation of construction: Technology readiness at the organizational level. *Automation in Construction*, 109, 102974.
 40. Smith, P. (2014). Project Cost Management – Global issues and challenges. *Procedia - Social and Behavioral Sciences*, 119, 485–494. <https://doi.org/10.1016/j.sbspro.2014.03.054>
 41. Szeliski, R. (2022). *Computer vision: algorithms and applications*. Springer Nature.
 42. Taher, G. & ZARSMI. (2021). Industrial Revolution 4.0 in the construction industry: Challenges and opportunities. In *Management Studies and Economic Systems (MSES) (Vols. 6–6, Issue 3/4, pp. 109–127)*. https://www.msae.org/article_140504_1d5f182cf5bc70a06e4a181e884359e0.pdf
 43. Wijesundara, W. M. N. D., Thayaparan, M., & Costa, M. D. D. (2025). Addressing data management challenges in Sri Lankan construction industry through blockchain integration. In K. G. A. S. Waidyasekara, H. S. Jayasena, P. L. I. Wimalaratne, & G. A. Tennakoon (Eds.), *Proceedings of the 13th World Construction Symposium* (pp. 98–111).
 44. Zainon, N., Mohd-Rahim, F. A., Aziz, N. M., Kamaruzzaman, S. N., & Puidin, S. (2018). Catching up with Building Information Modeling: Challenges and opportunities for quantity surveyors. *Journal of Surveying, Construction and Property*, 9(1), 19–31.
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