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A Survey of Technology-Based Construction Progress Monitoring and Intelligent Prediction Using Deep Learning

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***Abstract*—Construction progress monitoring is important for ensuring that building activities are completed according to the planned schedule, budget, and quality requirements. Traditional monitoring often depends on manual inspections, which can be time-consuming and may delay the identification of construction problems. Recent developments in digital technologies, Artificial Intelligence (AI), and deep learning provide new opportunities to improve construction monitoring. This survey reviews three research papers in order of their relevance to the proposed SiteSense AI project.**

First, CPMTech presents a technology-based framework for organizing data acquisition, integration, inspection, and visualization. Second, a deep-learning-based monitoring and prediction model combines multiple data sources to identify safety issues and predict construction progress and quality. Third, an interactive image-processing system integrates object detection, segmentation, tracking, progress monitoring, and quality inspection. The papers are compared in terms of their methods, contributions, advantages, and limitations. The survey identifies a research opportunity for a practical software system that connects image-based progress observations with project records, cost and material calculations, schedule monitoring, and role-based dashboards.

Construction Progress Monitoring, Deep Learning, Image Processing, Computer Vision, Construction Management, Progress Prediction.

I. Introduction

Construction projects involve many activities, materials, workers, and deadlines. Monitoring these activities is essential to understand whether the actual work matches the project plan. However, traditional monitoring often depends on site inspections and manual reports, which may require considerable time and may not provide timely information for decision-making.

Digital technologies are increasingly being used to improve construction monitoring. Computer vision can analyze site photographs, while deep-learning models can identify visible construction objects, detect possible safety issues, and support progress prediction. Technology-based monitoring frameworks also help organize how data are collected, processed, inspected, and presented.

This survey focuses on three research papers. The first paper, CPMTech, provides a framework for integrating technologies into construction progress monitoring. The second paper explores deep learning for monitoring and intelligent prediction. The third paper presents an interactive image-processing system for progress and quality monitoring.

By studying these papers in priority order, this survey examines the development from a general monitoring framework to intelligent prediction and practical image-processing implementation. The findings are used to identify a research gap for SiteSense AI, a proposed software-based construction monitoring system.

II. Need for the Study

The main purpose of this survey is to understand existing technologies and identify opportunities to improve construction progress monitoring. The objectives are:

- To study technology-based frameworks for construction progress monitoring.
- To understand how deep learning can support safety monitoring, progress prediction, and quality prediction.
- To examine image-processing techniques used for construction object detection and monitoring.
- To compare the methods and limitations of the three selected research papers.
- To identify a research gap relevant to SiteSense AI.

III. Basic Concepts and Background

A. Construction Progress Monitoring

It involves observing actual construction activities and comparing them with planned work, quantities, and schedules. It helps identify incomplete activities and possible delays.

B. Deep Learning and CNN

Deep learning uses neural networks to learn patterns from data. A Convolutional Neural Network (CNN) can learn visual features from images and support classification, object detection, and segmentation. Other deep-learning architectures can analyze relationships across time or between connected activities.

C. Intelligent Prediction

Intelligent prediction uses collected data and trained models to estimate future conditions, such as construction progress, possible delays, safety risks, or quality outcomes. Its reliability depends on the quality of the input data and the validation of the model.

D. Image Processing

Image processing prepares and analyzes photographs or video frames. Object detection identifies objects and their locations, segmentation identifies image regions, and tracking associates objects across video frames.

E. Technology-Based Monitoring

A complete monitoring workflow may include data acquisition, processing, integration, inspection, and visualization. A framework helps determine how technologies fit into these stages.

IV. Literature Survey

A. Paper 1: CPMTech—A Technology-Based Model for Construction Progress Monitoring [1]

Authors: G. L. Serejo, V. A. dos Santos, A. F. B. Silva, and C. G. R. dos Santos (2025).
CPMTech proposes a technology-based model for organizing Construction Progress Monitoring (CPM). Instead of concentrating on only one AI algorithm, the paper examines how different technologies can work together throughout the monitoring process.

The study follows three main phases. First, the authors conduct a Systematic Literature Review (SLR) to identify existing research and develop the CPMTech model. Second, they conduct a case study at an active construction site to examine manual and controlled data-acquisition processes. Third, they use a virtual simulation to evaluate an instance of the model for autonomous data acquisition.

The model organizes construction monitoring around four main activities: data acquisition, data integration, inspection, and visualization. The study also discusses practical site challenges, including occlusion, lighting variations, construction debris, and inaccurate image positioning.

- **Advantages:** CPMTech provides a structured framework, considers real construction-site conditions, and examines both real and simulated monitoring scenarios. It can help professionals select and integrate technologies according to monitoring requirements.
- **Limitations and future needs:** The authors identify the need for further validation across sites of different sizes, more standardized evaluation measures, and improved integration with real-time project-management systems.
- **Key contribution:** CPMTech establishes the foundation for this survey by explaining how technologies can be organized into a complete construction progress monitoring workflow.

B. Paper 2: Research on Building Construction Process Monitoring and Intelligent Prediction Model Based on Deep Learning [2]

Authors: Xiu Luo and Zhouxin Yi (2025).
This paper proposes a deep-learning framework for monitoring and predicting building construction processes. It addresses the challenge of analyzing different types of construction-site information, including monitoring video, sensor data, and construction logs.

The proposed framework combines multiple data sources to support three main tasks: safety anomaly detection, construction progress prediction, and quality prediction. For safety monitoring, the authors use an improved YOLOv5s+Transformer architecture to identify potential hazards. For progress prediction, a spatio-temporal graph convolutional network (ST-GCN) is used to learn relationships across time and connected activities. For quality prediction, a Physics-Informed Neural Network (PINN) incorporates physical principles into model training, with concrete strength considered in the study.

The authors report a mean Average Precision (mAP@0.5) of 89.7% for safety anomaly detection. They also report Root Mean Square Error (RMSE) values of 0.89, 1.23, and 1.47 for 7-day, 14-day, and 30-day progress-prediction horizons, respectively. These values belong to the experiments described in the paper and should not be assumed to represent performance on every construction project.

- **Advantages:** The framework considers multiple data sources and combines safety detection, progress prediction, and quality prediction. It demonstrates how different deep-learning models can be selected for different construction-management tasks.
- **Limitations and considerations:** Such a framework requires suitable training data and access to reliable monitoring records. Transferring a trained model to a new site may require adaptation and additional training. Its multi-source design may also be more complex to implement than a lightweight system based mainly on uploaded photographs.
- **Key contribution:** This paper extends the monitoring discussion from observing current construction conditions to predicting future progress and identifying possible risks.

C. Paper 3: Construction of Interactive Construction Progress and Quality Monitoring System Based on Image Processing [3]

Author: Wei Wu (2024).
This paper presents an interactive system for construction progress monitoring and quality inspection using image processing and deep learning. Its system architecture contains data acquisition, image processing, progress monitoring, quality inspection, an interactive interface, and data storage and management.

The study uses YOLO-based object detection to identify construction objects, U-Net-based segmentation to analyze

image regions, and SORT tracking with Kalman-filter-based state estimation to track objects across frames. The system is designed to analyze construction-site images and provide monitoring reports and suggestions through an interactive interface.

The experiments include four construction-site scenarios. The paper reports object-detection accuracy values between 0.88 and 0.94, progress-forecast errors between 2.0 and 3.0 hours, and quality-inspection error rates between 0.03 and 0.07.

- **Advantages:** The system combines multiple image-processing techniques in one modular application. It includes both progress monitoring and quality inspection, as well as data storage and an interface for viewing results.
- **Limitations:** The authors note that stability in complex environments requires improvement. Lighting variations and occlusion may affect system performance. The approach also depends on suitable training images and labelled data.
- **Key contribution:** This paper demonstrates how image-processing techniques can be integrated into an interactive construction monitoring application.

V. Comparison of Existing Techniques

Comparative analysis: CPMTech explains how different technologies can be organized into a monitoring workflow. The deep-learning paper develops this idea further by applying specialized models to safety, progress, and quality prediction. The image-processing paper focuses on implementing monitoring functions in an interactive application.

The three studies therefore contribute at different levels: framework design, intelligent prediction, and application-level image processing. Together, they provide a useful foundation for designing a construction monitoring system that connects image analysis with practical project information.

VI. Advantages and Limitations of Existing Approaches

Technology-based construction monitoring offers several advantages:

- It can reduce dependence on repeated manual recording and inspections.
- Deep-learning methods can identify visible objects and support prediction.
- Multi-source data can provide more information about construction activities.
- Image segmentation and tracking can improve analysis of site images and video.
- Modular frameworks help organize data acquisition, processing, storage, and visualization.
- Interactive interfaces can make monitoring results easier for users to understand.

However, several challenges remain. Site conditions change with lighting, weather, camera angle, and construction activity. Workers, machinery, and scaffolding may hide important objects. Deep-learning systems require appropriate training data, while complex predictive models may require additional computing resources and reliable historical records.

It is also important to distinguish image analysis from project calculations. A photograph alone cannot reliably determine exact remaining cost or material quantities. These estimates require additional information such as project quantities, unit rates, material inventory, and the planned schedule.

VII. Research Gap

The reviewed papers provide three complementary contributions: CPMTech organizes the technology workflow, the deep-learning paper demonstrates intelligent monitoring and prediction, and the image-processing paper integrates visual analysis into an interactive application.

Based on their comparison, a potential research opportunity for **SiteSense AI** is to develop a lightweight, software-based monitoring system that connects image-derived progress observations with structured project records and role-based dashboards. The proposed research gap focuses on the following areas:

1) **Integrated workflow:** Connecting image-based observations with planned construction activities and progress records.
2) **Practical project management:** Using progress information alongside cost, material, and schedule data in a single application.
3) **Transparent calculations:** Calculating estimated remaining cost and materials from project quantities, unit rates, and inventory records rather than relying on images alone.
4) **User-specific monitoring:** Providing an overall project view for managers and project-specific information for customers.
5) **Practical evaluation:** Testing the progress estimates against engineer-verified observations and assessing performance under different image conditions.

This is a research opportunity derived from the three selected papers. It does not mean that every individual feature is absent from all existing systems.

VIII. Proposed Direction for SiteSense AI

SiteSense AI is proposed as a software-based construction progress monitoring and decision-support system. It will accept planned construction information and actual site photographs. A trained computer-vision model, potentially using a CNN-based architecture, will analyze the photographs to identify visible construction elements or stages.

The system will interpret these observations using a documented progress-calculation method and compare the estimated progress with the planned schedule. Separate calculation modules will use project quantities, unit rates, inventory, and schedule records to estimate remaining costs, materials, and potential delays.

TABLE I
COMPARISON OF REVIEWED LITERATURE

Aspect	Paper 1: CPMTech [1]	Paper 2: Deep Learning [2]	Paper 3: Image Processing [3]
Main focus	Technology integration framework	Monitoring and intelligent prediction	Interactive progress and quality monitoring
Main approach	Literature review, site case study, simulation	Multi-source deep-learning framework	Object detection, segmentation, tracking
Main technologies	Data acquisition, integration, inspection, visualization	YOLOv5s+Transformer, ST-GCN, PINN	YOLO, U-Net, SORT, Kalman filter
Main contribution	Organizes the complete monitoring workflow	Supports safety, progress, and quality prediction	Combines image analysis with an interactive system
Main strength	Flexible technology-integration framework	Predictive and multi-task capabilities	Practical monitoring modules and interface
Main challenge	Further validation and system integration	Data requirements and model adaptation	Lighting, occlusion, and complex scenes

The manager dashboard will display overall project progress and relevant management information. The customer dashboard will display information only for the customer's authorized project.

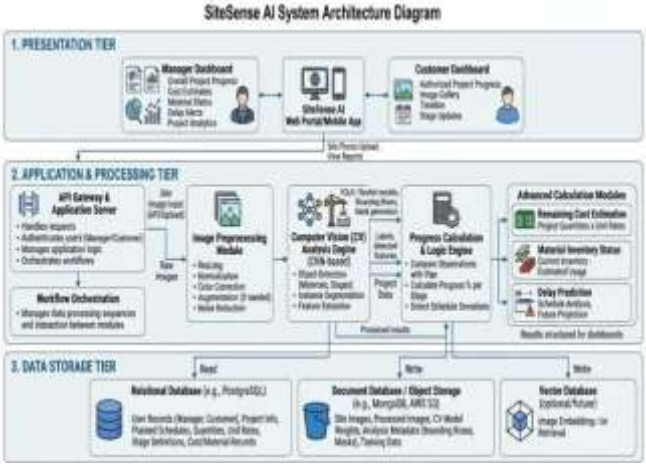


Fig. 1. SiteSense AI System Architecture Diagram

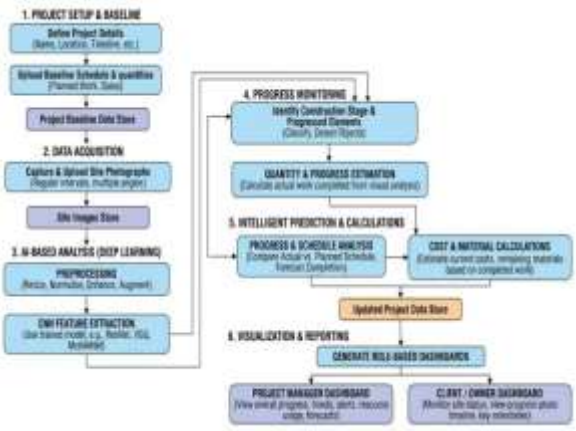


Fig. 2. SiteSense AI Operational System Flowchart

IX. Future Scope

Future development can include creating an annotated dataset of residential construction stages, evaluating suitable CNN-based models, and comparing predicted progress with engineer-verified records. The system could also be extended with improved handling of occlusion and lighting variations, secure role-based access, automated delay alerts, and integration with BIM or project-management software where feasible.

X. Conclusion

This survey reviewed three research papers in priority order. CPMTech provides a framework for organizing technology-based construction monitoring. The deep-learning study extends monitoring to safety anomaly detection, progress prediction, and quality prediction. The interactive image-processing study demonstrates how object detection, segmentation, tracking, and quality inspection can be combined in a monitoring application.

The comparison shows that effective construction monitoring requires more than a single algorithm. Data acquisition, image analysis, prediction, project information, and visualization must work together, while practical challenges such as occlusion, data quality, model adaptation, and integration must be considered.

Based on these findings, SiteSense AI is proposed as a software-based system that combines image-derived progress observations with project records, cost and material calculations, schedule monitoring, and role-based dashboards. Further implementation and testing are required to establish its reliability and practical value.

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