International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** V **Month of publication:** May 2024

DOI: https://doi.org/10.22214/ijraset.2024.63003

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

Construction Monitoring and Reporting using Drones and Unmanned Vehicles (UAV'S)

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Abstract: The application of drones and Unmanned Aerial Vehicles (UAVs) has significantly expanded in fields such as surveying and facility management. Recent technological advancements have made drones and UAVs more efficient and cost-effective for use in architectural engineering and construction management. This study proposes a framework for developing a fully automated system for smart construction monitoring and reporting, utilizing real-time data from drones and UAVs. By employing photogrammetry techniques, data from drone images and point clouds (3D scans of construction sites) can be used to create 3D models. These "drone models" can be compared with Building Information Modeling (BIM) at various stages to monitor construction progress. This integration can extend to real-time recording, reporting, billing verification, and planning. Using a case study, the research demonstrates how drone data effectively enhances construction monitoring and model comparisons. The system can substantially reduce the manual effort required for traditional monitoring, offering improved planning and on-site adjustments.

I. INTRODUCTION

With rapid technological progress, the utilization of drones and UAVs is increasingly prevalent across various industries. In the construction sector, these technologies significantly enhance the planning and monitoring of construction activities. Drones and UAVs can be utilized throughout the lifecycle of a construction project, including pre-planning, detailed site surveys, construction process monitoring, post-build inspections, and even sales and marketing phases. This study outlines a framework for developing a fully automated smart construction monitoring and reporting system using real-time data from drones and UAVs. The traditional approach relies on construction drawings to create BIM models, which are then used for planning and progress tracking. In contrast, our proposed method uses drone-captured images and point clouds to create 3D models through photogrammetry, allowing for real-time progress monitoring and enhanced project management.

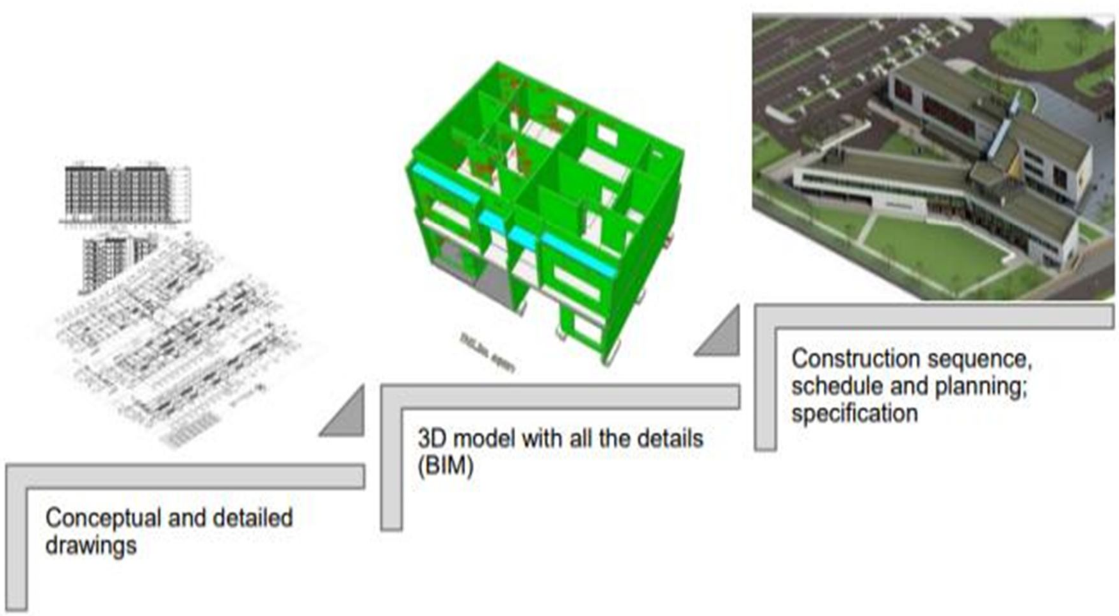

Figure 1: The key steps in traditional approach towards construction monitoring and planning

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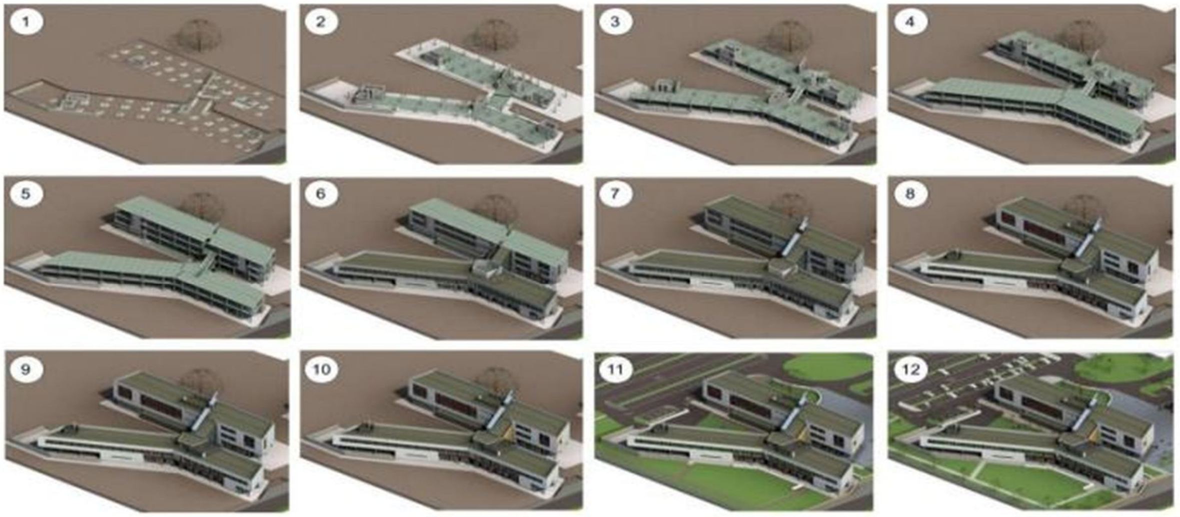

Figure 2: Various stages of a construction project as demonstrated by a sequence of 3D models

II. SMART CONSTRUCTION MONITORING USING DRONES AND UAVS

Traditional construction project monitoring is rigid, with limited scope for real-time data integration. In contrast, smart monitoring leverages real-time data collected through advanced tools like drone-mounted sensors. These sensors can capture photos, videos, thermal images, and infrared data. The data is then processed using sophisticated software to aid in better planning and on-site adjustments. Key applications include:

1) 3D Map Creation**:** Aerial monitoring generates data for 3D models and orthophoto maps, which can be updated and viewed interactively, providing better project control and real-time visual updates for stakeholders.
2) Aerial Photography and 3D Scanning: Aerial photos and videos offer clients impressive visuals, such as future views from windows, and create detailed 3D models for planning purposes.
3) Routine Construction Progress Monitoring: Regular drone flights over the site provide near-real-time progress reports for developers and stakeholders, capturing key milestones through scheduled visits.
4) Volumetric Measurement: Accurate aerial photogrammetry enables precise 2D and 3D measurements, essential for monitoring material volumes and site changes.

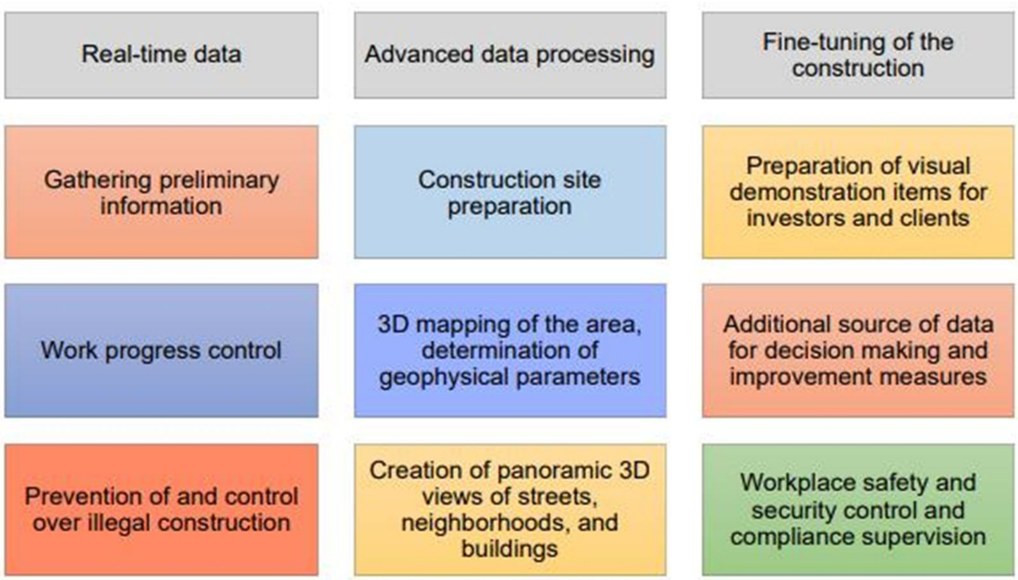

Figure 3: The key elements of smart construction monitoring system using drones and UAVs

Figure 4 presents the proposed framework for construction monitoring and reporting using drones and unmanned aerial vehicles (UAVs). High-resolution images and videos can be captured during weekly, bi-weekly, or monthly site visits, effectively allowing engineers to "always be on site." Tasks that previously took weeks can now be completed in days with the use of UAVs. Before construction begins, drone images and videos can be utilized for efficient workspace planning and optimization to minimize material flow bottlenecks. Additionally, periodic inspections can be conducted to assess safety measures. Reports detailing the amount of material moved, excavated, and filled, as well as the tracking and monitoring of assets throughout the project, provide a viable and scalable method for stakeholders to stay informed about on-site activities.

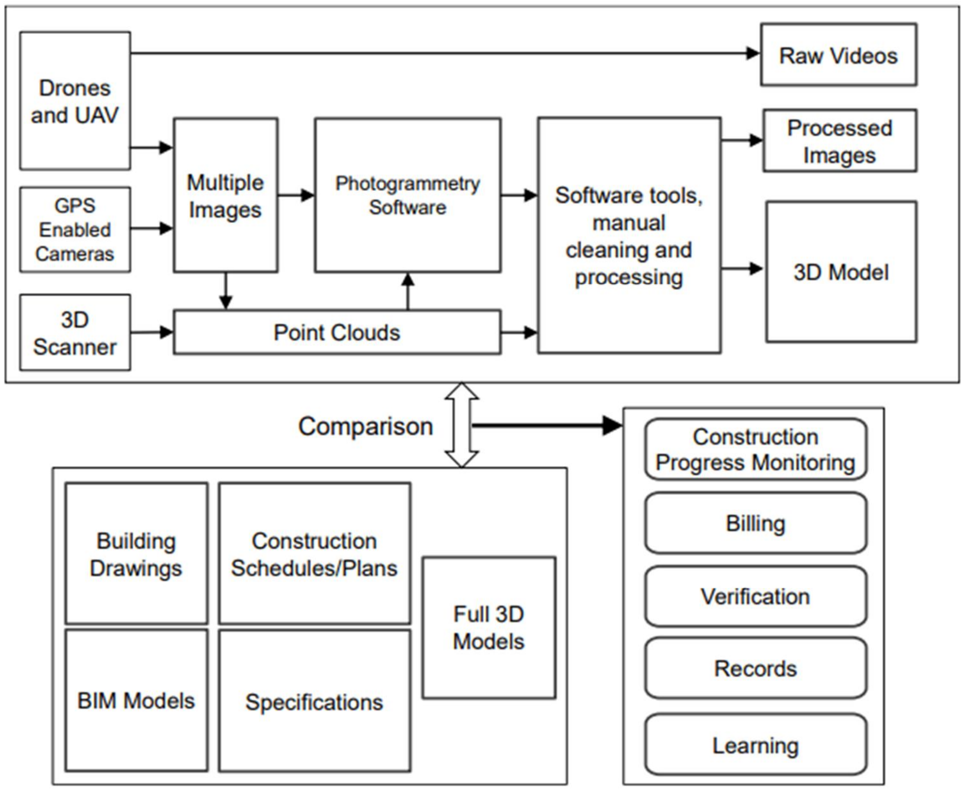

Figure 4: The overall concept of construction monitoring/reporting using drones and unmanned aerial vehicles (UAV)

Figure 5 demonstrates the fundamental concept of converting drone data into a 3D model, which can be routinely used to monitor the construction process throughout the project. This conversion process, known as 3D reconstruction, captures the 3D shape and appearance of real objects from images. Several software solutions can automatically extract thousands of common points between images, known as key points. When two key points in different images are identified as the same, they are called matched key points. Each group of correctly matched key points generates one 3D point. A higher overlap between two images results in a larger common area and thus more key points can be matched. The greater the number of key points, the higher the accuracy of the 3D reconstruction. Therefore, maintaining a high overlap between images is crucial.

For creating a 3D model of a flat surface, nadir imagery is generally sufficient. However, for constructing a 3D model of a structure, such as an under-construction building, overhead images alone are not enough to capture details on the sides of the building. Orbital flights around the structure capturing oblique imagery are recommended to enhance the quality of the 3D model.

The resulting 3D drone model can provide critical information about the construction process and serve as a valuable tool for managerial decision-making and cost control. For instance, it is essential to monitor the amount of material entering and leaving the construction site. Volumetric comparisons between the BIM model and the drone models can be conducted at various project stages to track material quantities. Additionally, drone data can be used to evaluate the quality of concrete pours and the accuracy of structural member dimensions.

Beyond construction scheduling and costing, this comparison can be extended to include real-time recording, reporting, billing, verification, and planning. Using a case study construction project, the effective use of drone data is demonstrated for smart construction monitoring and comparisons between the drone model and the BIM model. The study shows that this fully automated system can significantly reduce the effort required for traditional construction monitoring and reporting procedures. The system provides convenient and intelligent methods for site supervision and management, resulting in improved operations, planning, and effective on-site adjustments.

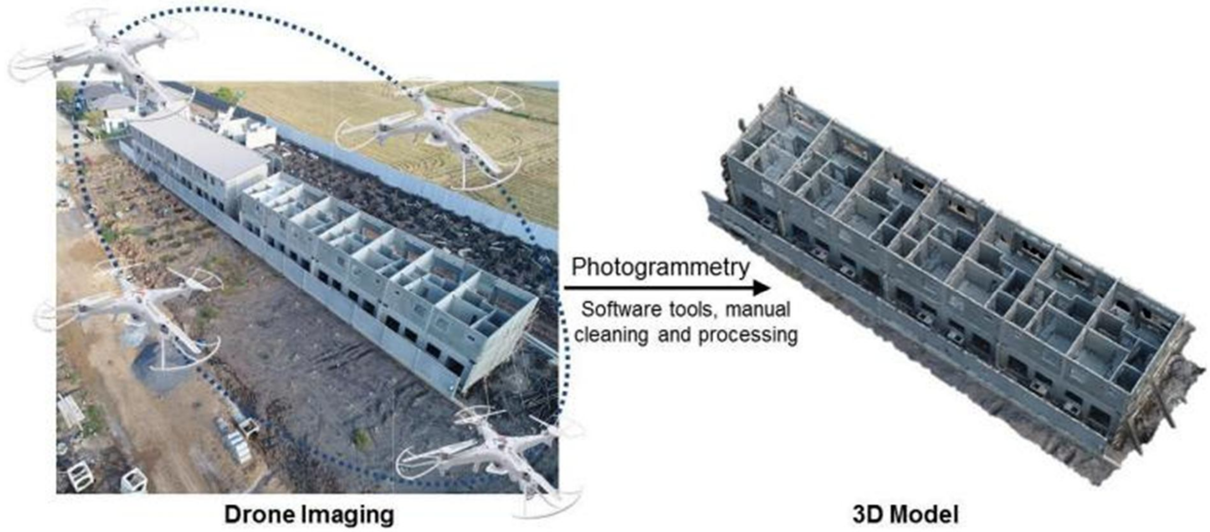

Figure 5: The conversion of drone data into 3D model

III. MONITORING OF A CASE STUDY PROJECT USING DRONES

The smart monitoring approach was tested on a case study involving a single-story residential apartment building. Drones were flown at different heights and angles to capture data at various construction stages. Using software like 3DF Zephyr, the data was processed into 3D models, which were then imported into REVIT for comparison with actual BIM models. This method enabled detailed comparisons of building dimensions and progress tracking. Figures 6 through 9 illustrate the results, showing how drone data can provide accurate and timely progress reports, benchmark assessments, and construction schedule comparisons

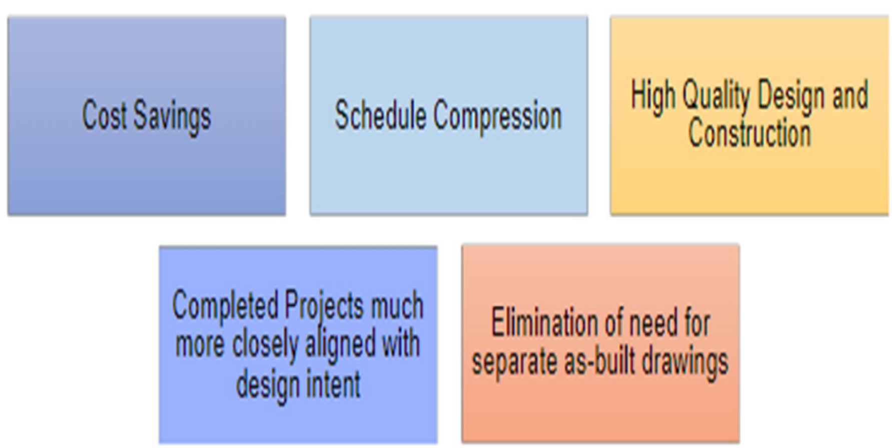

Figure 6: The potential range of results obtained from the drone-based construction monitoring approach

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Figure 7 illustrates the volumetric comparison between the construction plan/schedule and on-site progress for the chosen case study project. This comparison between the BIM model and the drone model provides a progress report. Various benchmarks and targets can be established, allowing for routine monitoring of the project with reasonable accuracy. Similar comparisons can be conducted at different stages of the project. For instance, Figure 8 presents a quantity comparison for the placement of toilets, indicating that all toilets are on schedule. Conversely, Figure 9 shows a schedule comparison for the placement of windows, revealing that their installation is behind schedule. This case study demonstrates the effectiveness of the proposed approach for smart monitoring of construction projects

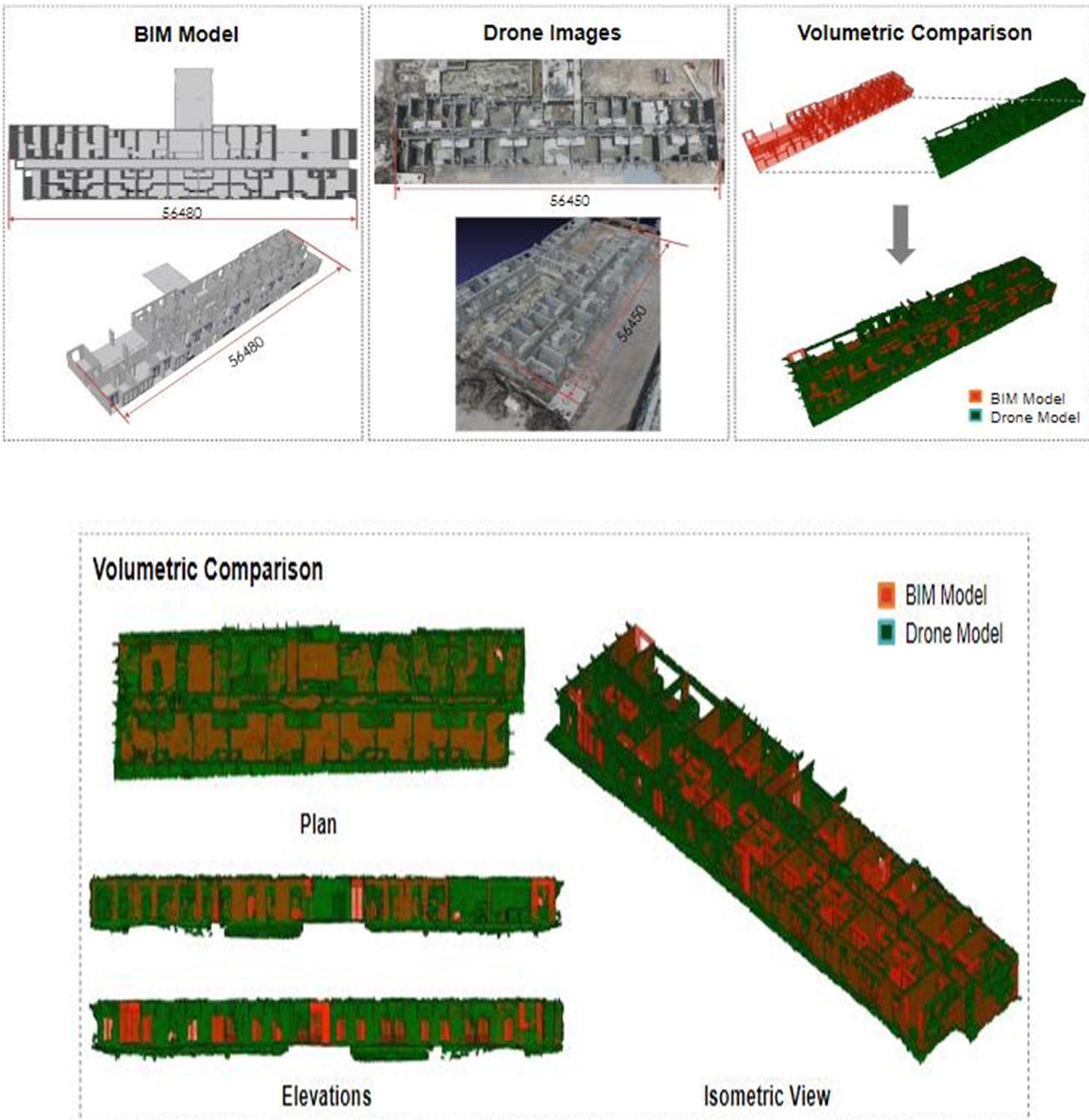

Figure 7: The volumetric comparison between construction plan/schedule and on-site progress

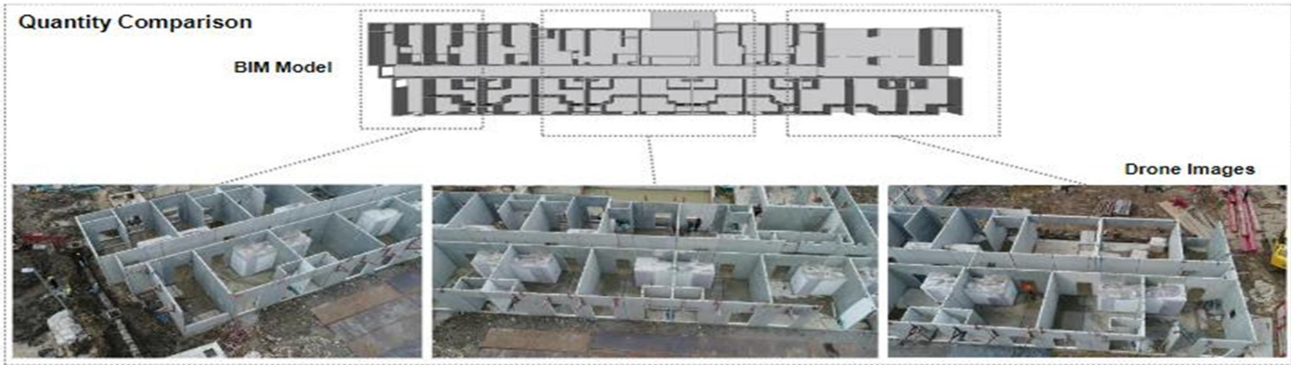

Figure 8: An example quantity comparison for the placement of toilets – All toilets are on schedule

Figure 9: An example schedule comparison for the case study project – The placement of windows is delayed by schedule

IV. ON-SITE REPORT: MALPANI LOGISTIC PARK, CHAKAN (PUNE) VENDOR: YELLOSKYE

Figure 10: Malpani logistic park, Pune.

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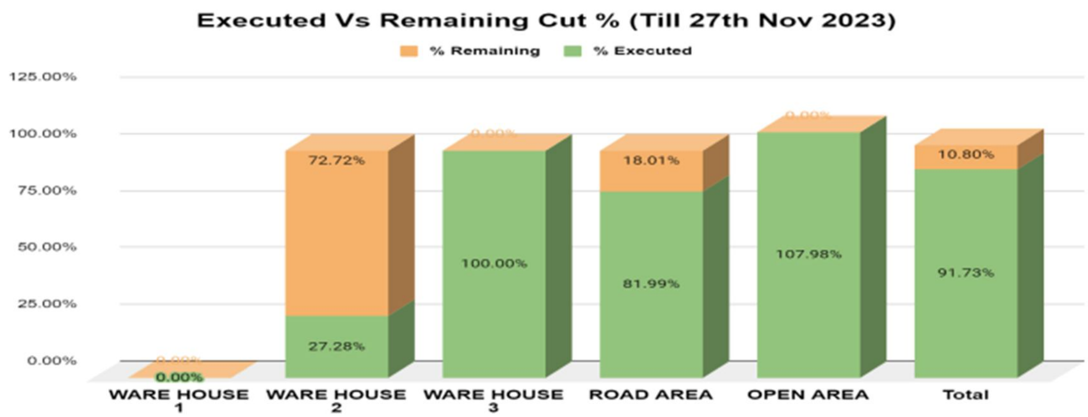
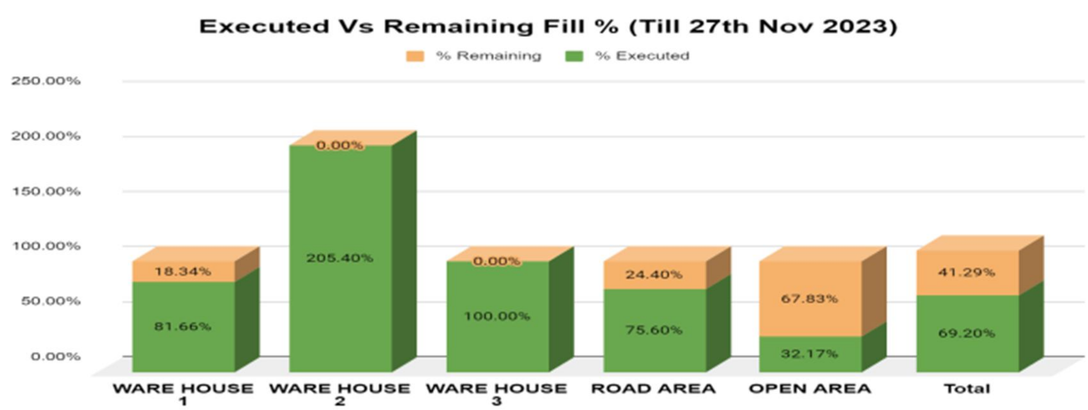
A. Executive summary

Executed cut completed-91.37%



Executed cut has gone beyond the planned cut for the open area.

Executed fill completed-69.2%

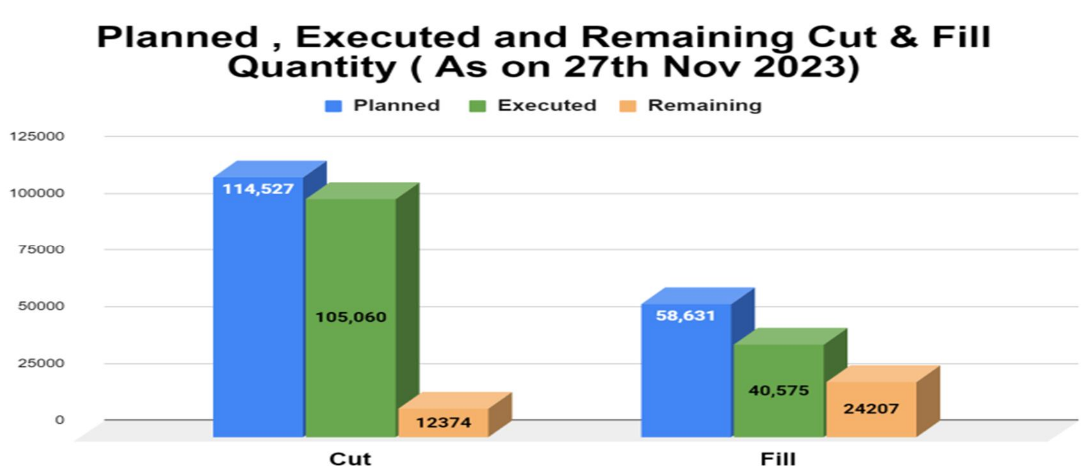


Warehouse 2- executed fill quantity shows value of 11,9807 Cum.

Planned Cut (m³)= 114,527 and Planned Fill (m³)= 58,631

Executed Cut (m³)= 105,060 and Executed Fill (m³)= 40,575

Remaining Cut (m³)= 12374 and Remaining Fill (m³)= 24,207



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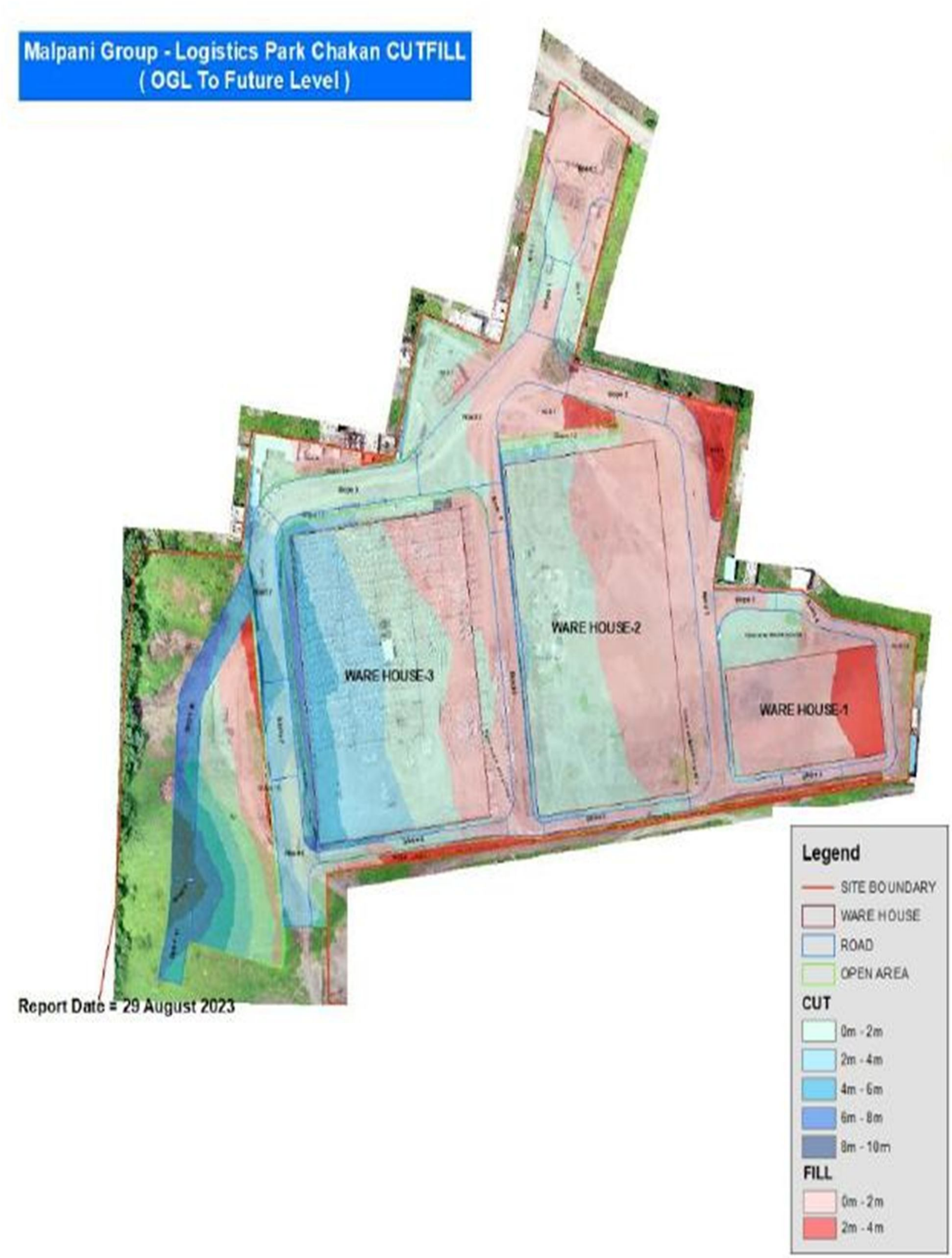
B. Cut/Fill map

Planned cut/fill quantity (OGL to future level)



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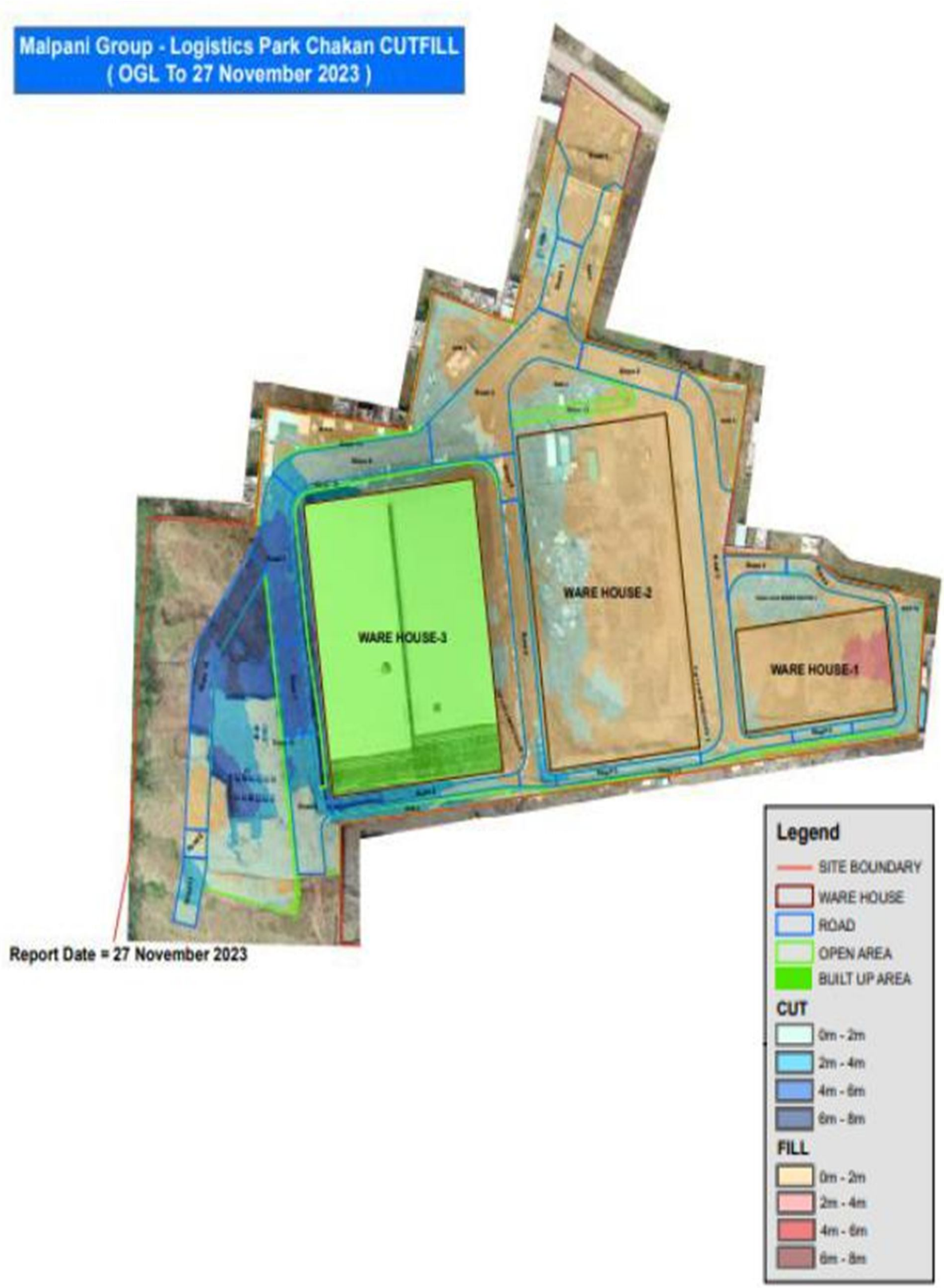
Executed cut/fill quantity



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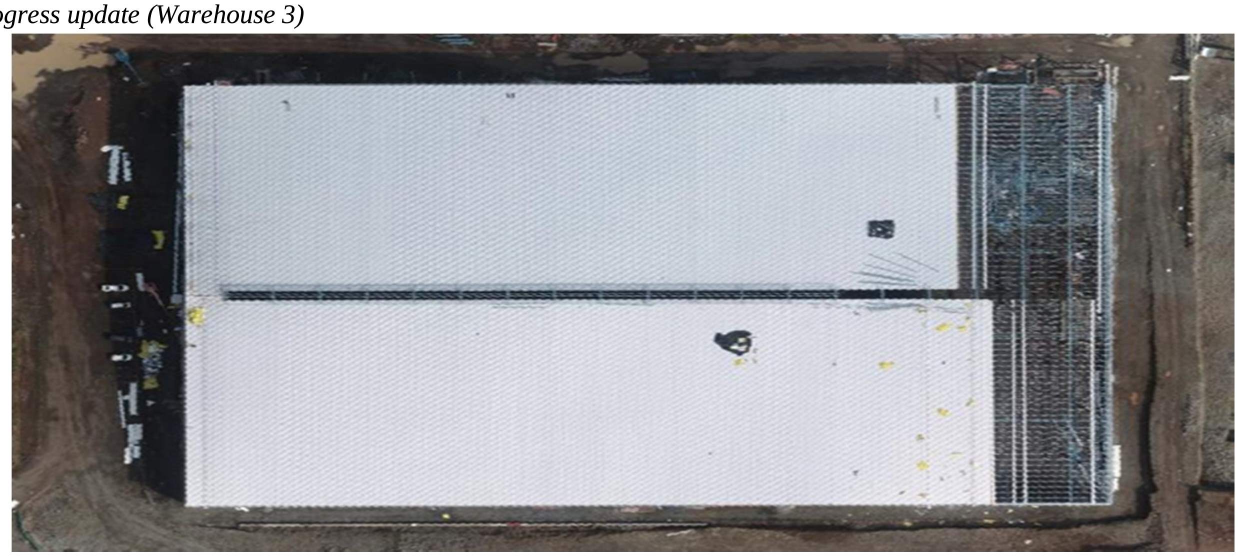
C. Planned, executed and remaining cut/fill quantity

Area	Future Level	Planned Quantity (OGL to FFL)	
		Planned Cut (m^3)	Planned Fill (m^3)
WARE HOUSE 1	680.35	0	7,648
WARE HOUSE 2	682.35	7,648	5,836
WARE HOUSE 3	687.2	32,640	3,421
ROAD AREA	N/A	37828	12,664
OPEN AREA	N/A	36,411	29062
Total		**114527**	**58,631**

Area	Executed Quantity (OGL to 27th Nov 2023)			
	Executed Cut (m^3)	% Completed	Executed Fill (m^3)	% Completed
WARE HOUSE 1	0	0.00%	6,245	81.66%
WARE HOUSE 2	2,086	27.28%	11,987	205.40%
WARE HOUSE 3	32,640	100.00%	3,421	100.00%
ROAD AREA	31,016	81.99%	9,574	75.60%
OPEN AREA	39,318	107.98%	9,348	32.17%
Total	**105,060**	**91.73%**	**40,575**	**69.20%**

Area	Remaining Quantity (Till 27th Nov 2023)			
	Remaining Cut (m^3)	% Completed	Remaining Fill (m^3)	% Completed
WARE HOUSE 1	0	0.00%	1,403	18.34%
WARE HOUSE 2	5,562	72.72%	0	0.00%
WARE HOUSE 3	0	0.00%	0	0.00%
ROAD AREA	6,812	18.01%	3,090	24.40%
OPEN AREA	0	0.00%	19,714	67.83%
Total	**12374**	**10.80%**	**24,207**	**41.29%**

D. Progress update (Warehouse 3)



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- Excavation works completed.
- Foundation works completed for the space frame structure.
- Purlins, rafters and shoulder erection work are completed.
- Sheeting erection works is in progress at south region.
- Monitor purlin and rafter work are in progress for south region.
- Boundary wall works completed.
- Vertical sheeting erection works is completed for west, north and south and in progress for east region.

E. Project images

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V. CONCLUSIONS

This research presents a framework for a fully automated construction monitoring and reporting system utilizing drones and UAVs. By integrating real-time data from drones, 3D models can be created and compared with BIM models at various construction stages. This approach can significantly streamline traditional monitoring processes, offering more efficient site supervision and management, as well as improved planning and on-site adjustments.

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