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DRONE TECHNOLOGY AS A TOOL FOR EFFECTIVE CONSTRUCTION MONITORING FOR STANDARDS COMPLIANCE IN NIGERIA

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Abstract

Constructions all over the world are capital intensive and contribute about $8.5 trillion dollars yearly to the world economy. However, the ineffectiveness in monitoring the material procurement process and production management causes delay and double the overall construction budget amount and subsequent abandonment of several construction projects in Nigeria. The purpose of this paper is to examine the possibilities and benefits of using drone as a digital technology in the monitoring of building construction process instead of the present norms of site residency and periodic visitation by professional's and control officials. Primary data were gathered for the traditional approach from different building construction site visitation in Ikole-Ekiti, Port-Harcourt, Lokoja Kogi State, and Abuja to check for compliance with building permit approval standards for foundation depth, foundation footing, block quality, thickness of over-site concrete, floor heights, ceiling level, headroom, setbacks, minimum door/lintel height, sizes of reinforcement, professional engagement in design and construction and the secondary data were gathered through literatures and other archival sources to draw conclusions on drone monitoring approach from developing countries. Using permit compliance standard value table against a site measured value for analysis. It was observed that the drone technology have possess higher benefits and opportunities than

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the present norms of site visitation to monitor construction compliance and the technology can enable better construction site monitoring, give accurate volume and material types inventory as required, provide both the length, width and elevation for building construction, roads and other infrastructures on site, provide annotating images and maps for easier communication to both client and professionals. From this finding this study urge the development control officials and policy makers to give the drone technology the necessary attention and chances to take an essential place in the monitoring of building construction process in Nigeria.

Index Terms: Drone Technology, Monitoring, Compliance, Standard, Nigeria.

1. INTRODUCTION

In the capital city of Nigeria, FCT Abuja and to the far North and Central, Eastern, Southern, and the Western parts litters one uncompleted or total abandoned construction projects owned by the Federal, State or Local Government in Nigeria [1]. It is no longer news seeing construction projects started very well but abandoned half way due to one reason or the other by the contractors [2]. The poor functional Government policies, improper procurement procedures, incompetent contractors, defective cash flow and lack of efficiently and effectively control in monitoring resources for thousands of abandoned projects are factors that contributed to those problems [3]; therefore, motivating the investigation into the use of using drone technology to monitored construction projects for effective delivery in Nigeria as applicable in every other part of the world [4]

Construction project planning is critical and involves establishing deadlines for all activities to be executed therefore prompting the production of construction work programme which outlines methodologies for construction, monitoring, recording and reporting the procedures. Construction site work is a typical manual and strenuous activity by people and machine for the procurement of materials, execution of works, writing the progress report and backing it with virtually photographic material [5]. This in essence necessitated the advocacy for the introduction of drones and unmanned aerial vehicle in the industry to improve professionals and control officials in monitoring construction sites.

For some years now, drones or an unmanned aerial vehicle (UAV) has become the new innovation in business and industry. The construction industry is not an exception in this innovative rush of drone technology for effective project delivery [6]. The technology has the ability for timely and efficient delivery of data reports from monitoring than the traditional ways of professional site visitation [7].

Today, the impact of drone technology on the digital transformation of the construction industry is undeniable. Drones' technology has already broken through rigid traditional barriers in industries which otherwise seemed impenetrable by similar technological innovations [8]. [9] formed that the drone technology increases work efficiency and productivity, reduces individual and organizational workload and production costs, and improves work accuracy and standards, decreases doubt of work reports, and resolves security threats on construction sites, drones are capable of reaching remote areas with little effort, time, and energy by the use of app or a controlled remote [10]. Monitoring construction progress is an old challenge within the construction industry, but the new technology of drones is a practical way to eliminate these old problems with the

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miniaturization drone incremental development which is smaller, lighter, and cheaper than the previous generation [8]. The study stressed further that the limits of miniaturization are unknown. The smallest commercially available drones are more or less the size of credit cards, but experts indicate that within a few years we can expect drones the size of insects [11]. The diversion of construction cash, incompetency of contractors and unethical or substandard material procurement, abandoned or uncompleted building construction projects within the country motivate this research to examine the use of drone as a digital technology in the monitoring of building construction process to replace of the traditional site visitation and inspection process. The efficient and effective way of checking the material and labour quality, accuracy in the placement of these materials and the control of progress of a building construction project is called construction monitoring [12].

2. LITERATURE REVIEWS

2.1. Traditional building construction project progress monitoring practices

The traditional method of controlling building construction projects involves the planning, organizing, directing and coordinating people (all professionals and artisans) and materials daily throughout the project life cycle to ensure adequate progress of works, maintaining quality and complying with standards [13].

The principal aim of any building construction control inspections in any developed or developing nations is for compliance with building regulations at various stages of construction. This including; setting out stage, excavation and earth filling, foundation stage, floor construction (Sub-structural work details), superstructure (Wall, lintels, form work, upper floor construction), Roof construction stage, finishes to walls, floors, roofs and external work and in compliance with Health and Safety regulations for all the construction methodology [14].

This traditional construction monitoring requires additional hands to consultant team to be effective such as the appointment of clerks of works to provide an independent assessment of works, report daily with photographs, maintain site records or diary, take site material inventory, ensure compliance with site policy on accessibility, waste management, attend construction progress meetings and to produce regular written reports. The clerk of work represents the consultant architect and He or She can only inspect, could condemn work but any instructions would be issued by the architect or consultant to the project [13,14]. Figure 1 present a summary of traditional method of project progress monitoring typical practices. The diagram discussed the project progress in line with the work schedule within time and budget to forecast the possible project delivery date. The report involves a lot of stages and trust issues regarding quality, compliance with standards and therefore request for a test result approval of contract changes and modification. The traditional approach requires documentation of every detail for proper reporting and this create a lot of burden of material reduction on site, pending issues from site progress meeting, attaching photographs to justify every point, editing and updating of progress reports on the project manager instead of focusing on

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project delivery within the time and budget frame alone [cited in 13]. To achieve success on the traditional approach of construction progress control, the project manager must rely heavily on reliable monitoring system from team mates that can provide timely reporting of positive and negative project progress [15; 14]. [6] has affirmed that the use of unmanned aerial vehicles and drones is an effective tool and smart solutions to solve the planning and monitoring of construction activities for maximum productivity. The traditional approach is time consuming, waste scarce construction resources, relies on many operators to be successful, and always causes delay in project delivery and completion [16; 14].

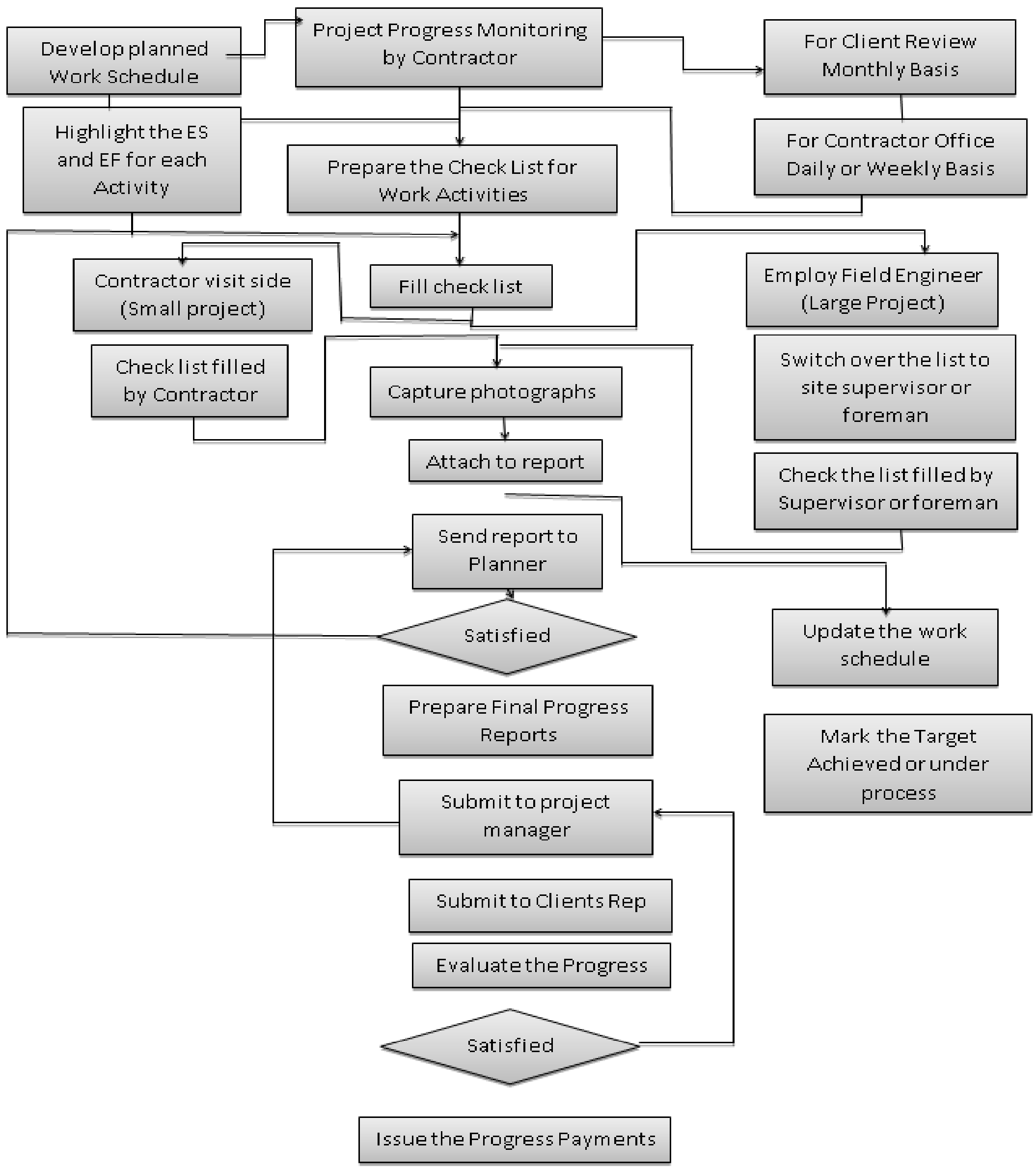

Figure 1: Traditional method of project progress monitoring typical practice

Source: [16:pp27]

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2.2. Building construction project progress monitoring using drone technology

Using drone and unmanned aerial vehicles (UAVs) is a new trend in different fields and industries to solve real-time problems and the field of architecture and construction Engineering has embraced the innovation especially for large projects for its ability to cover a wide range of applications [6; 8]. The drones and UAVs serve as real time tool for planners to monitor construction projects on the ground for conformity with standards and regulations. The technology can capture real-time data to help keep daily records of activities on the construction site [6]. [7] uphold the significant role of monitoring and control in construction project delivery as shown in Figure 2 to ensure projects are implemented successfully, achieve high quality, and obtain value for money, save time to the satisfaction of clients and other stakeholders. Adoption of drone and UAVs to monitor construction project will ensure scarce resources (materials, human and financial) are properly managed.

In the traditional approach of monitoring construction work; several activities are tracked and recorded daily in a logbook. This document can be complemented with tools, such as control sheets, measurement diaries, progress charts, and site-meeting minutes, to help monitor construction progress, update the construction schedule, and, thus, minimize delays in project deliveries [5].

Figure 2: Monitoring and Evaluation of project with Management roles

Source: [IUCN, WORKING DRAFT, 2000 cited in 7]

Traditional approach of construction project monitoring and control involve a strict or prescriptive execution plan without given much allowance for innovative changes. The approach limits, accurate real-time data showing bit-by-bit construction progress for reporting by the project manager [6; 17; 16]. Several authors such as [17; 8; 15] have outlines the benefit of introducing drone technology and UAVs into construction monitoring and control as follows:

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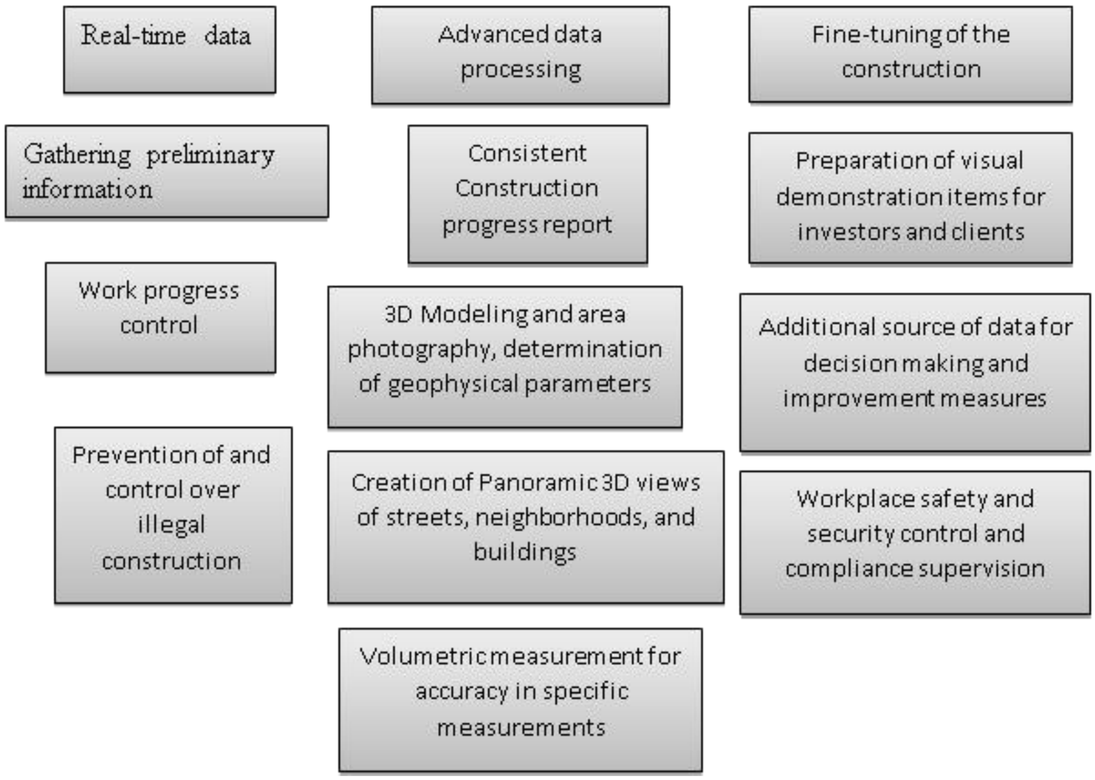

Figure 3: The key elements of smart construction monitoring system using drones and UAVs;

Source: [6].

With drone technology and UAVs there is an assurance of better construction monitoring and control during the entire project operations, high quality construction, elimination of material waste, cost savings, planning and adjustment, and complete projects much earlier within budget and time [6]

[16] has used questionnaire survey within the Malaysian construction industry (MCI) to investigate develop a systematic model for monitoring construction project progress and the readiness of the stakeholders in the industry to digitalise the MCI monitoring and control process. Similarly, [6] used the case study approach of flying drones over the construction activities at every construction stage four times to monitor the projects at different height and different angles of first flight of 00- and 30-meter height, second flight of 800 and 20m height, 450 and 30m height, and fourth flight of 300 and 50m height respectively. The study further concluded after analysis with software that autonomous drones and UAVs can be used efficiently to produce a more practical and cost-effective operations in the construction management and monitoring [6]. This paper aimed to examine the possibilities of using drone as a digital technology in the monitoring of building construction process instead of the present norms of site visitation and therefore adopting the following methodology.

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2.3. Study objectives

This study investigates drone technology for construction monitoring in Nigeria. And the following objects guides this research.

I. To Enable digital approach to construction monitoring in Nigeria

II. To identify the benefits associated with drone technology

III. To bare the traditional construction monitoring and its problem.

3. RESEARCH METHODOLOGY

3.1 Data collection

This study used a cased study approached as suggested by [6] by visiting the construction project sites to capture data physically on the progress of construction work at different stages with a Structured Building Construction Compliance Form designed by this study with recommended minimum standards by the Nigerian Building compliance regulations to collect primary data at TETFUND Project FUOYE Ikole-Ekiti, and Port-Harcourt construction site, Lokoja Kogi State, and Abuja FCT construction site respectively for compliance with approved building foundation depth, foundation footing sizes and thickness, block quality, thickness of over-site concrete, material quality, compliance with approves floor heights, ceiling level, headroom, setbacks, minimum door/lintel height, sizes of reinforcement, expansion joints, professional engagement in the design and construction and then relies on secondary sources from literature research for digital data captured by drones and UAVs equipped with infrared enabled cameras to enhance surveillance capabilities on a construction site to track work progress, workers, equipment and materials on site similar to the one this study visited and captured the data traditionally. The data was captured using tables with the first column indicating location of construction projects visited and the subsequent columns captured minimum recommended value and the measured value of the various variables measured from different construction site to ascertain the level of compliance.

3.2 Data analysis

This study analysed the data by comparing the required standard value and the site measured value and the thematic approach of secondary data

4. RESULTS AND DISCUSSIONS

4.1 Sample

The characteristics of the samples used for case measurement was one (1) storey to three (3) storey building for a period of six months (6) by stratified sampling as presented in table 1 and that of drone analysis from secondary sources are also analysed and discussed.

Table 1 is the measurement of the traditional approach of monitoring building construction progress for a 1-3-storey building within a period of 6 months at different sites

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Table 1: Results of Traditional monitoring Approach

Construction elements monitored during investigated		Ikole-Ekiti	Port-Harcourt	Lokoja Kogi State	Abuja	
	RSV	SMV	SMV	SMV	SMV	Percentage compliance
Foundation depth	930mmm-1500mm	650mm, 720mm, 825mm	700mm, 750mm, 600mm	450mm, 800mm, 730mm	700mm, 850mm, 1200mm	65%; 50%, 36%
Foundation width	600mm-1000mm	450mm, 467mm, 425mm	450mm, 580mm 470mm	450mm, 485mm, 582mm	500mm, 550mm, 576mm	19%, 19%, 20%
Foundation footing	100mm-300mm	50mm, 75mm, 65mm	50mm, 82mm, 48mm	55mm, 60mm, 51mm	100mm, 120mm, 85mm	45%, 50%, 60%
Reinforcement bars for foundation work	Columns/Beams: 25mm,20mm, 16mm,	16mm, 12mm, 12mm	16mm, 12mm, 12mm	16mm, 12mm, 10mm	16mm, 12mm, 16mm	21.9%, 30%, 40%
	Stirrups: 8mm	6mm, 6mm, 6mm	6mm, 6mm, 6mm	6mm, 6mm, 6mm	6mm, 6mm, 6mm	
Setback	Front (3000mm-6000mm)	2000mm, 4000mm, 6000mm,	2000mm, 5000mm, 3500mm	2500mm, 1500mm, 3000mm	5000mm, 6000mm, 2800mm	66%,53%, 58%
	Back (3000mm-6000mm)	600mm, 900mm, 1200	900,1100 mm, 2000mm	400, 1200mm, 600mm	2700, 3000mm, 3200mm	20%, 28%, 42%
	Sides (3000mm-6000mm)	1000mm, 2000mm	1000mm, 1500mm	600mm, 2000mm, 1200mm	2500mm, 3000mm, 1500mm	33%, 20%, 41.6%
Plain concrete	Thickness: 150mm	50mm, 75mm, 80mm	75mm, 50mm	82mm, 90mm, 87mm	120mm	33.3%, 37.2%, 68.2%
	Width: 200mm-225mm	100mm	120mm	150mm	220mm	50.3%, 53.3%, 87.1%

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	Overall width: 675mm	450mm	500mm	499mm	700mm	66.6%, 74%, 80.2%
Reinforced Concrete	Blinding: 75mm	25mm	27mm	32mm	50mm	33.3%, 36%, 42.6%,
	Footings on soil: 150mm	50mm	50mm	67mm	76mm	33.3%, 33.3%, 44.6%
	Footings on poles: 300mm	100mm	100mm	101mm	127mm	33.3%, 33.3%, 33.3%
Concrete curing	7days, 14days & 28days before work commences	3 days	5 days	1 day	2 days	21.4%, 35.7%, 0.07%
	Wetting: morning & evening for 5 days	0	0	1^{st} day	3 days	0.0%, 0.0%, 2.0%
Back/Earth filling	300mm earth filled	80mm	76mm	82mm	120mm	26.6%, 25.3%, 26.7%
	Rammed or Compacted	rammed	Rammed	Rammed	compacted	33.3% compacted
Hardcore Filling	150mm-300	0mm	0mm	23mm	120mm	0.0%, 0.0%, 15.3%
	Material used	nil	nil	Broken blocks	stones	30.2% used stones
Professional on site and design	Builder: Compulsory Residency	nil	nil	nil	nil	0.0% resident builder
	Structural engineer: Weekly or as need arises	nil	nil	nil	nil	0.0% structural engineer
	Architect: Monthly or as need arises	nil	nil	nil	yes	30.3% non-registered compliance
	Design	Unapproved arch. design	Unapproved arch. design	Unapproved arch/struct. design	Approved arch/. design	30.3% approval compliance
Oversite concrete	Thickness: 150mm	76mm	73mm	72mm	101mm	50.6%, 48.6%, 48%
DPC/DPM provision	**Must** be installed (DPC)	no	no	no	no	0.0%
	DPM	no	no	no	yes	30.3%
	Beams: 20mm,16mm	16mm	16mm	12/16mm	16mm	

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Reinforcement bars for suspended floor	Slab: 12mm	12mm, 11mm,	12mm, 10mm	11, 12, & 10mm	12mm, 11mm	55.8%, 60.3% compliance
	Stirrups 8mm	6mm	6mm	6mm	6mm	75%
Max. allowable length of wall	Without column: 3650mm	3000mm	3000mm	3600mm	3600mm	82.1%, 82.1%, 95.6%
	With column: 7000mm	4000mm	5000mm	4000mm	3000mm	57.1%, 71.4%, 42.8%
Sand crete block quality	Size: 225mmx450mm	225mmx45	225mmx450	225mmx450mm	225mmx450mm	99% size compliance
	Broken Crushing height: 900mm	300mm	275mm	175mm	450mm	33.3%, 30.5%, 19.4%
Lintel provision on door/window	Thickness: 225mm	225mm	120mm	230mm	225mm	90.6%, 67.6%,
	Height: 2100mm	2100mm	2100mm	2100mm	2100mm	95.3%
Min. headroom	3000mm	3450mm	3000mm	3000mm	3000mm	95.3%
Min. ceiling level	3000mm	2750mm	2900mm	2975mm	3000mm	67-80%
Expansion (Control) joint compliance. Min length before introduction 30m-120m	IS 3414 Joints code for structures: 30m IS: 456:2000: 45m for one or more	NA	NA	No	yes	30.3%
	Steel structures: 400ft (120m)	NA	NA	no	no	0.0%
Staircase	Risers: 150mm	145mm	165mm	170mm	155mm	60.5-80% compliance
	Tread 250-300mm	300mm	250mm	250mm	300mm	80-95%
	Nosing: 25-50mm	NA	NA	NA	27mm	30.3% compliance

Source: (Authors field work 2023)

RSV = Required Standard Value

SMV = Site Measured Value

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Table 1 above has revealed in details the percentage of compliance with standards from the site measured value (SMV) against the required standard value in the traditional site monitoring for standard compliance. In which, foundation depth has 65%,50% and 36% compliance respectively within the three (3) cities observed, while the foundation footing recorded 45%,50% and 60% respectively in three cities. The reinforcement bar provision for foundation work has 21.9%, 30% and 40.2% compliance. For the building set back compliance, the front has 66%, 53%, & 58% while the back has 20%, 33% and 41.6%. Plain concrete was also observed and measured with the thickness compliance of 33%, 37 and 68% in different cities, the curing process for the number of days before the commencement of next work has 21, 35, & 0.7% and the wetting requirement of morning and evening for at least 5 days 0% and 2% compliance respectively in those cities. The hard-core filling has 0% and, 15%, provisional involvement compliance has 0% resident builder, 0% structural engineer and 30% of unregistered architects (academically trained but not license to practice professional). For the approval of building design by relevant authorities; 70% of the site visited had no building approval, 0% of them also made provision DPC/DPM, and 33, 30, 19.4% of the sites sand crete block had compliance for crushing quality test and 30% has expansion joint provided and complied with the standards.

4.2 Results of drone monitoring from secondary data

a. Drone Monitoring for Construction Project: A Case Study Report

A case study of construction project monitoring of a single-story residential building carried out by [6] using drone revealed the following construction activities at several stages of construction, the drone is flown a minimum of four times to capture various data with different height and camera angle settings as show in table 2.

Table 2: Drone flight to capture various data

	Camera angle settings	Height of Flight from building height
1st data set	0^0	30m
2 data set	80^0	20m
3rd data set	45^0	30m
4th data set	30^0	50m

Source: [6]

After the completion of aerial photography and analysis of the 3D models with software, the reconstruction and regeneration were done and exported to REVIT for comparison of building dimensions. The potential results obtained from the drone-based construction monitoring approach were: Cost Savings, Schedule Compression, High Quality Design and Construction, Completed Projects much more closely aligned with design intent, and Elimination of need for separate as-built drawings [6].

b. Comparison Framework report for traditional/drone construction monitoring process

Similarly, [12] developed a comparing framework for traditional and drone construction monitoring methods with clear benefits and draw backs on both automated and traditional

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approaches shown in in Fig. 4. The submission opined that the larger the project the more people on site and the harder to monitor and providing personal protective or safety equipment (PPE) for everyone. But drone views such as Photogrammetry and algorithms identify building defects, saving time and money, share data via BIM and creating 3D models. Musara advocated the raw data collection in construction should be automated closed-loop monitoring with high-definition sensor and camera to transfer data to a central server for AI algorithm analysis. The loop is should be closed with actionable information and visuals that improve decision-making and execution. This value chain from data inputs to decision outputs shows how automated solutions benefits the entire construction monitoring process [12]

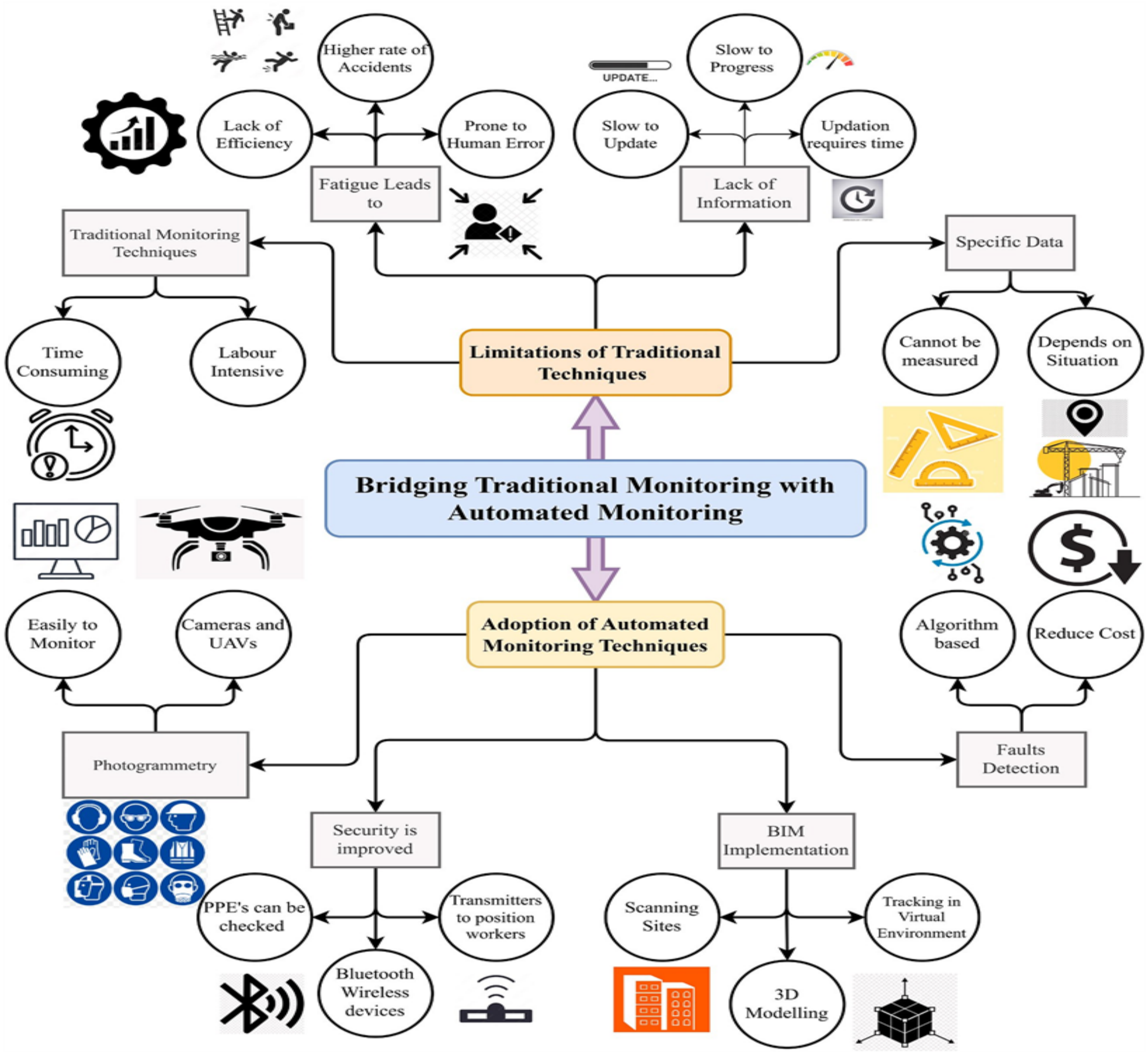

Figure 4: Framework for construction traditional/drone monitoring process

Source: [12]

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c. Report on the use of artificial intelligence for construction inspection

In the UAE, it was revealed that China State Construction Engineering Corporation (CSCEC) used artificial intelligence (AI) to facilitate the inspection processes on their construction project. The corporation was able to conduct inspections remotely during the lockdown of 2020 from the office, the construction site and camps using drone rather than in person. Some countries have already started using robots on sites for plastering and other tasks; this reduces the need for human resources [17]. In the UAE's construction sector, companies are also exploring the drone game-changing solutions to break ground. However, this is harder to achieve when you use the traditional construction inspection process [13]. It was further revealed that using drones in the construction industry prevents costly mistakes as they allow construction managers to identify challenges in the pre-construction stage, spot mistakes, and measure progress during construction. Drones also improve health and safety in the industry that poses a high risk and work-related fatalities for construction workers [13].

The primary areas in which drones are utilised by the construction sector as stated by Rashid are:

1 Progress monitoring

[13] noted that progress monitoring through drones reduces project value costs and wastages by 18.4% and can decrease the time spent to compile the snag list (or inventory of tasks by contractor) by 32% this eliminate the unnecessary cost of regular manual supervision and inspections of professional, for drone ability to consistently monitor the construction progress and repeat flights, it can reduce the possibility of doing manual rework by 25% saving unnecessary meetings, boosting productivity amongst workers as they can focus on other aspects of the project. It was also revealed that its aerial views capability allows construction managers to sit down and easily determine critical construction path early and plan solution to the problem save time and unnecessary expenses, accomplish task in a minute unlike traditional approach that can take days to complete.

2 Site mapping

Traditional mapping of wide construction sites used to be rigorous and taken a long time. It was revealed with drones that contractors can produce a speedier workflow with less effort needed [13]. The finding stressed that drones can finish the task accurately as well as sends up-to-date data straight into a computer for fast-track analysis, the mapping are more precise than a satellite and faster than land survey produce data [13].

The traditional method of construction progress monitoring is highly inefficient; because the method relies on written reports, information flow from contractor, to site engineers and finally the project manager who now spend time to compile the report and updated site photos ensuring the project is on track [14]. Fig 5 is an example of drone construction monitoring showing overall site details.

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Figure 5: Drone construction Progress Monitoring

Source: (https://www.vecteezy.com/free-photos/construction-site-drone)

3 Cloud Reporting

The data acquired from drones can be used to conduct volumetric calculations to track quantity or inventory of site materials and progress, the models can be shared with team members for better project management and up-to-date on the site progress [14]

4 Saving Time

It was also revealed by Mani that drone save time from writing reports manually, visiting site, capturing images and compiling of inventory list, multiple site meetings to review progress and reports. This agree with [13] that the technology have saved 32% on snag list compilation, 25% reduction in time spent in reports and meetings which can be used for more productive things by using drones [14]

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

What this paper aimed to achieve was to examine the benefits of using drone as a digital technology in the monitoring of building construction process rather than the traditional method of site residency and periodic visitation for inspections construction progress by professional's and control officials. It was observed that the traditional method of monitoring construction process was time consuming, wasting resources, more expensive in compiling snag list, and delay in communication inflows from contractors to site managers.

The findings indicates that site measured values (SVM) of most site indicators inspected and measured during traditional monitoring does not complied with the required standard value (RSV) in the depth, width and footings of foundation, Reinforcement bars used at foundations and suspended floor, in the thickness of plain concrete, in concrete curing, blinding, back filling and compaction method, sandcrete block crushing test and in the compliance with require professional that must be on site in the construction process. With drone technology as monitoring tool such inefficiencies can easily be identified as a real-time data can be captured and update will be sent straight into a computer for fast-track analysis as stated by [13] from literature reviews.

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From the case study and secondary data analysis, drone technology is demonstrated as an effective tool for monitoring construction progress on site. It is shown that drone is more effective than the traditional method of construction monitoring for compliance with standard. Deploying the technology reduces the effort required in traditional construction monitoring and reporting procedures.

Drone technology save 32% of time on preparing list of work needed to be done, 25% of reduction in time spent in reports and holding meetings, and reduces waste by 18.4%, spots mistake, reduces risk of injuries in construction, support the conduct of site inspection while in your office, it can identify critical path and proffer solution, boost productivity, and accomplish task on time unlike the traditional method.

The drone technology is convenient and a 'New Normal' smart ways of construction process monitoring for standard compliance for better planning, management, and effective decision taken.

5.2 Recommendations

Based on the findings from this research, the following recommendations are put forward for consideration:

- The industry and the Government should collaborate for the training development on drone technology to enable digital switch in the industry
- This research recommends a strong regulatory/legal policy framework for the security and safety of drones' operations in construction project monitoring.
- The regulations should also increase the demand of the use of drone technology Professionals, Governments, and the public should be enlightened on the benefits of using drones' innovations on construction monitoring.
- In project delivery effort should be towards reporting to include inspection and image acquisition.
- This research recommends adoption of photogrammetric processing of data images to assist in project communication and proper project work monitoring.
- This paper recommends integration of drone technology into project management monitoring and delivery

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Research Limitation

The researchers could not afford to purchase a drone to monitor the constructions sites visited for physical measurement and therefore rely on drone secondary data report to make a conclusion on this research.

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