FIMEK

Journal of Agronomy, Technology and Engineering Management

Article

Practice-driven Difficulties and Need-driven Plausibility for the Utilization of Robotic and Autonomous Construction Systems in Nigeria

Olugboyega Oluseye [1,*], Oseghale Godwin Ehis [1] and Clinton Aigbavboa [2]

[1] Department of Building, Faculty of Environmental Design and Management, Obafemi Awolowo University, 220103, Ife, Nigeria.
[2] cidb Centre of Excellence, University of Johannesburg, PO Box 2107, Brooklyn Square 0075, South Africa.
* Correspondence: oolugboyega@oauife.edu.ng

Received: 01 May 2022; Accepted: 30 July 2022

Abstract: The retrofitting of common construction plants and equipment with the robotic system has some way or another crossed over the technological gaps between economically advanced and backward counties. This implies that economically and technologically disadvantaged countries like Nigeria are by implication taking advantage of the efficiency, quality, and safety benefits of construction robots. This study researches the status quo and future of construction robotic and autonomous construction systems in Nigeria. The legitimacy of the research was determined by positivism philosophy. The research was targeted at construction organizations in Lagos State. The research's findings support the utilization of robotic and autonomous construction systems (RACS) (mostly portable equipment) in terms of intelligent construction systems. The findings also revealed that the greatest obstruction to the use of RACS is the assumption that the construction sector is a mass employer of labor. Accordingly, the study concluded that those that are utilizing RACS primarily embrace it for work efficiency.

Keywords: automation; construction robots; robotic and autonomous equipment; robotic and autonomous construction system; robots.

1. Introduction

Robotic and autonomous construction system alludes to the utilization of robotic and autonomous construction equipment for construction-related production, processes, organization, and management. Construction equipment becomes robotic – equipped with a multifunctional controller and route controls - or autonomous – follows a fixed sequence of remote controls – when it is designed to move material, parts, tools, and specialized devices for the performance of a variety of tasks. Utilizing robots and automating construction sites is not new – the principal research and publication on construction robotics date back to the 1970s in the former Soviet Union [7,10,20]. By the mid-1980s, robotic systems were created and presented for inspection tasks on a radioactively contaminated building site. By 1991, the first full-scale utilization of construction automation occurred in Japan [19].

Quick forward right around forty years, the utilization of robots and construction automation is extremely restricted or non-existent. The industry battles to pass the model and examination stages, and their development and applications are as yet thought to be exploratory and generally led by colleges and research centers. The fundamental reasons are generally equivalent to those that forestalled their execution during the 1980s and 1990s. Be that as it may, significant technological advancements are pushing the construction industry towards digitalization and automation [13, 17]. Because of this progression, new robotic technologies, for example, mobile and cloud computing, big data and deep learning, wireless sensor networks, and different BIM instruments are accessible today which didn't exist during the 1980s or 1990s. Insightful implementation of these robotic technologies can have a huge effect on the achievement of construction robot applications today as compared with what was available many years prior. Specialists accept that the utilization of robotic and autonomous construction equipment can decidedly affect the entire life pattern of a construction project from project origination to the furthest limit of the life stage [21]. This conviction is pivoted primarily on the way that robotic technologies can perform tasks fundamentally quicker, work in cruel and dangerous conditions where people are reluctant or incapable to work, give more prudent development strategies, ensure quality work, give more prominent command over the user interaction, and give more noteworthy command over the end-product of the cycle. One more contention for the utilization of robotic and autonomous construction equipment is that the adoption of robotic technologies and promotion of automation is a portion of the ways of digitalizing the construction industry [2].

The advantages of robotic and autonomous construction systems have as of late incited the improvement of a few unique sorts of robotic systems and conceivable different construction-related applications. Quite a few numbers of construction robot prototypes have opened up. The possibilities and capacities of these construction robotic systems in exceptionally unstructured and brutal conditions of construction sites have been illustrated. After some time, the possibilities of construction robotic systems have developed, permitting them to be conveyed in various and different applications [4]. Likewise, the retrofitting of common construction equipment with improved control and safety has made construction robots become ubiquitous and empowered the defeating of conventional construction system’s impediments.

This implies that construction robots are straightforwardly and by implication being used generally. The retrofitting of common construction plants and equipment with the robotic system has some way or another crossed over the technological gaps between economically advanced and backward counties. This implies that economically and technologically disadvantaged countries like Nigeria are by implication taking advantage of the efficiency, quality, and safety benefits of construction robots. Considering the exceptionally repetitive nature of construction activities, particularly in non-industrial nations where hardly any automation of construction activities is still low, the expanded motorization or wholesome adoption of the robotic and autonomous construction system in the delivery of construction projects can be extremely useful. Efficiency is of the essence to sustain productivity and economic growth. Technologically disadvantaged countries like Nigeria can put resources into research and development of construction robots and automation to supplement economic activities and achieve economic sufficiency rather than relying entirely upon natural resources. This approach makes economic sense since half of each country's total investment is allotted to the construction sector [4]. Accordingly, this study researches the status quo and future of construction robotic and autonomous construction systems in Nigeria. The particular goals cover the construction robotic and autonomous equipment being used in Nigeria, practice-driven difficulties confronting the utilization of construction robotic and autonomous equipment in use in Nigeria, and need-driven plausibility for the utilization of construction robotic and autonomous equipment in Nigeria.

Research into robotic and autonomous equipment has been in some way troublesome. A large portion of the investigations has been review-based. For instance, [5] evaluated past and current propensities for construction robotics and automation. [18] looked into the pointers for surveying the sustainability performance of utilizing construction automation and robotics for buildings. [**Error! Reference source not found.**] led an audit of robotics and automation in construction-related fields with the end goal of uncovering the area of the focal point of past investigations. [1] investigated state-of-the-art research into automated construction via autonomous mobile robots. [7] explored the advancement of both scholarly exploration and pragmatic use of automation and robotics based on literature and market audit. [16] explored different automation techniques that are presently utilized in many regions of the planet. [6] directed a bibliometric examination on the state of affairs of robotics in construction. These examinations have portrayed different utilization of construction robotics, demonstrated the capacity and productivity of robot systems in assorted fields, and laid out that conventional construction methodology has arrived at its cut-off points.

The reviews have uncovered that emphasis is put on construction automation, industrial robots and application, robots' systems and designs, robotics in earthworks, and robots' control and information system. Other data from the examinations incorporate (i) there is a low degree of spotlight on robotics in construction; (ii) with ceaseless exertion put into research and development, construction robotics may before long enter a development stage and experience reception for way bigger scopes; (iii) single-task construction robots, on-and-off site construction robots, and robotized construction sites are turning out to be considerably increasingly more urgent in robotic construction system; (iv) difficulties and future robotic requirements for the automated construction; (v) construction automation has many obstacles because of its quick development in all aspect; (vi) adoption of computerization procedures are sufficiently fundamental to hold the advancement of innovation with worldwide cutthroat climate; and (vii) the development patterns of scholarly exploration and robot application in construction sector entail concurrent advancement drove by similar party, advancement at a comparable speed with the different sides starting to lead the pack in various perspectives, scholastic examination giving essential advances to item improvement, and accessible advances in scholastic examination without any items found.

Various examinations have zeroed in on the advancement of robotics and autonomous. Kumar and Kumar (2018), for instance, broke down the effectiveness and handiness of robotization and mechanical technology in construction to further develop wellbeing and quality guidelines in construction utilizing automation. The investigation discovered that mechanized instruments are effective by lessening normal time consumed for significant exercises by 57.85% of the time taken, and decreasing expense brought about in systems administration cost by a normal of 51.67% in contrast with cost caused for execution by physical work. As far as quality performance, the study announced that the nature of the result is extraordinarily expanded and the cost brought about for rework and scrap is diminished by 66.76% by utilizing computerization. The plan interaction boundaries and contemplations pertinent to creating automated frameworks for building construction were introduced by [12]. As per the study, there are three procedures for incorporating modern advanced mechanics: prefabrication systems for off-site operations; mobile platforms for on-site operations; and embedded designs for adaptive integration onsite. Moreover, the study featured the difficulties relating to the design of those systems and propose recommendations that might uphold improved future designs and more extensive adoption of robotics in the construction industry. The study by [14] talked about the important data content to make a helpful information model for tunnel construction and mining equipment.

There have been various studies investigating the conceivable outcomes of utilizing construction automation and robots. The study by [18] consolidated literature review, industry survey, on-site contextual investigation, co-creation workshops, and potential pilot project to evaluate the current on-site construction operation and the existing bottlenecks that can be upgraded by implementing robotics and automation in Hong Kong. A scope of robotic applications that are tailor-made for the Hong Kong public housing industry is suggested and progressively sorted in the review. [8] contemplated that the shortage of building material resources, urbanization, aging workforce, enhanced connectivity and convergence, environmental reasons, and safety purposes will prod the utilization of robotics in construction. [3] featured that the utilization of construction robots will be impacted by the industry's significant degree of fragmentation, project planners' absence of integrating technology in planning, apprehension about the hazard and monetary misfortunes, and organizations' resistance.

In contrast to [3], [11] distinguished the elements influencing the utilization of construction robots to incorporate maturing and untalented workforce, absence of training, high capital speculation, low return on investment intensive capital and smother collaboration contracts, impervious to change, anxiety toward employment misfortune, robot-human interaction, low interest in innovative work, weak innovation and complex implementation, competitive and high risk, poor communication, low profits, and restricted utilization of digital modeling. [22] explored the difficulties of the implementation of construction robotics technologies in the Malaysian construction industry and the improvement method. The discoveries uncovered that significant costs to keep up with and update the advances will influence the utilization of construction robots. The best technique to further develop robotics implementation, as indicated by [22] is for the public authority to join forces with a robot innovation organization.

2. Materials and Methods

This research determines its legitimacy and objectivity from positivism philosophy. Therefore, the exploration depends on factual and objective information. A framework is available in Figure 1. The research framework assists with understanding robotic and autonomous construction systems. As displayed in the framework, there are three kinds of robotic and autonomous construction systems. These gatherings are recognized because of the degree of computerization of the robotic and autonomous construction equipment employed in each group. The primary gathering is distinguished as a Computer-aided construction system (CACS) - the equipment utilized in this system has partial automation, all-out mechanization, and remote control. The system is helpful for high-skill and heavy construction operations. The subsequent group is portrayed as a computer-integrated construction system (CICS) – in this system, the equipment has complete automation and can be depicted as construction robots. The system is appropriate for dangerous construction operations. The last group is alluded to as intelligent construction systems (ICS). Here cognitive construction robots, for example, BIM-integrated tools and distributed Artificial intelligence are utilized.

The research was targeted at construction organizations in Lagos State. However, because of the enormous size of the population, only organizations with construction sites where at least one construction plant was utilized were viewed as eligible for the study population. This was done as such to survey individuals from the population so the aftereffects of their study can be utilized to determine conclusions that will apply to the entire population. A total of 315 were affirmed to be utilizing at least one construction plant on construction sites. Endeavors were made to guarantee that a construction organization does not have more than one construction site in the sample size. In light of these measures, an aggregate of 163 construction sites was included in the sample size. The details of the construction organizations that were surveyed are introduced in Table 1. Ethics approval for the research was provided by the Obafemi Awolowo University Research Ethics Committee. The questionnaire utilized for the study caught applicable inquiries on the companies' profiles, utilization of robotic and autonomous construction systems, barriers, and facilitators of machine-aided construction systems. The mean score was utilized to dissect the information gathered. For the mean score analysis, the significance level of the scores was settled as follows: very low (1.00 – 1.80), low (1.81 – 2.60), medium (2.61 – 3.20), high (3.21 – 4.20), and very high (4.21 – 5.00).

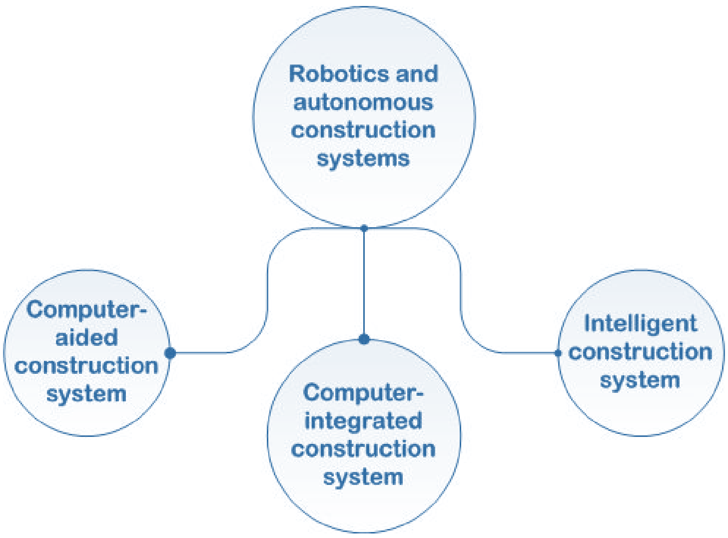

Figure 1. Research framework.

Table 1. Profile of construction organizations.

Scale of operation	
Local level	1.4%,
State level	21.4%,
Inter-state level	11.5%,
National level	64.1%,
International level	0.3%
Area of operation	
Building construction projects	47.9%,
Civil engineering projects	6.8%,
Building construction and Civil engineering projects	39.7%,
Industrial construction projects	1.4%,
Special construction projects	2.7%
Company age	
6-10 years	2.6
11-15 years	15.8
16-20	7.9
21 years & above	73.7
Company size	
<50 employees	2.7
50-100 employees	8.1
100-150 employees	21.6
>150 employees	67.6

3. Results

The research framework in Figure 1 provided insights into the various classes of robotic and autonomous equipment. As displayed in Figure 1, this equipment can be grouped as computer-aided construction systems, computer-integrated construction systems, and intelligent construction systems. Tables 2, 3, and 4 show the results of the mean score analysis performed on the reactions gathered from the respondents on a 5-points Likert scale. Table 2 uncovers that computer-aided construction systems, elevator systems (MS=3.401), unmanned aerial vehicles (MS =3.983), automated levels (MS=3.700), automatic laser receiver (3.677), automated batching plant (MS=3.793), and automatic sensor (MS=3.793) are the robotic and autonomous equipment with high-level of use. Autonomous dump trucks (MS=3.008), automatically guided vehicles (MS=2.600), and autonomous excavators (MS=3.178), are robotic and autonomous equipment relating to computer-aided construction systems that are having a medium degree of utilization. Computer-aided construction system (CACS) has the following equipment with a low level of utilization: automated 3D laser scanner (MS=2.188), automated road curbs making machine (MS =2.412), light detection and ranging (MS=2.057), and automated stone-cutting machine (MS=2.814). Others include automated sort-grading machines (MS=2.814), automated pipe construction machines (MS=2.938), barcoding technology (MS=2.212), and high-tech mechanical devices (MS =2.991). This equipment has partial automation and remote control as its robotic feature.

As shown in Table 3, only robotic total station (MS=2.014) and bar fixing robot (MS=2.086) have a low degree of utilization among the robotic and autonomous equipment that is classified as a computer-integrated construction system. Other equipment recorded an exceptionally low degree of utilization.

Regarding intelligent construction systems (ICS), Table 4 uncovered that BIM-based construction technology (MS=3.472), drone technology-based construction technique (MS=3.487), and mobile technology-based construction technique (MS=3.433) have an undeniable degree of utilization. None of the equipment has an extremely undeniable degree of utilization, only CACS and ICS have some equipment with an exceptionally significant degree of utilization.

Table 2. Computer-aided construction system (CACS).

CACS	Mean score
Automated cranes	3.225
Automated conveyor systems	3.016
Automated elevator systems	3.401
Autonomous dump trucks	3.008
Automatically guided vehicles(AGVs)	2.606
Automated 3D lasers canning	2.188
Automated road kerb making machine	2.412
Unmanned aerial vehicles (UAVs)	3.983
Light detection and ranging (LIDAR)	2.313
Automated construction sites e.g WAN	1.421
Automatic levels	3.700
Autonomous excavator	3.178
Automatic laser receiver	3.677
Automated batching plant	3.793
Automated rebar placing vehicles	2.057
Automatic sensor	3.793
Automatic slipform machines	1.066
Automated mortar-spreading and brick-laying machines	1.291
Automated stone-cutting machine	2.921
Automated sort-grading machines	2.814
Automated pipe construction machines	2.700
Automated concrete distribution machine	2.938
Push- Up	0.177
T-UP (totally mechanized construction system)	0.108
Automatic Up-Rising construction by Advanced technique (AMURAD)	0.160
Big canopy	0.100
Automated Building Construction System (ABCS)	0.134
Mast Climbing Construction System (MCCS)	0.181
Automated Weather-unaffected building construction system (AKWTSUKI 21)	0.119
Barcoding technology	2.212
Remotely controlled machines	1.990
Computer Assisted manoeuvring	2.007
High-tech mechanical devices	2.991
Tele-operated micro tunneling machines	1.070

CACS is the entry-level for RACS and ICS has portable and affordable equipment. The significant degree of utilization of some equipment in these classes recommends that profoundly perplexing projects are scarce in Nigeria and the technological backwardness of Nigeria is influencing the choice of the construction system in the country. Elective clarification could be that robotic and autonomous equipment is excessively intricate and strange. The vast majority of this equipment may not be engaging and practicable in a craft and labor-based construction sector as found in Nigeria.

Table 3. Computer integrated construction system (CICS).

CACS	Mean score
Automated cranes	3.225
Automated conveyor systems	3.016
Automated elevator systems	3.401
Autonomous dump trucks	3.008
Automatically guided vehicles(AGVs)	2.606
Automated 3D lasers canning	2.188
Automated road kerb making machine	2.412
Unmanned aerial vehicles (UAVs)	3.983
Light detection and ranging (LIDAR)	2.313
Automated construction sites e.g WAN	1.421
Automatic levels	3.700
Autonomous excavator	3.178
Automatic laser receiver	3.677
Automated batching plant	3.793
Automated rebar placing vehicles	2.057
Automatic sensor	3.793
Automatic slipform machines	1.066
Automated mortar-spreading and brick-laying machines	1.291
Automated stone-cutting machine	2.921
Automated sort-grading machines	2.814
Automated pipe construction machines	2.700
Automated concrete distribution machine	2.938
Push- Up	0.177
T-UP (totally mechanized construction system)	0.108
Automatic Up-Rising construction by Advanced technique (AMURAD)	0.160
Big canopy	0.100
Automated Building Construction System (ABCS)	0.134
Mast Climbing Construction System (MCCS)	0.181
Automated Weather-unaffected building construction system (AKWTSUKI 21)	0.119
Barcoding technology	2.212
Remotely controlled machines	1.990
Computer Assisted manoeuvring	2.007
High-tech mechanical devices	2.991
Tele-operated micro tunneling machines	1.070

Table 4. Intelligent construction systems (ICS).

ICS	Mean score
Distributed artificial intelligence-controlled robots	0.200
BIM-based construction technology	3.472
Digital fabrication	0.750
3D-printing technology	0.500
Drone technology-based construction techniques	3.487
Mobile technology-based construction techniques	3.433
Construction apps	2.910
Global positioning system (GPS) based construction technology	2.774
Smart sensors and sensing technology-based construction techniques	2.889
Virtual and Augmented Reality-based construction technology	3.009

This study looked to additionally examine the obstructions to the utilization of RACS. Thirty Likert items on a 5-point scale were utilized to quantify the variables comprising a hindrance to the utilization of RACS. The scale went from 'less significant to most significant with a weight value of 1 – 5 respectively. Every one of the things was evaluated as having a high impact barrier to the utilization of RACS. To decide the main barriers, the mid-point of the scope of the high mean score (3.21-4.20) was assessed. This gives a mean score of 3.70. Factors with a mean score of 3.70 or more were thought of as exceptionally huge. Given this basis, nine items were distinguished as exceptionally critical barriers to the utilization of RACS. These include the effect on wages and job availability (MS =3.805), unique nature of the construction work process (MS =3.806), unstructured construction methods (MS =3.750), new training for workers (MS =3.771), low technology literacy (MS =4.000), difficulty in acquiring automated equipment (MS =3.709), low profitability and capitalization (MS =3.771), conservative project design (MS =3.709), and diverse structure and shape of building elements (MS =3.968).

Table 5. Barriers to the use of robotic and autonomous equipment.

	Mean score
Inaccurate geometrics of construction	3.378
Level of the accuracy of construction tasks	3.675
Changing environments and routines in construction	3.621
High cost of machines and automated equipment	3.588
Environmental and social aspects of automated construction processes	3.615
Effect on wages and job availability	3.805
Fragmentation of construction process	3.580
Lack of adaption of machines	3.594
Dynamics of construction operations	3.413
Structure of the construction industry	3.535
Unique nature of construction work processes	3.806
Culture and workplace requirements	3.666
High investment required	3.645
Unstructured construction methods	3.750

Rate of advancement in technologies	3.685
Diverse nature of construction projects	3.551
Weather impact	3.388
The complex operation of machines	3.647
Negative attitude	3.545
New training for workers	3.771
Low technology literacy	4.000
Difficulty in acquiring automated equipment	3.709
Politics and regulations	3.500
Diverse interests of stakeholders	3.642
Low profitability and capitalization	3.777
Conservative project design	3.709
Lack of standardization	3.617
Non-readiness of automated equipment	3.515
Lack of information on automated equipment	3.600
Diverse structure and shape of building elements	3.968

Following a similar cycle in Section 4.2, the outcomes in Table 6 show that the main facilitators of the utilization of RACS include: improve safety and work quality (MS=3.950), higher output & increased productivity (MS=3.885), less variability (MS=3.828), decreased human errors (MS=3.888), greater control and consistency (MS=3.857), safe working environment (MS=4.000), flexibility in work (MS=3.815), and economical use of resources (MS=3.918). Others are improved manpower (MS=3.805), improved efficiency (MS=4.054), increased safety and health of workers (MS=3.833), decrease in cost (MS=3.750), greater control over the productive process (MS=4.000), risk reduction (MS=3.764), and decrease in design time (MS=3.969). From this outcome, it very well may be seen that the utilization of RACS is for the most part because of work productivity.

Table 6. Facilitators to the use of robotic and autonomous equipment.

	Mean score
Optimize equipment operation	3.575
Improve safety and work quality	3.950
Reduced labor dependability	3.500
Higher output and increased productivity	3.885
Less variability	3.828
Reduced human errors	3.888
Greater control and consistency	3.857
Safe working environment	4.000
Flexibility in work	3.815
Economical use of resources	3.918
Reduction in waste	3.435
Reduction in working time	3.641
Improved manpower	3.805
Improved efficiency	4.054

Increased safety and health of workers	3.833
Reduction in cost	3.750
The declining number of skilled construction workers	3.421
Time and cost pressures	3.605
Greater control over the productive process	4.000
Increased competitiveness	3.636
Risk reduction	3.764
Elimination of arduous and repetitive tasks	3.684
Reduction in design time	3.969

4. Discussion

The findings on partial automation and remote control suggest that this equipment could be affordable, available, and simple to utilize. The undeniable degree of utilization of some of them was found in this study. Additionally, the equipment with a significant degree of utilization is generally utilized for heavy construction. Heavy construction is capital-intensive and exceptionally hazardous. [6, 16] have maintained that robotic and autonomous equipment are productive in the perilous workplace, this contention suffices for the high utilization of robotic and autonomous equipment for heavy construction in Nigeria. Additionally, the fact that contractors engaging in heavy construction in Nigeria are mostly multinational firms, the high profit they derive from the projects, or the high cost of the projects could be the explanation why they had the option to utilize this equipment. This suggests that the Nigerian construction industry is not yet technologically advanced to the degree of utilizing equipment with absolute robotization for construction activities. The issue could be because of the inaccessibility of this equipment in the nation or the absence of need for them because of the level of risks and danger intrinsic in the sorts of projects that are prevalent in Nigeria. The results in Table 3 further uncovered that construction surveying and steelwork are the two areas where computer-integrated construction systems have been thought of.

This illuminates that the level of advancement in these two areas or the nature of surveying and steelwork support the utilization of the system. BIM technologies are parametric and provide intelligent construction systems. Most BIM tools empower intelligent decision-making and planning through their decision-support features. Mobile and drone technologies are some way or another like BIM. They all support digitalization. According to [9], mobile technologies, wireless sensors, and BIM tools have made robotic and autonomous construction systems implementable and past trial and error. This implies that this approach is compelling and has prompted the infiltration of RACS into both technically advantaged and disadvantaged countries. The main test is that BIM, drone, and mobile technologies are portable equipment that might be closing this technological gap between technologically advantaged and disadvantaged countries. However, the economic power and technological capability to utilize non-portable equipment separate them. The equipment in intelligent construction systems with a medium degree of utilization (construction apps, GPS-based construction technology, smart sensors, and virtual and augmented-based construction technology) support the clarification that only the utilization of portable equipment addresses the type of intelligent construction adopted in Nigeria.

This result suggests that the construction system in Nigeria is still labor-oriented; where the work process is unstructured and intended to be labor-based and conservative. In most building designs in Nigeria, the shape of building elements is inflexible and not inventive. This kind of design will not uphold the utilization of 3D-printing equipment and digital fabrication. The discoveries uncovered that training on the utilization of RACS is expected before the utilization of robotic and autonomous equipment can be widespread. This illuminates that the accessible reference booklet and educational program are old and non-receptive to the interest and progress in the construction sector. From the result, it appears to be that the construction sector is as yet seen as a mass employment industry where a large number of non-skilled and semi-skilled laborers are locked in. The construction sector will at any point stay a mass employer; however, the role that the sector plays in the technological and economic development of a nation is turning out to be more fundamental than its conventional role as a mass employment provider. This implies that the work process, project design, & construction system should embrace the innovation and technology that are emerging in the sector. The necessary ranges of abilities and capabilities anticipated by construction workers and professionals have transformed from craft and labor-based skills. Training, development, and recruitment in the industry should mirror this reality. This outcome goes against those of [22] in Malaysia and [11] in the UK. [22] revealed the significant cost to maintain and update construction robotics technologies as the main obstruction, while [11] distinguished the aging workforce and poor communication as the absolute most critical. As found in this study, the hindrances to the utilization of construction robotics technologies focus on job availability, conservative work process & project design, and training.

RACS shows up as a more prudent and productive construction system. The inferred advantages like productive process, improved manpower, reduction in time and cost, and improved safety are because robotic and autonomous equipment can perform tasks quicker, precisely, and effectively. Likewise, robotic and autonomous equipment have diverse applications [4]. With these advantages, as facilitators of their utilization, it is justifiable why [**Error! Reference source not found.**,7,6,18] believed that construction robotics will soon encounter adoption on a larger scale. In Hong Kong, [18], inferred that fostering a tauter-made construction robot will guarantee an enormous adoption in Hong Kong. Learning about the work usefulness advantages of construction in different nations or writing may not do the trick for the enormous adoption of construction robots in a developing country. Only firms with the financial means to experiment with the utilization of construction robots might have the right data regarding the real advantages of construction robots. Additionally, because of contrasts in territory and settings, what comprises work usefulness might vary across nations. But if construction robots are customized and developed locally, they will enjoy a large-scale adoption and would contribute to the technological and economic progress of the country. [4] noticed that local development and manufacturing of construction robots make economic sense because of the tremendous investment countries usually make in infrastructural development. The explanation given as facilitators of the utilization of RACS via [8] is not equivalent to those found in this current study.

This study has brought to the fore, the need to refresh the education and training curriculum for construction professionals. There is a requirement for upgrading skills and knowledge about automation technologies. This is a significant approach to guaranteeing the acknowledgment of RACS in the Nigerian construction sector and the availability of experts that could plan and oversee RACS- based projects. The large-scale adoption of RACS is vigorously subject to interests in robotic and automation R & D. Researchers in the construction industry require a colossal asset to expand on their digital capability and understanding. The construction industry in Nigeria cannot develop by importing robots and autonomous machines from other industries and countries. What will help the country and its construction sector is the local development and manufacture of construction and Nigerian-explicit robots. Through this approach robotics and autonomous equipment will be reasonable, accessible, and simple to utilize. Additionally, the accessibility of native robotic and autonomous construction equipment will take care of the local problems in the Nigerian construction industry. This model has been effective in the food processing industry where local problems associated with the preparation of 'pounded yam' have been addressed with autonomous 'pounded yam machines'. This study is proposing the development of portable construction robotic and autonomous equipment. This equipment will be economical, compatible with existing practices and current construction operations, and function like a tool.

Evidence in this study on the utilization of intelligent construction systems has shown that portable intelligent technologies are helpful and appealing in the Nigerian setting. This opportunity must be built on by automating the most laborious, hazardous, non-value-adding, and dreary activities through excavation, fabrication, rebar flying, assembly, and maintenance will incredibly profit from human-assisted or portable robotic and autonomous equipment. Quality work is not guaranteed with the continued utilization of a labor-based construction system where the merits are mass employment and exceptionally low wages. These cannot bring the expected productivity, project success, and economic development. The dread that RACS will prompt joblessness, particularly in labor-intensive construction industries like Nigeria might be used as an excuse by small-size firms not to put resources into construction robots. Be that as it may, the gains derivable from the labor-based construction system are for the present moment. Even the employment it provides for non-skilled and semi-skilled labor is not sustainable. With training and re-training, labor will get employed in RACS and the firm will grow financially and capacity-wise. RACS cannot eliminate the use of humans for construction activities. This is because humans are still much needed in information-intensive activities. Robotic and autonomous equipment is preferable in labor-intensive activities dissimilar to information-intensive activities, labor-intensive do not require judgment, sensing, and versatility that humans provide.

5. Conclusions

The fundamental objective of this study was to explore the status and eventual fate of robotic and autonomous construction systems in Nigeria. This investigation has discovered that the robotics and autonomous equipment that are exceptionally utilized in Nigeria are those with incomplete computerization and controller. This portrays an aberrant utilization of RACS where common construction plants retrofitted with robotics features are utilized. The most recent model of the construction plant is retrofitted with robotic features. The study has likewise given proof of the utilization of parametric BIM technologies, drone technologies, and mobile technologies. The evidence supports the utilization of RACS (mostly portable equipment) in terms of intelligent construction systems. An implication of this is the possibility of large-scale adoption of RACS in Nigeria through the local development of portable robotic equipment. This versatile robotic equipment presents an immense chance to resolve local problems, advance Nigerian-specific construction systems, foster the economy, and add to the technological advancement of the country. The discoveries of this examination achieve the end that the greatest obstruction to the use of RACS is the assumption that the construction sector is a mass employer of labor. The nature and culture of activities in the sector have been restricted to labor-based construction systems inferable from this assumption. Accordingly, those that are utilizing RACS primarily embrace it for work efficiency.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Aghimien, Douglas Omoregie, Clinton Ohis Aigbavboa, Ayodeji Emmanuel Oke, and Wellington Didibhuku Thwala. "Mapping out research focus for robotics and automation research in construction-related studies: A bibliometric approach." *Journal of Engineering, Design and Technology* 18, no. 5 (2019): 1063-1079.
2. Ardiny, Hadi, Stefan Witwicki, and Francesco Mondada. "Construction automation with autonomous mobile robots: A review." In *2015 3rd RSI International Conference on Robotics and Mechatronics (ICROM)*, pp. 418-424. IEEE, 2015.
3. Bailey, Diane E., and Stephen R. Barley. "Beyond design and use: How scholars should study intelligent technologies." *Information and Organization* 30, no. 2 (2020): 100286.
4. BAKIR, AMMAR, and ISSA BALCHI. "Development and Implementation of Robotics in Construction A Case Study of a Contractor Firm." Master's thesis, 2018.
5. Bock, Thomas. "The future of construction automation: Technological disruption and the upcoming ubiquity of robotics." *Automation in construction* 59 (2015): 113-121.

6. Bock, Thomas. "Construction robotics." *Journal of robotics and mechatronics* 28, no. 2 (2016): 116-122.
7. Boulos, Timothy, Farid Sartipi, and Khoshaba Khoshaba. "Bibliometric analysis on the status quo of robotics in construction." *Journal of Construction Materials* 1 (2020): 2-3.
8. Cai, Shiyao, Zhiliang Ma, Miroslaw J. Skibniewski, and Song Bao. "Construction automation and robotics for high-rise buildings over the past decades: A comprehensive review." *Advanced Engineering Informatics* 42 (2019): 100989.
9. Carra, Guglielmo, Alfredo Argiolas, Alessandro Bellissima, Marta Niccolini, and Matteo Ragaglia. "Robotics in the construction industry: state of the art and future opportunities." In *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, vol. 35, pp. 1-8. IAARC Publications, 2018.
10. Chen, Xichen, Alice Yan Chang-Richards, Antony Pelosi, Yaodong Jia, Xuesong Shen, Mohsin K. Siddiqui, and Nan Yang. "Implementation of technologies in the construction industry: a systematic review." *Engineering, Construction and Architectural Management* (2021).
11. de Soto, Borja Garcia, and Miroslaw J. Skibniewski. "Future of robotics and automation in construction." In *Construction 4.0*, pp. 289-306. Routledge, 2020.
12. Delgado, Juan Manuel Davila, Lukumon Oyedele, Anuoluwapo Ajayi, Lukman Akanbi, Olugbenga Akinade, Muhammad Bilal, and Hakeem Owolabi. "Robotics and automated systems in construction: Understanding industry-specific challenges for adoption." *Journal of Building Engineering* 26 (2019): 100868.
13. Dritsas, Stylianos, and Gim Song Soh. "Building robotics design for construction." *Construction Robotics* 3, no. 1 (2019): 1-10.
14. Ghosh, Arka, D. J. Edwards, and Mohammad Hosseini. "Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry." *Engineering, Construction and Architectural Management* (2020): 1-25.
15. Jalas, P., V. Isoherranen, R. Heikkilä, T. Makkonen, J. Nevalainen, and S. J. Fraser. "Information Modeling of an Underground Laboratory for the R&D of mining automation and tunnel construction robotics." In *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, vol. 35, pp. 1-5. IAARC Publications, 2018.
16. Kumar, N. Vimal, and C. Selva Kumar. "Development of collision free path planning algorithm for warehouse mobile robot." *Procedia computer science* 133 (2018): 456-463.
17. Mahima, KT Yasas, Mohamed Ayoob, and Guhanathan Poravi. "Adversarial Attacks and Defense Technologies on Autonomous Vehicles: A Review." *Appl. Comput. Syst.* 26, no. 2 (2021): 96-106.
18. Newman, Chris, David Edwards, Igor Martek, Joseph Lai, Wellington Didibhuku Thwala, and Iain Rillie. "Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study." *Smart and Sustainable Built Environment* 10, no. 4 (2020): 557-580.
19. Pan, Mi, Thomas Linner, Wei Pan, Huimin Cheng, and Thomas Bock. "A framework of indicators for assessing construction automation and robotics in the sustainability context." *Journal of Cleaner Production* 182 (2018): 82-95.
20. Bahrami, Mohammad Reza. "A novel design of an electrical transmission line inspection machine." In *Advances in Mechanical Engineering*, pp. 67-73. Springer, Cham, 2016.

21. Skibniewski, Mirosław J., and Edmundas K. Zavadskas. "Technology development in construction: a continuum from distant past into the future." *Journal of Civil Engineering and Management* 19, no. 1 (2013): 136-147.
22. Van de Gevel, Ad JW, and Charles N. Noussair. "The nexus between artificial intelligence and economics." In *The Nexus between Artificial Intelligence and Economics*, pp. 1-110. Springer, Berlin, Heidelberg, 2013.
23. Yahya, Mohd Yamani Bin, Yin Lee Hui, Azlina Binti Md Yassin, Roshartini Omar, Rolyselra Orbintang anak Robin, and Narimah Kasim. "The challenges of the implementation of construction robotics technologies in the construction." In *MATEC Web of Conferences*, vol. 266, p. 05012. EDP Sciences, 2019.