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ADOPTION OF INDUSTRY 4.0 TOOLS IN ACHIEVING CONSTRUCTION 4.0 FOR SUSTAINABLE INFRASTRUCTURE DEVELOPMENT

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Abstract

Construction 4.0 has been enabled through the introduction of Industry 4.0and its tools. The rate of adoption of the Construction 4.0, however, to create a good ecological landscape has been rapid which needs enhancement for achieving sustainable infrastructure. This study therefore aims at presenting an integral approach to creating a pathway-model for technological innovation, industrial and sustainable infrastructural development using Lean thinking, Industry 4.0 technologies and sustainability concepts. The main objective of the study is to study the issues around the adoption of industry 4.0 to achieve Construction 4.0 for achieving sustainable infrastructure. The study articulated the following objective parameters to carry out the survey, such as (i) Industry 4.0 application drivers in the construction industry in achieving sustainable infrastructural development, (ii) prospect of Construction 4.0 in achieving industrial development of Industry 4.0,(iii) factors influencing the adoption of Industry 4.0 for technological development, (iv) future of Construction 4.0 in construction industry in infrastructural development and (v) socioeconomic implications of Industry 4.0 tools adoption.A total of 150 samples was used for the study from a population frame of 250 construction. The sample frame of 250 construction companies that are medium and large scale in the category we used as the sample frame for the study. The following statistical tools of SPSS 25 were used to process the data: Mean index, Kruska-wallis,ANOVA, Pearson ranking, Cronbach Alpha and Chi square. The study recommends the following:However, adoption of the Construction 4.0, there are numerous parameters that influence the adoption of industry 4.0 for technological development,which need to be considered to achieve sustainable infrastructural development. For instance, there is a need for attitudinal change, cultural orientation,economic development, and technological innovation. There is a future for success in the application of Construction 4.0 in creating a robust infrastructural economy which is sustainable.

Key Word: Industry 4.0, Construction 4.0, Circular economy, Sustainability, Infrastructure, Adoption

1.1 Introduction

Sustainable industrialization is one of the desirable development envisages in the fourth industrial revolution (Industry 4.0) in construction industry. Construction industry allover the world has witnessed a new dimension of development that has encouraged investment activities in the sector. The importance of construction industry can not be overemphasized in terms of delivery and performance, this should account for industrialization and infrastructural development being painted as one of SDG goals of United Nations, which formed part of the focus of this study which is the sustainable industrialization of SDG goal 9. In the construction field in recent times, the output is driven by innovations, which account for many breakthroughs in digital technology finding applications in the construction field. The current dispensation of industrial revolution has witnessed industry 2.0, 3.0, and 4.0, which birthed digital innovations in the construction field. Digital innovation is necessary as an intervention in lieu of the growing need for accommodation, alternative energy, and improved efficiency. There is a need for a paradigm shift in the construction industry in the wake of the digitization era. The reality has manifested in the fact that to command new results,old ways of doing things in the industry must be changed, therefore, the industry embraced industrial revolution 4.0 intervention in the industry.

The industry 4.0 revolution has brought about changes in process, technology, and output. The advent of industry 4.0 has led to the automation of keys important in the process and technology of construction and manufacturing, which culminates in Construction 4.0. However,the rate of assimilation and acceptance of technology adoption in the industry is perceived to be militating against the rapid response of to the adoption of the technology of change which need to be investigated and profiled. Most of the industrialized countries like Germany, United States of America, France,Belgium, Soviet Union, Japan,China, and Korea, among others, got to their current state of industrialization and construction excellence through growing along the hierarchy of all industrialization advent that has led to enhanced construction deliveries. Similarly, Chun et al., (2012), Alaloui et al., (2018), and Artherinis (2018) posited that industry 4.0 contributes to all facets of production and manufacturing by industrialization adventure.

Industry 4.0 has the potential of enhancing industrial and infrastructural development, infrastructural and industrial development, the changes brought about through the use of industry 4.0 tools were the main architect of construction 4.0, therefore construction 4.0 entails the use of process technology and and product of industry 4.0 tools. Construction industry according to Bigrentz (2021) has witnessed a tremendous change from the primitive use of construction tools to the early nineteen century when locomotive engines and machine that uses fossil fuel were discovered. The design and automation of building products has thus witnessed a transformation from manual and analogue to digital application, which birthed the concept of construction 4.0. Therefore, construction 4.0could be discussed as the era in construction where the digital application determines the results obtainable. The aim of the adoption of construction 4.0 is to create a sustainable environment for industrial development,sustainable infrastructure to fulfil SDG goal 9. In Chun et al., (2022), sustainable infrastructural development refers to a development that meets the infrastructural needs of the citizen in a way that the capacity to discharge their civil responsibilities is enhanced elaborately. Infrastructural development is regarded as one of the pillars of economic development. Therefore, research have been going on about ways to harness resources towards further infrastructural development, which is one of the focus of United Nations Strategic Goal 9.

To this end, this study focused on the mechanism of infrastructural development which is industry 4.0. Industry 4.0 has brought about the adventure of Construction 4.0 which enables advance tools to be engaged in construction work to lead to more productivity in infrastructural development. This study attempted to survey the factors that influence the adoption of Industry 4.0 tools and technology in order to achieve Construction 4.0 for industrial and technological change. The study therefore articulated the following objective parameters to carry out the survey, such as (i) Industry 4.0 application drivers in the construction industry,(ii) prospect of Construction 4.0 in achieving industrial development,(iii) factors influencing the adoption of Industry 4.0 for technological development, (iv) future of Construction 4.0 in construction industry in developing countries and (v) socioeconomic implications of Industry 4.0 tools adoption.

1.2 Literature Overview of Relevant Concepts

Construction 4.0 and Industry 4.0 (I 4.0) adoption in Construction in Developing Countries

The concept of construction 4.0 has been widely adopted in most of the developing countries of the world, some of the construction 4.0 technologies are now being rapidly diffused into the countries of the world through the host communities. For instance, the construction companies in Asia and Europe engage their technologies in the countries of the world where their projects are located. Some of the construction companies from France such as Boughes, Strabag, and the like engaged their technologies in road construction and sky scrapper construction, among others. These countries engage automation in the design process, costing,and management of the construction process. Similarly, companies from European countries ;like Germany have massively introduced construction 4.0 technology to the construction landscape in developing countries, for instance, Julius Berger, Sterling Construction, and others of international construction companies have introduced the concept of automation in mass production of construction products and materials, there have been contributions in the field of Artificial intelligence, Robotics, Virtual reality, System Augmentation to advance soft and hard wares. In all cases, industry 4.0 tool were believed to be the innovation carrier, it was the adoption of the tools that gave rise to the concept of construction 4.0. Construction 4.0 entails the practical applicability of the concept of industry 4.0 tools to bring results and enhance productivity in construction industry. In Chung, Heng and Skitmore (2012), construction 4.0 was described as a major game changer in industry production, and manufacturing. In construction 4.0, the major applications are automation.In design, there have been machines aided with sensor-based applications being engaged in the design and conversion of client needs or specifics into iconic features. The sensor-based applications can then changes the paradigm from manual to automatic application. Similarly, Dallasega (2018), Alison et al., (2015), and Ghada (2018)agreed that construction 4.0 entails physical-digital interaction to improve the process, technology and product inter-phase of industrial production and management. Moreover, construction 4.0 has been widely adopted in developed nations of the world on account of its good attributes, for instance, Garcia et al., (2019) presented the implication of construction 4.0 to be chiefly for enhanced workforce,organization system and better productivity. The study further submitted that the major implication have been enhanced construction productivity, thus, Garcia et al., (2019) was corroborated by Farmer (2016), Dubois and Gaddae (2022) and Gerbert et al., (2017) which posited on the observed changes in peoples, mindset disposition in the use of industry 4.0 tools. However, the spread of construction 4.0 in developing countries is gradually gaining momentum chiefly on account of the digitization gap and other allied factors. For instance,in Ghada (2022), it was alluded that factors such as political factors, social factors, technological factors, environmental factors, and legal and economic factors are some of the ones influencing the construction 4.0 applications in the construction industry. However, in the context of this study, an attempt was made at situating the factors that influence the adoption of industry 4.0 tools in achieving construction 4.0 development. Right from the outset of the development of industry 4.0 in Germany,the rate of adoption has been slow in the developed countries as alluded in Ghada (2022), Alaloui (2018) and Alisson (2015) that the rate of adoption in the western countries takes a geometric increase pattern while little or no in some developing countries.

1.2.2 Industry 4.0 Tools application in Construction Industry for Sustainable infrastructure

Industry 4.0 tools have found many applications in the construction industry. The past 10 years has been interesting year as far as the industrial application of industry 4.0 tools is concerned. In construction parlance, it was viewed as a major game changer of basic applications.considering various antecedents in the application of equipment and tools in construction work which are done predominantly through mechanical means. Adventure of industry 4.0 in the construction industry has enhanced output throughout the life cycle of construction projects. The inclusion of basic technology in the construction field can not be overemphasized. There have been basic improvements in terms of automation of basic functions and activities in the construction process such as design, costing,planning, actual construction work, monitoring and control, training and development,health and safety,production management,security,drone technology, internet of things, data analytic, software manufacturing, 3 D printing and animation, automated marketing system,post occupancy evaluation among others. There have been companies in the developed world of Europe,Asia, America, and others that are the forerunner of industry 4.0 applications, for instance, Germany originated industry 4.0 and has since been on the leading edge. In recent times,there has been an emergence of cutting edge technologies that cut across the area earlier mentioned, for instance,in the design and manufacturing of construction product components and parts. Some of the industry 4.0 tools that have found their application in the construction field include: Front-end engineering tools, Back-end development technology, Visual design technology,Website development, Mobile application for construction works, Artificial intelligence, Site cyber-security system, Data management, digital marketing, Industry 4.0, Cinematography and Picture encoding. In a contemporary construction sites in developing nations like Nigeria,Ghana, Cameroun, and South Africa,a certain operation that begins from planning, procurement,tendering, and constructionhas witnessed tremendous success while the procurement system has gone digital on several projects allover the world. Moreover, digital marketing has replaced the freelancing methods being widely practiced in pre-industry 4.0 era. Specialists now adopt content sorting in content classification prior to advertisement of construction products. Similarly, monetization technology, scope-wrighting, prosing, and story telling are now introduced as cutting edge industry 4.0 technologies in contemporary times. Construction industry has witnessed the introduction of visual design development technology with emerging areas of specialization and expertise in visual UI/UX, Photoshoping, illustrator, Adobe XD, Corel draw,design and innovation thinking among others. This has led to more emerging areas of new technology in the construction industry with an attendant positive effects on productivity enhancement.

In the aspect of design,the old method of calligraphy has been replaced with a more versatile design systems that led to the modern web development with the aid of Internet of things approach. New technology has come upon account of the development, such as front-end development,visual graphics,mobile application, invention and development, word press, CMS, domain hosting and design, among others, and have since become a game changer in the construction industry. In construction work, there are many applications and tools that address the issue of concern in design, material, and technology, this has led to the emergence of the adoption of industry 4.0 tools such as Javascript, Python, Android studio, React AND Python-Django among others.

1.2.3 Achieving Construction 4.0 for Sustainable infrastructure using Industry 4.0 Applications and Circular economy.

Attaining sustainable infrastructural development with the aid of Construction 4.0 has been a major concern of construction stakeholders and innovative champions in recent industrial revolution times,on account of its positive contributions to the construction industry at large,and this has in a way validated the assumption of the relevance of circular economic initiative. In circular economy,as presented in Amusan, Aigbavboa, Fayomi and Owolabi (2020), Anderson (2006), and Lieder and Rashid (2016),the circular economy presents the input of resources with an intermediate links of the process system to product output in the form of consumer or customer products over time. The process component keeps evolving in terms of change initiative, which led to the evolution of industry 4.0 initiatives. The circular economy thus operates a loop economy, which culminates in waste elimination and effective resource scheduling and sequencing of resource allocation and distribution. Geissoerfer, Savage, Boken, and Hultink (2016) in Amusan et al., (2020) submitted that in a circular economy,the process of change is a necessity for the inclusion of an interdisciplinary dimensions in terms of collaboration of resources or pooling together of resources to enable an affective diffusion of technology into the system. Therefore, to achieve circular economic initiative,industry 4.0 tools are very essential. Circular economy has enabled the introduction of automation to achieve the task of resource allocation and automation rides on the wing of industry 4.0. In the context of this study, certain industry 4.0 tools have been effectively engaged to the end of enhancing productivity and worker performance. The tool follow the path of open innovation that enables openness in innovation to be adopted. In Amusan et al., (2020) open innovation was described as a vehicle of change and knowledge diffusion with innovation diffusion mechanism,this follows the submissions in Anderson (2006), Su et al., (2013), Lieder & Rashid (2016), European Commission (2015) and Geissdoerfet at al ., (2015). The following industry 4.0 tools therefore have been of great help in achieving construction 4.0in industry 4.0 era include: automation in design and supply chain performance in Fatorachian and Kazemi (2020) the key enablers include cloud computing,Internet of things (IoT) which could help to achieve the deployment of industry 4.0 such as Figma, SQL, DMS, Java programming,Branding, Visual graphics, Android studio among others. Similarly,issues around construction 4.0 design could be achieved through the adoption of Visual Design Tools such as Design thinking, Software and application, Visual UX/UX, Illustrator, Photoshop, Figma, Adobe, Corel Draw and Others.

However, there are technologies that could assist in enabling industry 4.0, such as augmented reality.virtual reality,robot technology, 3 D printing, Artificial intelligence, Internet of things, Drones, among others. According to Mahmoud Christian, HaraldHala (2021), the key drivers of enhancement of construction 4.0 through industry 4.0 include Virtual Reality, System Augmentation, 3 D Printing, and Robotics. Augmented reality of industry 4.0 could be adopted in construction work to simulate the effect of real time monitoring. It has been used effectively in minimizing design and error in construction design and management. Virtual reality could be used to reinforce health and safety contravention on site.It reinforces in the mind of construction workers by simulating what should be the real effect of breaking a particular health and safety protocol. 3D printing can provide more accurate photocopying or printing of projected documents in an automatic way considering the effect of 3D printing quality over 1D and 2D printing. Moreover, robot have the tendency of complimenting human effort on site, however, robotic application has been successfully engaged in USA, USSR,Germany, Asia, and Korean and other advanced countries. The submission above is aligned with the research submissions in Chen,Lai and Lin (2020),Chen, Chen, Cheng,Wang and Gan (2018), Calderon-Hernandez and Brioso (2018), the studies agreed to the fact that in achieving construction 4.0 through the lens of the focus of circular economy and industry 4.0. Augmented reality could be used to achieve maintenance and inspection of projects, adoption of big data,work orders of maintenance work, using big data to achieve project life cycle,application of robots in construction enterprise and supply chain management of human resources and materials, this facts was further corroborated in Anderson (2006), Su et al., (2013), Lieder & Rashid (2016), European Commission (2015) and Geissdoerfet at al ., (2015).

3.1 Material and Methods

In this study, a qualitative research method was used. A total of 150 samples was used for the study from population frame of 250 construction

3.2 Population frame: The sample frame of 250 construction companies that are medium and large scale in the category we used as the sample frame for the study.

3.3 Research Sampling: The sample constitute construction professionals that are 150 in number. The 150 questionnaire was administered to respondents.

3.1 Results and Discussion

3.2 Bio-data Information about the Respondents

Table 1 Biodata of respondents' gender

Particular	Frequency	Percentage (%)
1. Respondents Gender **Male**	90	64.29
Female	60	35.71
Total	150	100
2. **Respondents Profession**		

Architect	30	21.43
Builder	50	28.57
Quantity Surveyor	35	25.00
Engineer	35	25.00
Total	150	100
3. **Respondents Qualification**		
W.A.S.C.E	10	7.14
O.N.D	30	21.43
B.SC	70	42.86
M.SC	30	21.43
Others	10	7.14
Total	150	100
4. **Respondents Work Experience**		
1-5 years	20	14.29
6-10 years	80	57.14
Above 10 years	50	28.57
Total	150	100
5. **Project Type Involvement**		
Residential	60	35.71
Office	30	21.43
Industrial	30	21.43
Civil	20	14.29
Institutional	10	7.14
Total	150	100

Source: Field Survey (2021)

Biodata information of the respondents which include gender composition, profession, academic qualification, work experience, and project type,was presented in Table 1, analysis of the gender inclusion among the respondents revealed that respondents' gender composition was 70% male and 30% female, based on **Table 1a.** This indicates that females compete favorably with men on construction sites. There are now more women interested in site construction work,which is a good indicator of good things happening in the construction industry. In Alaloul, Liew, Zawawi and Kennedy (2020) and Allison (2015) submitted that the construction industry is experiencing tremendous change in recent times on account of industry 4.0 tools introduction to the sector. There are a lot of off site applications that enable remote real time monitoring of the site as illustrated in Allison (2015),which has made it possible for women to fit into the site monitoring and reporting tasks. **Table 1b** presents the respondents' profession composition which included Architect, 21.43%; Builder, 28.57%; Quantity Surveyor, 25% and Engineer, 25%. This indicates a good spread of respondents , and this represent good composition of experienced professionals. Respondent Qualifications of the respondents presented in **Table 1c** include the first school leaving certificate referred to as West African School certificate (W.A.S.C.E), 7.14% of respondents belong to this category,21.43% of respondents also had Diploma certificate refereed to as ordinary national diploma certificate (O.N.D) which constitute 21.43% of all respondents, 21.43% has graduate degree that is Bachelor of science degree in engineering and technology based vocation (B.Sc), 21.43% has master degree, Master of Science (M.Sc) while 14.29% has other degree such as vocational certificate. Similarly, the work experience of the respondents was presented in **Table 1d**, 14.29% of respondents had 1-5yrs work experience, 57.14% of respondents had 6-10 years work experience while 28.57% had work experience of above 10 years. Moreover, respondents involvement in project participation was studied, for instance, the involvement of respondents in the survey indicated that 28.57% of respondents were involved in residential building projects, 14.29% in Office projects, 21.43% in Industrial projects, 14.29% in Civil engineering projects while 21.43% were involved in Institutional projects (Allaloui 2018, Allison 2015, Ghada 2021, and Pascal 2019).

Table 2 Operationalization of Research Variables

Variable Label	Description of Objectives	Scale	Analytical Tools	Citation, supporting text
Q1-5:Biodata information of Respondents	Description of respondents' work experience, age, gender, Professional grade	Ordinal, Scale,Interval	Simple percentage,Frequency,Pearson ranking,CronbachAlpha.	Woolley et al., (2020); Pealoza et al.,(2020); Rowlinson, (2004); Stiles et al., (2012);
Q6-12:Industry 4.0 application drivers in the construction industry	(i) To study industry4.0 application drivers in the construction industry	Numeric,Nominal,Scale	Relative mean index,Chi square,ANOVA,Pearson ranking	Dallasega, Rauch and Linde (2018), García de Soto, Agustí-Juan, Joss and Hunhevicz (2019)
Q13-19:Prospect of construction 4.0 in achieving industrial development	(ii) To examine prospect of construction 4.0 in achieving industrial development	Numeric,Nominal,Scale	Relative mean index,ANOVA,Chi square,Pearson ranking	Dallasega (2018), Botton (2020), and Fatorachian and Kazemi (2020).
Q20-38:Factors influencing the adoption of industry	(iii) To study factors influencing the adoption	Numeric,Nominal,Scale	Relative mean index,ANOVA,Chi	Dallasega, Rauch and Linde (2018), García de Soto, Agustí-Juan, Joss,

4.0 for technological development	of industry 4.0 for technological development,		square,Pearson ranking.	and Hunhevicz (2019).
Q39-51:Future of construction 4.0 in construction industry in developing countries	(iv) future of construction 4.0 in construction industry in developing countries and	Numeric,Nominal,Scale	Mean index, Chisquare, Kruskawalli, ANOVA, Pearsonranking	Kazemi (2020), García de Soto, Agustí-Juan, Joss, and Hunhevicz (2019).
Q52-67:Socioeconomic implications of industry 4.0 tools adoption.	(v) To establish the socioeconomic implications of industry 4.0 tools adoption.	Numeric,Nominal,Scale	Relative mean index,ANOVA,Chi-square, Pearson ranking	Atheni (2008), Allison (2015) and Chung (2012)

Table 2 Conceptualization, Scaling and Operationalization of Research Variables

Table 3 Statistical Table of Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.808	0.817	73

Reliability test carried out on the instruments of data collection and respondent category data in Table 3. Cronbach's alpha test was carried out on the data while the summary was presented in Table 2. A Cronbach's Alpha coefficient of 0.808 was obtained from the analysis, while the Cronbach's alpha level of reliability based on standardized items was 0.817, which illustrates the high level of reliability, which could be translated to mean 82% reliability. The results indicate consistency in the calibration of data collection instruments and its associated variables. On Cronbach's alpha scale, to determine the extent of data reliability on a scale of 0 to 1, the closer the SPSS value to 1, the more reliable and consistency are the variables under measurement and vice versa. Therefore, in the context of this study,the calculated value was 0.817, which was close to 1.0, indicating a high level of reliability and consistency in the structure (Chung, Heng and Skitmore 2012, Dalasega 2018, Garcia et al. 2019 and Ghada 2022).

3.3 Industry 4.0 Application Drivers in Construction Industry for Sustainable Infrastructure Development

Table 4 Industry 4.0 Application Drivers in Construction Industry for Sustainable Infrastructure Development

Industry 4.0 Application Drivers for Sustainable Infrastructural Development	Architect		Builders		Civil Engineer	
	Mean Index	Rank	Mean Index	Rank	Mean Index	Rank
E-Procurement	0.857	1st	0.854	1st	0.856	1st
E-Monitoring	0.856	2nd	0.852	2nd	0.855	2nd
E-Maintenance with Maintenance Software	0.855	3rd	0.748	5th	0.855	3rd
E-Design	0.850	4th	0.849	3rd	0.750	7th
E-Costing using Costing software	0.850	4th	0.750	4th	0.787	4th
Robotics	0.768	6th	0.740	7th	0.765	5th
E-Security system	0.765	7th	0.748	5th	0.754	6th

Relative Agreement Index

In the construction industry, the multidisciplinary approach has been the system that makes things work season out of season. In the industry 4.0 era, there are numerous applications that form the basis of the working system that drives effective operations in the construction industry, therefore, Industry 4.0 application driver were presented in Table 4. Three (3) categories of respondent, i.e., the Architect, Builder, and Civil engineer, were used for this particular section considering the synchronization of their duties and functions on site. E-procurement was rated 1st as a foremost driver of industry 4.0 application by the Architect, Builders, and Civil engineers with mean index values of 0.857, 0.854, and 0.856 respectively. E-monitoring was ranked 2nd while E-design and E-maintenance with maintenance software was ranked 3rd with mean index values of 0.855 and 0.748, respectively. Similarly, E-costing software was ranked 4th while robotics was ranked 5th while E-security system was ranked 7th by Architects and 6th by Civil engineers. The process of procurement of materials for industrial and manufacturing purposes has taken a new dimensions in current industrial revolution dispensation with the advent of automation. In previous times, according to Amusan et al., (2020), the procurement system is often tedious and cumbersome, involving rigorous paperwork and processing which the industrial revolution has improved through automation. E-design has also improved efficiency in the construction industry, since automation has replaced the analogue method of design which has enhanced efficiency. Project monitoring and construction has also been enhanced in terms of productivity with the introduction of software and sensor based applications in the construction industry. Artificial intelligence in recent times has also changed the course of operations in the industry, with the advent of expert systems and robotics. In the light of industrial development and infrastructure development, the application presented in the table have found to impact the infrastructural provision landscape tremendously,this was alluded in Dallasega, Rauch and Linde (2018), García de Soto, Agustí-Juan, Joss, and Hunhevicz (2019). Furthermore, analysis was carried out to validate the authenticity of the data presented in terms of hypothesis validation as presented in Table 4.

Table 5 Chi-square Test Statistics of Industry 4.0 Application Drivers in Construction Industry

Test Parameter	E-procurement	E-monitoring	E-maintenance	E-design	E-costing	Robotics	E-security system
Chi-Square	0.000[a]	0.000[a]	0.000[a]	0.333[b]	0.000[a]	0.000[a]	0.000[a]
df	2	2	2	1	2	2	2
Asymp. Sig.	1.000	1.000	1.000	.564	1.000	1.000	1.000

a. 3 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.
b. 2 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.5.

Statistical test results on Industry 4.0 application drivers in construction industry were presented in Table 5. The Chi-square values obtained from the analysis of the parameters ranged between 0.000 to 0.333, the analysis was conducted at P-value 0.005. The SPSS statistical value of 0.000 were obtained for six variables, i.e.E-procurement, E-monitoring, E-maintenance, E-costing, Robotics, and E-security system , the values are less than the P-value of 0.000, therefore Null hypothesis is rejected. It could be inferred that there is strong agreement in the response of respondents to the variables while opinion differs on E-design among the respondents.

Table 6 Analysis of Variance (ANOVA) on Industry 4.0 Application Drivers in Construction Industry

Hypothesis 1 N_0: There is no significant positive correlation in the opinion of respondents with drivers

Hypothesis 1N_1: There is a significant positive correlation in the opinion of respondents with drivers

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
E-procurement	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			
E-monitoring	Between Groups	.006	2	.003		
	Within Groups	0.000	0			
	Total	.006	2			

E-maintenance	Between Groups	.007	2	.004		
	Within Groups	0.000	0			
	Total	.007	2			
E-design	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			
E-costing	Between Groups	.006	2	.003		
	Within Groups	0.000	0			
	Total	.006	2			
Robotics	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			
E-security system	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			

The result of SPSS analysis scores were as presented in Table 6. The variables were tested for consistency and homogeneity of variables correlation. The P-value benchmark score of 0.05 was used to validate the SPSS values calculated and presented in the table. E-procurement has mean value of 0.000, E-monitoring has 0.003, E-maintenance 0.004, E-design 0.00, E-costing 0.003, Robotics 0.000 and E-security system has mean value of 0.000. The mean values for all variables were less than p-value 0.05 which indicates that the null hypothesis should be rejected, therefore there there is a significant positive correlation in the opinion of respondents with drivers. The uniformity in the response could be attributed to the commonality in the usage of the industrial 4.0 tools by the professionals, and this tend to position them in a way to give valid feedback as regards the issues and challenges and what should make it work effectively.

3.4 Construction 4.0 in achieving Industrial Development

Construction 4.0 has contributed immensely to industrial development

Table 7 Prospect of Construction 4.0 in achieving Industrial Development

Prospect of Construction 4.0	Architect		Builders		Civil Engineer	
	Mean	Rank	Mean Index	Rank	Mean Index	Rank

	Index					
Emergence of New World Order	0.885	1st	0.887	1st	0.854	3rd
More building component being ICT compliant	0.885	1st	0.887	1st	0.854	3rd
Proficient use of 3D technology	0.884	3rd	0.834	3rd	0.888	1st
Advanced in equipment and robotics technology	0.867	4th	0.748	6th	0.760	5th
More efficient management of construction resource	0.850	5th	0.857	4th	0.866	2nd
Advancement in construction Technology	0.845	6th	0.764	5th	0.835	6th

Construction 4.0 without doubt has been proven to be a major key to industrial development. The civilization. The civilization has led to much demand for consumer goods and infrastructural development at a rate higher than what it is used to be. To cope with the demand on an enhanced system that would accommodate the high flow of industrial process would be much needed. It is with this as a background that an industry process that are highly digitized has evolved in the world of industrial development, to a process that are superficial like those obtainable in Construction 4.0. Professionals are relying heavily on the tools of Construction 4.0,which was rated in industry 4.0 as submitted in Dallasega (2018), Botton (2020) and Fatorachian and Kazemi (2020), that the further prospect of using Industry 4.0 and Construction 4.0 to create infrastructural development and industrial development is plausible. In this study, therefore,inline with Botton (2020), Fatorachian and Kazemi (2020), and Mahmoud et al., (2021, the following are presented as advantages and benefits derivable from the integration of Construction 4.0, in construction industry for industrial development. This include the following: the emergence of a new world order in construction materials, manufacturing and usage, making all components of the building to be ICT compliant , creation of proficiency in the use of 3 D technology more than ever before now. Production and provision of construction products and advanced infrastructure,more efficient use and adaptation of cutting edge management of construction resources, and evolution of advanced systems and procedures in construction management. Variables that relate to the prospect of construction 4.0 in achieving industrial development were presented in Table 7. The variables includes: emergence of new world order and ranked 1st by the three classes of respondents, that is, the Architect, builder and Quantity surveyors, building components being ICT compliant, proficient use of 3D technology, advanced in equipment and technology, more efficient management of construction resources was rated 3rd by Civil engineer, while rated 4th by Architect and Builders, while advancement in construction technology was ranked 5th by Architect, Builders and Civil engineer, this was supported by Dallasega (2018), Botton (2020), Ogundipe et al. (2021), and Fatorachian and Kazemi (2020).

Table 8 ANOVA Analysis on Prospect of Construction 4.0 in achieving Industrial Development

Hypothesis 2 N_0 : There is no divergence of perspective on the prospect of Construction 4.0 in achieving industrial development

Hypothesis 2 N_1: There is a homogenous agreement of respondents perspective on the prospect of Construction 4.0 in achieving industrial development

ANOVA						
Prospect Parameter		Sum of Squares	df	Mean Square	F	Sig.
Emergence of new world order in digital technology	Between Groups	.001	2	.000		
	Within Groups	0.000	0			
	Total	.001	2			
More building component being ICT compliant	Between Groups	.001	2	.000		
	Within Groups	0.000	0			
	Total	.001	2			
Proficient use of 3D technology	Between Groups	.002	2	.001		
	Within Groups	0.000	0			
	Total	.002	2			
Advance in equipment technology	Between Groups	.009	2	.004		
	Within Groups	0.000	0			
	Total	.009	2			
More efficient management of construction resources	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			
Advancement in construction technology	Between Groups	.004	2	.002		
	Within Groups	0.000	0			
	Total	.004	2			

Table 9 Chi Square Test Statistics on Prospect of Construction 4.0 in achieving Industrial Development

Test Statistics						
	Emergenceofneworder	Morebuildingcomponent	Proficientuseof3Dtech	Advanceinequipment	Moreefficientmanagement	Advancementinconstruction

Chi-Square	.000[a]	.000[a]	.000[a]	.000[a]	.000[a]	.000[a]
df	2	2	2	2	2	2
Asymp. Sig.	1.000	1.000	1.000	1.000	1.000	1.000
a. 3 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.						

Analysis of variance and Chi-square test was carried out on the data to validate the null hypothesis at P-value of p<0.005 and presented in Tables 8 and 9. The null hypothesis was rejected at p<0.005 for the following factors having Sig. Values less than 0.005, the factors are emergence of new world order in digital technology, more building components being ICT compliant, proficient use of 3D technology, advance in equipment technology, more efficient management of construction resources, advancement in construction technology among others. It could be inferred that there is homogenous value of agreement of respondents on variables on the prospect of Construction 4.0 in achieving industrial development.Therefore, to achieve Construction 4.0, the following are essential, such as, making more building components being ICT compliant, proficient use of 3D technology, advance in equipment technology, more efficient management of construction resources and advancement in construction technology

3.5 Adoption of Industry 4.0 Tools in Technological Development

Table 10 Factors Influencing Adoption of Industry 4.0 Tools in Technological Development

Factors	Architect		Builder		Civil engineer	
	Mean Index	Rank	Mean Index	Rank	Mean Index	Rank
A.Psychological Factors						
People psychological attachment to old ways of doing things	0.885	1st	0.789	3rd	0.885	1st
Educational underdevelopment	0.884	2nd	0.865	1st	0.884	2nd
Unwillingness to transfer skill to learners on projects	0.867	3rd	0.836	2nd	0.862	3rd
Government policy	0.850	5th	0.768	5th	0.763	5th
Unwillingness of construction practitioners to learn new skill	0.845	6th	0.789	4th	0.771	4th
Non E-readiness of construction industry practitioners	0.842	7th	0.675	7th	0.678	6th
B. Economic Factors						

High cost of High-tech equipment	0.875	1st	0.771	1st	0.821	1st
Nations' bilateral agreement	0.864	2nd	0.732	3rd	0.771	2nd
Notoriety of African market	0.852	3rd	0.765	2nd	0.765	3rd
Monopoly of Technology	0.785	4th	0.654	4th	0.732	4th
C. Social Factors						
Cultural infringement	0.854	1st	0.731	2nd	0.751	1st
Tendency for job loss among workers	0.832	2nd	0.732	1st	0.732	2nd
Attachment to local content initiatives	0.801	3rd	0.613	3rd	0.614	3rd
D. Technical Factor						
Lack of training and scarcity of skill transfer platform	0.888	1st	0.875	1st	0.691	1st
Non availability of requisite tools	0.751	2nd	0.865	2nd	0.532	2nd
Non readiness for skill transfer and knowledge acquisition	0.614	3rd	0.751	3rd	0.514	4th
Non readiness to adopt new technology	0.525	4th	0.652	4th	0.503	5th
Need for advanced knowledge	0.501	5th	0.613	5th	0.517	3rd

Some of the factors influencing the adoption of Industry 4.0 tools in technological development like psychological, economic, social, and technical factors were presented in Table 10. People psychological attachment to old ways of doing things,educational underdevelopment, and unwillingness to transfer skills to learners on projects are rated first, second, and third, respectively, were adjudged the highest among the psychological factors by the three categories of respondents, architect, builders and quantity surveyors. Similarly, sub-factors under technical factors include lack of training and scarcity of skill transfer platform, availability of requisite tools, and non readiness for skill transfer, and knowledge acquisition. The factors related to the technical component of projects are adjudged as important since they relate directly to the physical completion of the project. Moreover, social factors impact on variables such as cultural infringement, tendency for job loss among workers, and attachment to local content initiatives. Economic factors that influence the adoption of industry 4.0 technology could be be described as high cost of high-tech equipment, nations' bilateral agreements,notoriety of African market, and monopoly of technology, among others. The survey above is corroborated with supportive submission in Dallasega, Rauch and Linde (2018), García de Soto, Agustí-Juan, Joss, and Hunhevicz (2019).

Table 11 Factors Influencing Adoption of Industry 4.0 Tools in Technological Development

Test Statistics			
	Architect	Builders	Civilengineer
Chi-Square	.000[a]	2.222[b]	1.556[c]
df	17	13	15
Asymp. Sig.	1.000	1.000	1.000
a. 18 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.			
b. 14 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.3.			
c. 16 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.1.			

Statistical test results on Factors Influencing Adoption of Industry 4.0 tools in technological development were presented in Tables 10 and 11. The Chi-square values obtained from the analysis of the parameters ranged between 0.000 to 2.222, the analysis was conducted at P-value 0.005. The SPSS statistical value of 0.000 were obtained for three variables of respondents, I.e., Architect, builders and Civil engineering, the values are less than the P-value of 0.005, therefore null hypothesis is rejected. It could be inferred that there is strong agreement in the response of respondents on the variables while opinion differs between builders and civil engineers..

Table 12 Factors Influencing Adoption of Industry 4.0 Tools in technological development

Hypothesis 3 N_0 : There is no homogeneity of opinion among respondents on the variables of factors Influencing Adoption of Industry 4.0 Tools in technological development

Hypothesis 3 N_1: There is No homogeneity of opinion among respondents on the variables of factors Influencing Adoption of Industry 4.0 Tools in technological development

ANOVA						
Respondents Variable		Sum of Squares	df	Mean Square	F	Sig.
Architect	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			
Builders	Between Groups	.003	2	.001		
	Within Groups	0.000	0			
	Total	.003	2			
Civilengineer	Between Groups	.000	2	.000		
	Within Groups	0.000	0			
	Total	.000	2			

In Table 12, the analytical results of the test carried out on factors influencing the adoption of Industry 4.0 tools in technological development. Analysis of variance was carried out on the respondents data. At P.value 0.005, all respondents agree on the commonality of opinion. There was homogeneity of opinion among the respondents since the mean square values of the architect,builders and civil engineer are below 0.005.

3.6 Construction 4.0 application in Construction Industry for Sustainable Infrastructure

Table 13 Future of Construction 4.0 in Construction Industry for Sustainable Infrastructure

Parameters for Future of Construction 4.0 Developments for Sustainable Infrastructure	Architect		Builders		Civil Engineer	
	Mean Index	Rank	Mean Index	Rank	Mean Index	Rank
Internet of things application tendency in automation	0.797	1st	0.797	1st	0.876	1st
Application of Physical Cybercontrol systems	0.786	2nd	0.786	2nd	0.763	2nd
Introduction of BIM in solving construction challenges	0.769	3rd	0.700	5th	0.712	4th
Infrastructural development innovations	0.769	3rd	0.765	4th	0.763	2nd
Breaking of digital barriers in ICT development	0.769	3rd	0.769	3rd	0.760	7th
Cloud computing in processing large construction data	0.683	6th	0.668	4th	0.761	6th
Introduction of Additive manufacturing	0.661	7th	0.600	7th	0.689	6th
Creation of improved construction process and product	0.661	8th	0.660	6th	0.663	9th
Application of 4D and 5D in design and construction	0.578	9th	0.535	9th	0.712	8th
Evolution of new methodology and process	0.565	10th	0.662	5th	0.562	11th
Application of artificial intelligence and informatics	0.535	11th	0.578	8th	0.613	10th
Rolling out of virtual reality, knowledge augmentation	0.517	12th	0.517	10th	0.531	12th

In Table 13, discussion on the future of Construction 4.0 in construction industry in developing countries. The cadre of respondents from developing countries like Nigeria is a developing country. In the contemporary time of industry 4.0, relevant parameters that could be used to drive development include Internet of things application, tendency in automation, application of physical cyber-control systems, introduction of BIM in solving construction challenges, infrastructural development innovations,breaking of digital barriers in ICT development, cloud computing in processing large construction data, introduction of, additive manufacturing, creation of improved construction process and product, application of 4D and 5D in design and construction, evolution of new methodology and process, application of artificial intelligence and informatics and rolling out of virtual reality, knowledge augmentation. The three categories of respondents, i.e., Architects, Builder, and Civil engineers, that were used for the survey ranked the factors in the order Dallasega, Rauch and Linde (2018), Emetere et al (2021a),Emetere et al. (2021b), García de Soto, Agustí-Juan, Joss, Amusan and Oyewole (2018), and Hunhevicz (2019).

Sustainable development is an evolving concept that borders about meeting the infrastructure needs of the present generation while evolving more advanced development towards meeting other future needs. Sustainable infrastructural development entails 3 elements according to Dan, Luminata, Alin and Vasile (2015), human existence, economy, and ecological landscape (infrastructural development). Sustainable infrastructure therefore should be able to provide a solution to the issue that revolves around 3 basic elements. The importance of sustainable development lies in the provision of environmental protection for human, animal, and bio systems components of development through innovation. The innovation should be the type that advances human boundaries in food, shelter, and environmental development. Therefore, sustainable infrastructural development should be a type that lasts beyond the current generation to the future and engages renewable resources. Industry 4.0 tools have been of tremendous assistance in providing renewable resources for development in the form of Industry 4.0 tools, which has led to the evolution of Construction 4.0.

Future of Construction 4.0 in Construction Industry

Industry 4.0 provides platforms for the engagement of the basic tools which are renewable. For instance, in providing support for the human component of sustainable technological development. Sensor-based applications of Industry 4.0 tools provides more flexibility to the human force in infrastructural development. Furthermore, analysis was carried out on factors on the future of Industry 4.0 on technological development using Kruskallis Wallis test and Analysis of Variance (ANOVA), the result were presented in Table 14.

Table 14 Analysis of Variance on Future of Construction 4.0 in Construction Industry

Hypothesis 4 N_0 :There is no homogeneous of opinion in the rating of factors on the future of Industry 4.0 on technological development

Hypothesis 4 N_1:There is a homogeneous of opinion in the rating of factors on the future of Industry 4.0 on technological development

Analysis of Variance [ANOVA]							Kruska Wallis
		Sum of Squares	df	Mean Square	F	Sig.	p-value
Internet of Things	Between Groups	.000	2	.000			0.000

	Within Groups	0.000	0				
	Total	.000	2				
Physical Cyber control	Between Groups	.006	2	.003			0.000
	Within Groups	0.000	0				
	Total	.006	2				
Introduction of IBM	Between Groups	.007	2	.004			0.000
	Within Groups	0.000	0				
	Total	.007	2				
Cloud Computing	Between Groups	.000	2	.000			0.000
	Within Groups	0.000	0				
	Total	.000	2				
Adventure of Additive Manufacturing	Between Groups	.006	2	.003			0.000
	Within Groups	0.000	0				
	Total	.006	2				
Application of 3D and 5D	Between Groups	.000	2	.000			0.000
	Within Groups	0.000	0				
	Total	.000	2				
Artificial intelligence application	Between Groups	.000	2	.000			0.000
	Within Groups	0.000	0				
	Total	.000	2				
Virtual reality	Between Groups	.001	2	.000			0.000
	Within Groups	0.000	0				
	Total	.001	2				
Infrastructurald evelopment	Between Groups	.001	2	.000			0.000
	Within Groups	0.000	0				
	Total	.001	2				

Breaking digital barrier	Between Groups	.002	2	.001			0.000
	Within Groups	0.000	0				
	Total	.002	2				
Improved construction process	Between Groups	.009	2	.004			0.000
	Within Groups	0.000	0				
	Total	.009	2				
Evolutiono f new methodology	Between Groups	.000	2	.000			0.000
	Within Groups	0.000	0				
	Total	.000	2				

In Table14, the following factors were analysis cross examining the four (4) groups of respondents validating the homogeneity of the opinion and responses.The factors are: Internet of Things,Physical Cyber control, Introduction of IBM, Cloud Computing, Adventure of Additive Manufacturing, Application of 3D and 5D, Artificial intelligence application, Virtual reality, Infrastructural development, Breaking digital barrier, Improved construction process and Evolution of new methodologies. The factor P-value of 0.000 for Kruskal Wallis test, while all P-value in ANOVA test was less than the standard P-value of 0.05. The implication of this lies in the rejection of null hypothesis, therefore, there is a homogeneous of opinion in the rating of factors on the future of Industry 4.0 on technological development. The analysis validates the authenticity of variables about the future of Industry 4.0on technological development.

3.7 Socio-economic Implications of Industry 4.0 Tools Adoption

Table15 Socio-economic Implications of Industry 4.0 Tools Adoption in Infrastructural Development

Socioeconomic Parameters	Mean Index	Ranking
Technological variables		
Information system integration	0.887	1st
Effective knowledge management	0.834	2nd
Man-machine-resources integration	0.748	3rd
Encourages multilevel interaction in the industry	0.852	4th
Encourages knowledge/skill transfer	0.764	5th
Economic variables		
Enhanced industrial productivity	0.856	1st
Promotion of gender equality	0.807	4th
Creation of sustainable construction system	0.713	6th

Economic effect in term of job loss and creation	0.850	2nd
Increase in GDP	0.840	3rd
Security of life and property	0.763	5th
Social implication		
Enhanced social status	0.785	1st
Emergence of new law and regulation	0.765	2nd
Evolution of new high tech business model	0.701	3rd
Language and cultural barrier	0.687	4th

All categories of respondents used for the analysis in this study were used for validating the socio-economic implications of industry 4.0 tool adoption in the construction industry.The categories of respondents included Architects, builders,civil engineer and quantity surveyors. Socio-economic implications of the adoption of industry 4.0 for technological innovation in achieving infrastructural development were presented in Table 15 above. The study approaches presentation in Table 15 from three perspectives, i.e., technological implication, economic perspective, and social implications. Technological implication lies in the direct effect of the adoption of industry 4.0 in a way that leverages on the technological components of the innovation. The components of the technical part border on information system,knowledge management, man-machine integration, multilevel interaction, and skill transfer. In technical content, integrating information system plays a major role in industry 4.0 system adoption,which was ranked first with a mean index of 0.887 by the three categories of respondents,encourages multilevel interaction in the industry was rated second with mean index value 0.852, effective knowledge management with mean index 0.834 and ranked third,encouraging knowledge and skill transfer was ranked fourth with mean index 0.764 while man-machine resources integration was ranked fifth with mean index value of 0.748. The highlight of industry 4.0 is the integration of information systems into aspects of production and management,industrial production systems and manufacturing has witnessed the diverse application of sensor-based instruments which has also culminated in the emergence of internet of things concept which formed the bedrock of application in the construction and manufacturing company with the system of production and manufacturing having an enhanced productivity,this was supported by Atheni (2008), Allison (2015) and Chung (2012). Similarly,Industry 4.0 encourages multilevel interaction among the construction industry players, which facilitates knowledge management through big data applications and skill transfer.

Conclusion

The study has made an attempt at positioning the concept of adoption of Industry 4.0 tools in achieving Construction 4.0 for sustainable infrastructure development. The study presented data on the research variables articulated at the beginning of the study. The study articulated the following objective parameters to carry out the survey, such as (i) Industry 4.0 application drivers in the construction industry in achieving sustainable infrastructural development, (ii) prospect of Construction 4.0 in achieving industrial development of Industry 4.0,(iii) factors influencing the adoption of Industry 4.0 for technological development, (iv) future of

Construction 4.0 in construction industry in infrastructural development and (v) socioeconomic implications of Industry 4.0 tools adoption.

Industry 4.0 tool has offered a good prospects of creating a good environment in achieving sustainable infrastructure development using Construction 4.0. Industry 4.0 tools provide more flexibility to the human force in infrastructural development provision through the engagement of advanced tools in construction work. Many applications have found their way into the economic system such as applications in building component usage such as access control, building, electrical and electro-mechanical components of buildings. Much of the applications uses sensor-based systems with the aid of renewal energy sources,which provide comfort for building occupants. Similarly, as regards the economy component of the development,the resultant effect of sustainable infrastructure development is the provision of free flow of income and cash through manufacturing and marketing of Industry 4.0 tools and equipment. The inflow of Industry 4.0 tools helps in further entrenching of Construction 4.0 economy. The flow of Construction 4.0 provides job opportunity, enlightment and rapid economic expansion and growth.It would enhance the continuous provision of goods and services which could lead to economic diversification and skill learning.

In adopting Industry 4.0 to create sustainable infrastructural development, certain drivers are needed which include engaging Electronic procurement, Electronic Design,Costing and Monitoring, also Robotics, and Electronic security system among others. The mentioned parameters are the major drivers that influence the creation of sustainable infrastructure in Industrial revolution time. In creating sustainable infrastructural development, the importance of the application of electronic media can not be overemphasized, therefore the combination of the electronic procurement, Electronic Design,Costing and Monitoring, also Robotics, and Electronic security system would assist in the effective achievement of infrastructural development that is sustainable

Similarly, Construction 4.0 application all over the world has proven the possibility of achieving industrial development, construction 4.0has a tendency to assist in achieving the building components being ICT compliant across the board on account of automation applications in buildings. Moreover, there is a tendency to achieve proficiency in the use of 3D,4D,5D, and 6D technology in the manufacturing and production of building components. Construction 4.0 has also led to the advancement of equipment and robotics technology, eventual efficient management of construction resources, and advancement in construction technology.

However, adoption of the Construction 4.0, there are numerous parameters that influence the adoption of industry 4.0 for technological development,which need to be considered to achieve sustainable infrastructural development. For instance, there is a need for attitudinal change, cultural orientation,economic development, and technological innovation. There is a future for success in application of Construction 4.0 in creating a robust infrastructural economy which is sustainable. It has been established that there are good expectations for brighter infrastructural provisions that would last generations, the fact lies in the tendency to apply Internet of things in construction automation,application of Physical Cybercontrol systems, and introduction of BIM in solving construction challenges in infrastructural development innovations. Finally,the studies can find relevance in the construction industry application, policy makers and Industry 4.0 tool manufacturers and all categories of ICT users in the society.

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