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ASSESSING THE ADOPTION OF INDUSTRY 4.0 IN THE NIGERIAN CONSTRUCTION INDUSTRY: A CASE STUDY OF CONSTRUCTION PROFESSIONALS IN ABUJA AND PORT HARCOURT

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Abstract

The focus of the study is improving the adoption of industry 4.0 in the Nigerian construction industry with special reference to construction professionals in Abuja and Port Harcourt. The aim of this study is to develop strategies that will improve the adoption of industry 4.0 among construction professionals in the Nigerian construction industry. The specific objectives are to determine the level of awareness of Industry 4.0 as a performance tool in the Nigerian construction industry; to determine the impact of industry 4.0 on the efficient project delivery in the Nigerian construction industry. The research design adopted in the study is mixed research design which combines quantitative and qualitative research techniques. The target population comprises of Registered Quantity surveyors, Architects, Engineers, Estate managers and Urban Designers which gives a total of 747 respondents. A sample size of 261 was gotten through Taro Yamane. Based on the nature of the objectives, OLS regression techniques were used to ascertain the impact of industrial 4.0 on the construction industry in Nigeria, efficient project delivery becomes the dependent variable whereas robotics, building information modelling, drones, and artificial intelligence were used as the independent variable. The findings of the study reveals that The direction of the relationship between the underlisted variables are majorly positive except the drones which implies that increase in the adoption of robotics, drones, building information modelling will lead to simultaneous increase in the efficient project delivery in Nigeria. The study also concludes that the signs of all the variable coefficient from the estimated model are not totally in line with a priori expectations. Robotics, building information modelling and drones, have a positive relationship with efficient project delivery, which conforms to the expected sign whereas artificial intelligence has negative relationship with efficient project delivery which does not conforms to the expected signs. The study recommends that Professionals are encouraged to continue to participate in learning and training in the field of technology in order to know ways in which industry 4.0 can be beneficial to their work processes.

Introduction

The Economic backbone of a lot of countries is the construction industry (Ngai, 2019), often accounting for between 7-10 percent of the Gross Domestic Product (Voordijk, 2020). The need for a vibrant construction

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industry can never be over emphasized, since its products and process affect virtually every human on the surface of the earth (Cheung, 2018). For instance, the construction industry has contributed to employment generation, infrastructural transformation, skill and manpower development, knowledge advancement, tourism and increased national GDP. Numerous of jobs have been created through the construction industry (Olabode 2019). The construction industry can pride itself in the provision of physical infrastructures such as roads, bridges, houses etc. that has transformed the built environment radically. There has been an increase in the output and income of people as a result of increased skill and manpower development in the construction industry (William 2019). The construction industry has accounted for over 8% gross domestic product (GDP) internationally (William 2019).

The Nigerian construction industry has its own share of these challenges. Ogunsemi and Jagboro (2019) noted that cost overrun is one of the greatest challenges facing the Nigerian construction industry. Majority of projects in Nigeria suffers delay (Odeyinka and Yusuf 2017), which has led to projects being abandoned (Idrus 2018). Other challenges of the Nigerian construction industry are inefficiency (Afolabi, 2020), and wastage of materials (Pistorius, 2017). The construction industry in Nigeria has been plagued with the none availability of skilled and trained staff (Olabode 2019). The workforce in the construction industry needs to constantly upscale in order to align with incoming responsibility. Most of these challenges in the construction industry can be resolved through the integration of industry 4.0 into the construction processes.

Industry 4.0 has no unanimous definition (Mario, 2018), as it could be referred to as the industrial age or the second machine age. It is the process that automates the construction processes as it allows for a more comprehensive, synchronized, and integrated approach. Industry 4.0 bridges the gap between the physical and digital world, and enhances a better communication system within an industry (Ghada, 2021).

Despite the ability of Industry 4.0 to solve some of the challenges in the construction industry, its adoption is still very low (Nassereddine 2020, Agarwal 2016, Oesterreich 2016, Alaloul, 2020 and Ayodeji 2018). The construction industry needs to fully harness the potentials offered by Industry 4.0 by adopting it just like, the manufacturing industry has done (Mahamood & Akinlabi, 2017).

Based on the guided introduction, this study will be set to examine the adoption of industry 4.0 in the Nigerian construction industry with special reference on the limitations and impact on project delivery.

Statement of the Problem

The inability of the construction industries to adopt digital construction technology such as the industry 4.0 has critically hindered the pace of construction development and execution of construction works. Poor industrial innovation has rendered construction managers struggling with archaic tools and drop down the time of execution of construction project (Tunji-Olayeni, 2022). More so, poor use of Industry 4.0 by construction managers has increased the rate of design error which has consequently led to collapse of many structures. Furthermore, the inability of the construction managers to apply the advance industrial technology of industry 4.0 has significantly increased the rate of material wastage in the construction sites.

The efficiency of the construction industry is in no doubt at a very low level when compared to other industries. According to Griffin (2019), there is need to increase the adoption of industrial 4.0 in order to have an increased industrial output, though the study fall short of appropriate statistical tool and needed methodology to drive home theoretical postulation with empirical findings. Digital automation of the construction process will reduce all human errors from design to implementation, thereby improving the efficiency of the construction industry. Data gathering and usage will improve the decision-making processes in construction works.

Based on the aforementioned research problems, this study seeks to examine the adoption of industrial 4.0 in the Nigerian construction industry with special reference to its limitations and impact on project delivery.

Objectives of the Study

1. Determine the level of awareness of Industry 4.0 in Nigerian construction industry.
2. Determine the impact of industry 4.0 on the performance of the Nigeria construction Industry.

Research Questions

1. What is the level of awareness of Industry 4.0 in Nigerian construction industry?
2. What is the impact of industry 4.0 on the performance of the Nigeria construction Industry?

1.4 Research Hypotheses

This study will be guided by the following hypotheses

1. **H_o:** Industry 4.0 has no significant impact on the performance of effective project delivery on the Nigerian construction industry.

Scope of the Study

For the purpose of feasibility, the study will be restricted to two cities in Nigeria which are Abuja and Port Harcourt. This will serve as the Study Area for this research. The choice of these location was made due to its economic nature in Nigeria. Abuja is the Federal Capital Territory (FCT) of Nigeria why Port Harcourt is the State Capital of Rivers State, a state with numerous mineral resources. Both Cities have the presence of foreign and local developers, with projects of high magnitude which will be able to absorb the high-Cost digital technologies.

The respondents will be the key players in the construction industry from the study area. These respondents will include registered architects, engineers, quantity surveyors, contractors, builders, quantity surveyors, civil engineers and structural engineers. Real estate developers will also make the list of respondents. The study will also use industrial output as the dependent variable which will stand as a proxy variable for the performance of Industrial 4.0. Whereas the independent variables range from design management, site management, construction development, standard construction and error management in the construction industry.

LITERATURE REVIEW

CONCEPTUAL FRAMEWORK

The Concept of Industry 4.0

The Industry4.0 system focuses on the physical-to-digital transition and then the digital to- physical transition to help coordinate, design, and execute built environment infrastructure more effectively and efficiently (Dallasega., 2018). The idea of construction 4.0 is still evolving, and it is informed by its predecessors' conception of Industry 4.0. Industrial 4.0 is focused on a convergence of patterns and innovations, similar to the definition of industry 4.0. (Both digital and physical technologies).

European Industry Construction Federation (EICF), “Construction 4.0” relates to the construction sector's digital transformation within the Architecture, Engineering & Construction (AEC) industry (Juan, 2019). Presently there are no agreed-upon meanings of Construction 4.0 in the literary works (Ali, 2019), except that most research relates to it as Industry 4.0's equivalent or counterpart (Juan, 2019). The researchers propose the subsequently employed description of Industrial 4.0, which was developed dependent on a systematic literature review.

Industry 4.0 is a model that integrates organizations, procedures, and information to effectively plan, build, and operate assets using cyber-physical structures, the Internet of Things, Data, and Services to associate the digital layer, comprising BIM, with the physical layer, comprising the asset, over its entire existence to establish an

integrated environment incorporating organizations, processes, and information. According to Rastogi (2019), the primary objective of construction 4.0 is to build a digital construction site that uses various techniques to track progression during a project's life cycle.

Industrial 4.0 implementation would transform not just the construction process, but also the company and project frameworks, transforming the fragmented construction industry into an integrated one (Rastogi, 2017). Although becoming one of the most profitable industries, the construction industry has one of the poorest R&D intensity levels. Likewise, employment growth in the AEC has decreased over time, although it has nearly doubled in other sectors (Oesterreich and Teuteberg, 2016). The function of human resources in an Industry 4.0 world is shifting from machine operator to strategic decision creator (Hermann, 2016).

Robots support humans in dangerous, stressful, and time-consuming tasks, for which humans must be adequately prepared for successful human-machine partnership (Awais and Henrich, 2013). Since it is a labour-intensive sector, the construction industry has a significant opportunity to increase productivity through technical advancement (e.g., robot use), particularly for potentially hazardous and dangerous human labour. Robots are used in restricted ways in the digital building platform, such as 3-dimension printing, structuring walls, placing rebar, welding, drones, and so on. Moreover, all of the aforementioned robots are having only one application (Chen, 2018).

Awareness of Industry 4.0

According to Merriam-Webster dictionary, awareness can be described as the quality or state in which one is aware or have knowledge and understanding about the existence of something or occurrence of an event. It also means being conscious of the existence of something or an occurrence/event. Therefore, in the context of this paper, awareness is used to describe the knowledge about the existence of lean construction practices.

In Rogers' innovation diffusion theory (Rogers, 2003) awareness has been identified as the first stage in the adoption of an innovation, in the form of an idea, product or process of doing things. This has also been described as the knowledge stage when the potential adopter seeks to know about the innovation by acquiring knowledge and information about it. The knowledge sought at this stage of innovation-decision process is basically awareness knowledge, which may include knowing how the innovation works and how to apply or use it. The awareness knowledge, involves the individual taking cognizance of the innovation, and this alone has the ability to make a potential adopter to decide to adopt the innovation or to get more knowledge on the procedure for using the innovation. In fact, the knowledge of how to use the innovation is essential in informing the adopter how the innovation can be used. This makes the potential adopter to have adequate knowledge of how the innovation operates and why it operates the way it does (Rogers,2003).

Whereas a previous study in Ghana (Ayarkwa, 2012) revealed that there was a good level of awareness among practitioners, studies in countries such as Germany (Johansen and Walter, 2007), Turkey (Tezel, and Nielsen, 2013) and Ethiopia (Ayalew, Dakhli, and Lafhah, 2016) indicated that there was a low level of awareness of industrial 4.0 in construction industries among people in the construction sector. In Nigeria, an earlier study by Olatunji (2008) suggested that the level of awareness of Industrial 4.0 in construction industries among stakeholders in the Nigerian building was also low.

Impact of Industry 4.0 on the performance of the Nigerian construction industry.

S/N	ENABLERS	IMPACTS	REFERENCES
1	Productivity Improvement	Technology permits businesses to improve the productivity of their manufacturing operations. Businesses could examine how employees invest time and implement procedures that improve the efficiency of systems. Task scheduling software helps a business keep on top of obligations, so nothing is forgotten.	(Griffin, 2019)
2	Flexibility Enhancement	Over the past 20 years, communication with colleagues has improved significantly, due to various technological advances that have allowed remote working. Users can also communicate with their peers at any time and from any place, enhancing the company's ability to respond to inquiries rapidly and effectively.	(Oesterreiha nd Teuteberg,20 16)
3	Technologies Keep Business Safe	Customers are essential to a company's survival, but leveraging technology to better their interactions with it will pay off lucratively. Interactive sites, online chat support, and 24/7customer care via social media will help you stand out from the crowd and boost profits.	(Fisher2018)
4	Butter Customer Services	Customers are essential to a company's survival, but leveraging technology to better their interactions with it will pay off lucratively. Interactive sites, online chat support, and 24/7customer care via social media will help you stand out from the crowd and boost profits.	(Pereira 2017) (Syberfeldt 2015)
5	Cybersecurity	Across all industries, communication strategies have greatly increased. Fellow teammates from all around the world will likely collaborate on the same tasks. Currently, networks such as Microsoft Teams, SharePoint, and remote access automated computing mechanisms are on the rise. Digital encryption is another important issue that needs to be discussed in the industry. Hackers and hackers are now using more sophisticated techniques to obtain access to confidential data; as a result, less tech-savvy employees can fail to avoid data loss or theft due to a lack of familiarity with new systems.	(Trappey 2017)
6	Artificial Intelligence & Robotics	Virtual assistants, expert systems, and automated tools are examples of machine intelligence that has changed the production process. Because of a lack of expertise, advancements in artificial intelligence and robotics have disrupted the construction sector. These improved technologies can harm staff.	(Sony and Naik, 2019)

		Adopting AI and Robotics in the construction sector would almost definitely improve efficiency, as the bulk of the work will be performed by automation.	
7	Cloud Computing & Big Data	Cloud computing and big data are used in industrial systems. Big data can be turned into usable insights using predictive analytics to help companies accomplish their goals. The real meaning of big data can be analyzed, sought, and analyzed by organizations. Cloud storage, on the other hand, provides businesses with cost effective and scalable ways to finance activities.	(Sony and Naik, 2019) (Craveiroa 2019)
	The Internet of Things	The Internet of Things (IoT) has expanded beyond internet-wired appliances. The convergence of innovations such as embedded systems, artificial learning, and wireless in the digital world. The Internet of Things (IoT) is crucial to the creation and launch ofIR4.0 Sensor sensors that are physically connected capture data in real-time. This has the potential to be very useful in the construction sector.	(Chris 2020)

Source: (Chris 2020).

Theoretical Framework

The Theory of Planned Behavior

Theory of Planned Behavior (TPB) is a follow-up from the principles of aggregation, which describes that the pool of particular attitudes in various situations, provide analytical validity of behaviors and other qualities.

In other words, theory of planned behavior focuses on specific motivational factors within exclusive context to describe occurrence of a particular behavior (Ajzen, 1991). However, the assumption is that intentions emphasize on the motivational factors that affect behaviour, thus implying that, an intention shows how committed an individual is ready to work, as well the extent of efforts put in, so as to execute the behaviour (Ajzen 1991). On the other hand, a normative belief is a person's opinion of social normative strains and how significant others (i.e., a spouse or partner, parent, nurse, etc.) believe in implementing the behaviour (Ajzen 2011).

However, the significant effect of attitude towards intention has the support from several studies (Taylor & Todd, 1995; Korzaan, 2003; May, 2005; Kelly, et. al., 2006). In line with above reviews, the following hypotheses were proposed as follows: (H1): Attitudes have positive impact on intention to adopt Industry 4.0 Technologies in Malaysia's dairy manufacturing industry.

Other researchers (Ajzen, 1991) characterized SN as a person's observation with respect to endorsement or dissatisfaction with his behaviour noteworthy. In a nation like Malaysia, with a culture which emphasizes the needs and goals of the group as a whole over the needs and desires of each individual. The culture is characterized by emphasis on cohesiveness and interconnectedness between people play a central role in each person's identity (Sinha, 2001). Subjective norm is controlled by regulating beliefs and motivation to conform to the beliefs. Subjective norm is taken into account as a right away determinant of activity intention in the Theory of Contemplated Activity (Fishbein & Ajzen, 1975) and Theory of Planned Behaviour (Hagger, 2002).

Research Methodology

Research Design

The research design adopted for this study will follow a pattern of both descriptive survey research and *ex post facto* research design. The research design refers to the overall strategy that the researcher chooses to integrate the different components of the study in coherent and logical way (Ebube, 2013). This study focuses on the adoption of industry 4.0 in the Nigeria construction industry. Survey research design and *ex post facto* research design were deemed necessary by the researcher because of the nature of the research objectives (The nature of the objectives determines the type of the analyses and the type of analyses determines the research design to be adopted).

Survey research provided the researcher with the accurate description of the respondents' opinion, and uses multi-variant statistics to analyze the data.

Method of Data Collection and Analysis

The responses of the respondents will be recorded on a four-point rating scale for part II. Responses for cluster A and B of part one will be on four-point Likert scale. This is because the researcher believed that the four points Likert scale is capable of eliciting necessary information from the respondents.

The responses of the respondents will be analyzed using the mean, with standard deviation. The mean rating of the numerical values assigned to the options will be summed up and the cut off will be determined by adding the sum of the nominal rating values and dividing same by the number of rating items. Thus,

$$\frac{4+3+2+1}{4} = \frac{10}{4} = 2.50$$

Statistical tool for Hypotheses

For the purpose of testing the hypotheses, the researcher will use the t-test statistical analysis, the research hypotheses will be tested at a 0.5 level of significance.

Decision Rule

If the probability (or significance) of the t-calculated is greater than 0.05, the null hypothesis (H_o) will not be rejected but if otherwise, the null hypothesis will be rejected.

Instrument for Data Analysis

Data generated will be subjected to descriptive statistical analysis and inferential analysis. It will be analyzed using simple percentage, mean, E. views8 software will be used for the regression analysis and SPSS version20 tool will used for correlation coefficient analysis, also known as Pearson correlation. One-sample test will be used to analyze the hypotheses. Microsoft excel 2013 will be used for plotting of graph. The presentation of data will be done using tables, graphs and charts.

Correlation coefficient

The correlation coefficient also commonly known as Pearson correlation is a statistical measure of the dependence or association of two numbers. When two sets of members move in the same direction at the same time, they are said to be positive correlation. When one series of number moves up as the other move down, they are said to have a negative correlation. This will result in a negative correlation coefficient. Since the data collected were historical data, correlation coefficient is a good statistical tool that will help analyze the data

Pearson correlation is a widely used statistical tool that is used to measure the extent or degree of relationship between two variables.

The formula for Pearson correlation coefficient is given as;

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x)^2)(n\sum y^2 - (\sum y)^2)}}$$

When r < + 0.5, a weak positive relationship exists.
When r ≥ + 0.5, a strong positive relationship exists
When r ≤ - 0.5, a strong negative relationship exists.
When r < - 0.5, a weak negative relationship exists.
When r = + 1, a perfect positive relationship exists.
When r = -1, a perfect negative relationship exists.
When r = 0, no relationship exists.

Research population and Sample Frame

Target population refers to all individuals that form part of the group that the researcher intends to study (Cooper & Schindler, 2013). It is the entire group or set of cases that a researcher is interested in generalizing. In this study, the target population comprises of consultants (Quantity surveyors, Architects and Contractors), Stakeholders (ministries and parastatals) and Clients. These individuals are selected because they are the people who are actively involved in the planning and management of construction projects; hence, they are likely to provide the information needed to answer the research questions. Two states were selected for easy and coherent analysis (Abuja, Port Harcourt). The target population for this research is 432 professionals.

Sample Techniques

Sampling techniques will be used to determine the sample size. The judgmental will be use to choose the participants who are viewed as the best source of information needed for the study. Stratified random sampling method will enable the researcher to ensure a fair representation of each of the identified segments or strata.

Determination of Sample size and Sampling procedure

According to Ugwu (2004) sampling is the act of selecting and observing only a specified subset of the population unit. The researcher based on the above population will determine the sample size by using the statistical formula pro-pounded by Taro Yamani (1964). That is;

$$N = \frac{n}{1 + N\,(e)^2}$$

Where;
n = sample size
N = finite population
e = level of significance
1 = constant

Then using the formula, to calculate the sample size at 0.05 level of significance will be;

N = 432/1 + 432(0.05)2 = 432/1 + 432(0.0025)

432/1 + 1.08 = 432/2.08 = 208

N = 208

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

In this chapter, Results of the field survey were collated, compiled, presented and analyzed based on the research questions, objectives and the hypotheses and in the order in which they were listed using appropriate statistical methods. All inferential decision was based on 95% confidence (i.e., 0.05 level of significance), with decision to reject null hypothesis if p-value ≤ 0.05, and accept if otherwise.

Moreover, for proper representation of the population and correct view of the Nigerian Construction Industry on project risk management practice, a total of two hundred and eight (208) questionnaires were distributed and two hundred and one (201) were duly returned. This represented a 90.5% rate of return which is a good basis for this analysis.

Presentation and Analysis of the Questionnaire Survey

Respondent Profiles

The respondents for questionnaire were the various professionals from building Construction industry. They includes: Project Managers, Architects, Engineers, Quantity Surveyors, Builders, and those that represent Governmental Agencies who have a very good knowledge in project risk management in construction industry.

Analyses of the Base Data

Data on questionnaire response as well as socio-economic characteristic of respondents were presented in this section.

Population Distribution of Questionnaire and Percentage Response

Table 5.1 Distribution and Response to the Questionnaire

Respondent	**Population**	**Sample Size**	**Questionnaire distributed**	**Questionnaire Returned**	**Questionnaire not returned**	**Percentage of Questionnaire Returned**
Construction professionals	**432**	**208**	**208**	**201**	**7**	**96.6%**

The above table shows that a total of 208 copies of questionnaire were administered. A total of 201 were completely field and returned while 7 questionnaires were not returned.

Population Distribution of Questionnaire and Percentage Response

Table 5.1 Distribution and Response to the Questionnaire

RESPONDENTS	**NUMBER DISTRIBUTED**	**NUMBER RECEIVED**	**PERCENTAGE RESPONSE%**
Builders	36	34	94.4%
Quantity Surveyor	29	27	93.1%
Architects	42	39	92.8%
Engineers	101	98	98.0%
Estate Managers	30	29	96.6%
Urban and Regional Planners	23	22	95.6%
Tota	261	249	95.4%

From table 5.1, a total of two hundred and eight (208) questionnaires were distributed to the. Civil engineers, mechanical engineers, electrical engineers, architect, quantity surveyors, project managers, site managers and land surveyors. A total of two hundred and one (201) questionnaires were completed and returned. This corresponds to response rate of 96.63%. As stated by Okolie (2011) “a range of response rates of 30-94 percent in the field of organizational research is acceptable.” Accordingly, the response rate of this study falls within the acceptable rate. The others were either not properly filled or not returned.

ANALYSES OF THE FIRST OBJECTIVE

Table 5.9: Determine the level of awareness of industry 4.0 in Nigerian construction industry.

S/ No	Item: **The level of awareness of industry 4.0 as a performance tool in the Nigerian construction industry.**	NK 5	FK 4	K 3	VK 2	HK 1	∑FX	INDEX	RANK
1	Smart factories	102 510	77 308	30 90	25 50	15 15	249 973	3.91	1st
2	Internet of Things IoT	100 500	75 300	29 87	30 60	15 15	249 962	3.86	2nd
3	Cyber-Physical System	98 490	72 288	27 81	32 64	20 20	249 943	3.78	3rd
4	Big data and Analytics	96 480	70 280	29 87	30 60	24 24	249 931	3.73	4th
5	Artificial Intelligence AI	95 475	69 276	30 90	32 64	23 23	249 928	3.72	
6	Autonomous Robots	93 465	67 268	32 96	32 64	25 25	249 918	3.68	8th
7	Cloud computing	92 460	65 260	33 99	33 66	26 26	249 911	3.65	11th
8	Augumented Reality	90 450	62 248	35 105	32 64	30 30	249 897	3.60	9th
9	Simulation	88 440	60 240	37 111	34 68	30 30	249 889	3.57	4th
10	Cybersecurity	87 435	58 232	40 120	34 68	30 30	249 885	3.55	5th
	Grand Mean								

Source: Researcher's field survey

Table 5.9 above shows that the level of awareness of industry 4.0 as a performance tool in the Nigerian construction industry are smart factories with a mean index 3.91, internet of things with a mean index of 3.86, cyber-physical system with a mean index of 3.86, big data and analytics with a mean index of 3.73, artificial intelligence with a mean index of 3.72, autonomous robots with a mean index of 3.68, cloud computing with a mean index of 3.65, augumented reality with a mean index of 3.60, simulation and munte carlo with a mean index of 3.57 and cyber security with a mean index of 3.55.

ANALYSES OF THE THIRD SECOND QUESTION

What is the impact of industry 4.0 on the efficient project delivery in the Nigerian construction industry?

Dependent Variable: OPP
Method: Least Squares
Date: 11/10/24 Time: 18:46
Sample: 2000 2023
Included observations: 24

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	45.75895	14.45265	3.166129	0.0051
RBT	0.550548	0.406315	1.354978	0.1913
BIM	0.033315	0.649684	0.051278	0.9596
DR	0.746371	0.357377	2.088467	0.0505
AI	-0.788230	0.355126	-2.219579	0.0388

R-squared	0.425954	Mean dependent var	43.92250
Adjusted R-squared	0.305102	S.D. dependent var	9.761371
S.E. of regression	8.137131	Akaike info criterion	7.213804
Sum squared resid	1258.045	Schwarz criterion	7.459232
Log likelihood	-81.56565	Hannan-Quinn criter.	7.278916
F-statistic	3.524597	Durbin-Watson stat	1.544534
Prob(F-statistic)	0.025882		

Source: Eviews Computation 2024

Where,

OPP = Operational Performance
RBT = Robotics
BIM = Building Information Modelling
DR = Drones
AI = Artificial Intelligence

Evaluation Based on Economic Criterion

This subsection is concerned with evaluating the regression results based on a priori expectations. The signs and magnitude of each variable coefficient is evaluated against theoretical expectations.

The signs of all the variable coefficient from the estimated model are not totally in line with a priori expectations. Robotics, building information modelling and drones, have a positive relationship with operational performance, which conforms to the expected sign whereas artificial intelligence has negative relationship with operational performance which does not conforms to the expected signs.

The constant term is estimated at 45.75895 which means that the model passes through the point 45.75895 mechanically, if the independent variables are zero, operational performance would be 45.75895 (Gujarati and Sangeetha, 2017).

The estimated coefficient for robotics is 0.550548, this implies that if we hold all other variables affecting operational performance constant, a unit increase in robotics will lead to a 0.550548 increase in efficient project delivery on the average.

The estimated coefficient of building information modelling is 0.033315 which implies that if we hold every variables affecting operational performance constant, a unit increase in building information modelling will cause operational performance to increase by 0.03315 on the average and a unit increase in drones will lead to a 0.746371 increase in efficient project delivery on the average. More so, a unit increase in artificial intelligence will lead to -0.788230 decrease in economic growth in Nigeria.

Evaluation Based on Statistical Criterion

R^2 –Result and Interpretation

This subsection applies the R^2, the t-test and the f-test to determine the statistical reliability of the estimated parameters. These tests are performed as follows;

The coefficient of determination R^2 from the regression result, the R^2 is given as 0.425954 this implies that 42.5954% of the variation in efficient project delivery is being explained by the variation in robotics, building information modelling, drones and artificial intelligence on the average.

t–Test Result and Interpretation

The t-test is used to measure the individual statistical significance of the explanatory variables, for a two tailed test, we use ($t_{a/2}$). We also employ the 95% confidence interval or 5% level of significance (i.e.α=0.05) and 37 as our degree of freedom (Gujarati, 2002).

Decision rule

Reject H_o if $t^* > t_{a/2}$ otherwise, do not reject.

Note: $t_{a/2}=t_{0.05/2}=t_{0.025}$

From the distribution table, $t_{0.025,31}= 1.960$

The result of the t-test of significance is shown in table 4.5 below:

The result of the t-test is presented below and evaluated based on the critical value (1.960) and the value of calculated t-statistics for each variable.

Result of t-Test of Significance

VARIABLES	t-computed (t*)	t-tabulated ($t_{a/2}$)	Conclusion
RBT	1.354978	1.960	Insignificant
BIM	0.051278	1.960	Insignificant
DR	2.088467	1.960	Significant
AI	-2.219579	1.960	Significant

Source: Eviews computation V.12

Significant (Reject H_o; accept H_1),

Insignificant (Accept H_o).

From the t-test result above, For RBT, $t^* < t_{a/2}$, therefore we accept null hypothesis. Hence robotics is statistically significant thus robotics is an insignificant variable to determine efficient project delivery in Nigeria.

For BIM, $t^* < t_{a/2}$ therefore we accept null hypothesis. Hence BIM is statistically Insignificant to determine efficient project delivery in Nigeria.

For DR $t^* > t_{a/2}$ therefore we reject null hypothesis, hence drones is a significant variable to efficient project delivery in Nigeria.

For AI $t^* > t_{a/2}$ therefore we reject null hypothesis, hence artificial intelligence is a significant variable to determine efficient project delivery in Nigeria.

Result and Interpretation of f–Test of Significance

The F-test significance is used to measure the statistical significance of the entire regression plane or the joint impact of the independent variables on the dependent variable. The degree of freedom for the numerator (v_1) and for the denominator (V_2) are given as K-1 and n-k

Where

N= sample size

K= number of parameters including the constant term.

Decision rule (F-Test)

If $F^* > F_{0.05}$ we will reject the null hypothesis and accept the alternative, otherwise, the alternative hypothesis H_1 will be rejected and null hypothesis H_o be accepted.

v_1=6-1=5, V_2=38-6=32, df=(2,33) at 5% level of significance and df=(5,32), $f_{0.05}$=3.33 and F*=4.149639, Since $f^* > f_{0.05}$, we reject the null hypothesis and conclude that the variables (RBT, BIM, DR and AI) have joint inference on economic growth. This implies that the entire regression is significant.

Result of f-Test of Significance:

Computed f-ratio value	**Critical f-ratio value**	**Result**
4.149639	2.33	Statistically significant

Result and Interpretation of Autocorrelation Test

Using the durbin-watson statistics, the region of no autocorrelation (positive or negative) is given as follows

$du < d^* < (4-du)$

du= 1.370

d*= 1.913574

(4-du)= 4 –1.370= 2.63

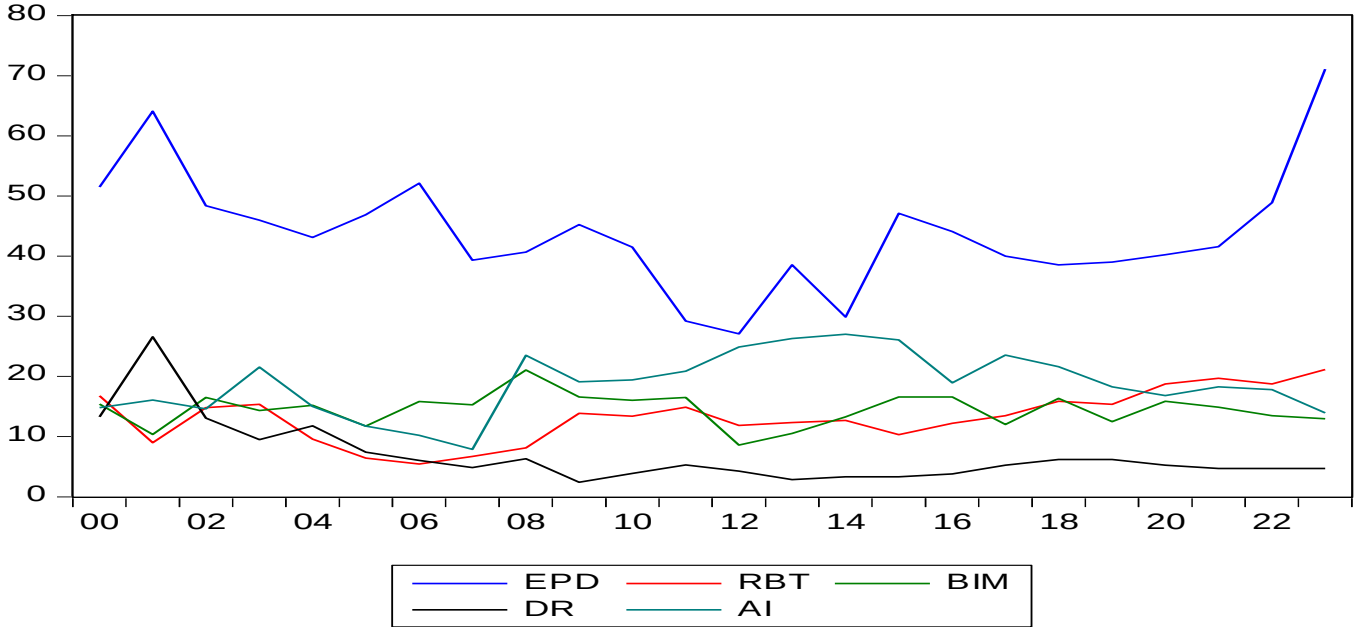
By substitution, the region becomes:

1.370<1.913574< 2.63

Du	d*	d-du	Result
1.370	1.913574	2.63	Autocorrelation absent

The result shows that there is no presence of autocorrelation problem in the model as the computed durbin Watson statistics fall within the zero autocorrelation regions.

GRAPH SHOWING THE TREND OF THE VARIABLES UNDER STUDY



GRAPH SHOWING THE TREND OF THE VARIABLES UNDER STUDY

Source: E views Computation 2024

The graph of the residual diagnostic reveals that the residual of the observed variables are normally distributed. This is evident from the fluctuating movement of the trend around the zero mean.

TABLE OF DESCRIPTIVE STATISTICS

	EPD	RBT	BIM	DR	AI
Mean	43.92250	13.20458	14.52083	6.877083	18.67833
Median	42.33000	13.43000	15.23500	5.240000	18.61500
Maximum	71.10000	21.15000	21.08000	26.60000	27.01000
Minimum	27.10000	5.450000	8.610000	2.420000	7.880000
Std. Dev.	9.761371	4.268541	2.687619	5.172273	5.135656
Skewness	0.866652	0.067469	0.125073	2.549926	0.181570
Kurtosis	4.444224	2.276969	3.356421	9.918047	2.369083
Jarque-Bera	5.090131	0.540982	0.189609	73.86786	0.529927
Probability	0.078468	0.763005	0.909551	0.000000	0.767234
Sum	1054.140	316.9100	348.5000	165.0500	448.2800
Sum Sq. Dev.	2191.540	419.0702	166.1358	615.3055	606.6241
Observations	24	24	24	24	24

TABLE OF DESCRIPTIVE STATISTICS

Source: E views Computation 2024

Table above showed the result of descriptive statistics of the variables used in the study. It could be observed that artificial intelligence (AI), recorded the highest mean values (18.67833) whereas drones (DR) recorded the least mean values (6.877083). all the variables under study (EPD, RBT, BIM, DR and AI) are positively skewed. On the basis of kurtosis, the study found that all the observed variables are normally distributed except drones which has the probability value lower than 0.05 level of significance. This is also evident from the values of their probability (prob > 0.05 for all the variables). Lastly, the study utilized 24 observations. Though, a small number of distributions, the technique used in this study would ensure that robust and reliable estimates are achieved at the end of the study.

TEST OF HYPOTHESES

Hypotheses one

Ho: Industrial 4.0 has no significant impact on the performance of the effective project delivery on the Nigerian construction industry.

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
Null Hypothesis	T	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Industrial 4.0 has no significant impact on the performance of the effective project delivery on the Nigerian construction industry.	0.035	201	.011	0.03300	0.021	0.302

Source: SPSS Computation 2023

From the test of hypothesis above using one sample test t-statistics, based on the decision rule, accept null hypothesis if the value of the t-statistics is greater than 0.05, from the result; the value of the t-statistics (0.035) is less than 0.05 hence we reject the null hypothesis and conclude that industrial 4.0 has significant impact on the performance of effective project delivery on the Nigerian construction industry.

Decision rule

Accept the null hypothesis (H_o) if the value of computed test statistics is greater than 0.05 level of significance.

Decision: we reject the null hypothesis and conclude that industrial 4.0 has significant impact on the performance of effective project delivery on the Nigerian construction industry.

Summary of key Findings

In the first objective, The study indicates that; Are you familiar with IoT has a mean index of 4.15, do you know of 2D printing has a mean index of 4.11, do you know of 3D printing has a mean index of 4.06, are you familiar with building information modelling has a mean index of 4.01, do you know of common data environment, have you heard of augmented reality has a mean index of 3.84, do you know of big data has a mean index of 3.79, do you know of blockchain has a mean index of 3.73, have you heard of laser scammers has a mean index of 3.69, Are you familiar with robotic automation has a mean index of 3.64 and are you familiar with off-site and on-site has a mean index of 3.52. the study concludes that the level of awareness of industry 4.0 in Nigerian construction industry is relatively high.

The result of the second research questions, the result indicates that the impact of industry 4.0 on itself is 1 which 100 percent whereas the impact of industry 4.0 on the performance of the Nigerian construction industry is 0.161 which practically indicates that a unit increase in industry 4.0 will lead to 16.1% increase in the performance of the Nigerian construction industry on the average. The result further indicates that industry 4.0 has positive relationship on the performance of the Nigerian construction industry such that an increase in industry 4.0 will lead to increase in the performance of the Nigerian construction industry on the average.

Conclusion

Based on the findings of the study, the researcher hereby concludes that the the level of awareness of industry 4.0 in the Nigerian construction industry is relatively high. Furthermore, the study concludes that the impact of industry 4.0 on itself is 1 which 100 percent whereas the impact of industry 4.0 on the performance of the Nigerian construction industry is 0.161 which practically indicates that a unit increase in industry 4.0 will lead to 16.1% increase in the performance of the Nigerian construction industry on the average.

Recommendations for further studies.

This research as earlier stated serves as a precursor for more researches in this field of study. Therefore, this research recommends that further studies should:

i. Professionals are encouraged to continue to participate in learning and training in the field of technology in order to know ways in which industry 4.0 can be beneficial to their work processes.
ii. The professional and regulatory bodies in the construction sector are encouraged to always organize seminars and workshops that will prepare and equip their registered members in modern day construction process that fully incorporates the use of industry 4.0 tools into the entire stages of modern constructions.

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