OPTIMAL SCALING APPRAISAL OF MATURITY STATUS OF NIGERIAN POLYTECHNIC EDUCATION IN INDUSTRY 4.0

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ABSTRACT: *The first industrial revolution in the 18th century is related to the transformation to mechanization by using hydro power and steam power to second, third and a new concept referred to as Cyber-Physical Systems (CPS) that combine Internet of Things (IoT) technologies with the manufacturing which is seen as a significant paradigm shift in industrial manufacturing, named as Industry 4.0 (4IR). This study explored the perspectives of people on the lingering issue of maturity of Nigerian Polytechnics in terms of 4th industrial revolution; thus, the paper aimed at appraising the maturity status of Nigerian polytechnics in the industry 4.0 using Optimal Categorical Scaling Regression (Catreg). Data collection was cross-region in Nigeria. This research used the stratified sampling method to ensure a proper spread and it was designed in line with descriptive survey, systematically examining the maturity status of their institution on 4IR through the primary data collected with the aid of questionnaire and focus group discussion from the stakeholders in private and public Nigerian polytechnics. The data were sourced from 18 Polytechnics, 1 each from federal, state and private in each geographical zone. Inferential statistical tools of optimal scaling regression analysis were deployed. The analysis inferred that eagerness of leaders and competence as well as modern ICT and mobile devices are fully mature but implementation of 4IR road-map, decentralization, modelling and simulation, sharing knowledge and open innovation, ICT competence and openness to new technology are still maturing. It is recommended that the educational policy and a blueprint of education for Industry 4.0 should be formulated and implemented to meet the global standard of education.*

KEYWORDS: Maturity, Catreg, Polytechnic, Education, Industrial Revolution 4.0.

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INTRODUCTION

There are several factors that have become impediments in adopting Industry 4.0 technologies. Lack of understanding and commitment of top management, lack of digital culture, difficult organizational process, lack of trained employees, lack of internet coverage and IT facilities, high investment cost, cyber security issues, lack of government support inadequate maintenance support and fear of failure are some of the major impediments in implementing Industry 4.0 technologies in Nigerian higher institutions especially Polytechnics.

The process of industrialization began with the introduction of mechanical manufacturing equipment by the end of the 18th century. The 1st Industrial Revolution is related to the transformation to mechanization by using hydro power and steam power. With this, the transformation from an agricultural to an industrial society started taking place. This revolution was followed by the 2nd Industrial Revolution around the turn of the 20th century, which involved automated mechanics in manufacturing that consumes electric power (i.e., mass-production). It was predominantly originated by organizational changes such as the implementation of Henry Ford's assembly line and the scientific management procedures highlighted by Frederic W. Taylor, better known as Taylorism. This was followed by the 3rd Industrial Revolution that started around 1969. This revolution is characterized by the implementation of information and communication technologies to achieve increased automation of manufacturing processes, as machines gradually take over and replace a large proportion of labour work. With the 3rd Industrial Revolution, the automation in the industry is improved by employing intelligent systems such as industrial robotics and the domains of "intelligent mechatronics and robotics" (Kunii, 1997) attract many practitioners due to various advantages. Consequently, a new concept referred to as Cyber-Physical Systems (CPS) that combine Internet of Things (IoT) technologies with the manufacturing ecosystem introduces a new era of the industrialization (Shrouf, Ordieres & Miragliotta, 2014), which is seen as a significant paradigm shift in industrial manufacturing, named as Industry 4.0. Thereby, physical items are supplemented by their virtual representations in order to increase the automation, flexibility, and diversity of products by means of having better integrated manufacturing processes and systems.

Industry 4.0 is defined by Kagermann, Wahlster, Held & Deutsche (2013) as *"the technical integration of CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services and work organization."*

Similarly, Oztamel and Gursev (2018) state that artificial intelligence (AI) allows the adoption of smart automation with usage of intelligent robots that can perform manufacturing tasks autonomously, can predict errors in the production process and solve the problem independently and helps human beings to make better decisions related to the production.

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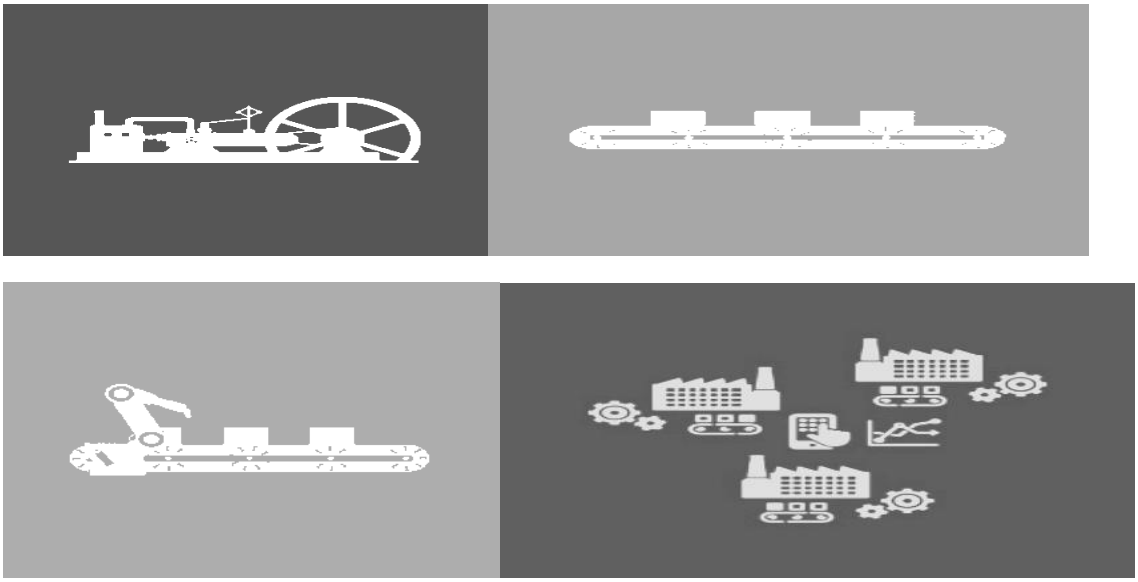

Figure 1: *Industry 1.0 (18th century), 2.0 (20th century), 3.0 (1970) and 4.0 (2015)*

Source: Rennung, Luminosu and Draghici (2016) and Rajnai & Kocsis (2018).

Academic researchers and business practitioners have given substantial attention to Industry 4.0 because of its various benefits in manufacturing organizations and so much research has been conducted on Industry 4.0 in recent years. Research on key concepts of Industry 4.0 is increasing potentially as most of the enabling technologies related to Industry 4.0 are still emerging (Majumdar, Garg, & Jain, 2021).

Industry 4.0 originated in Germany, so research was conducted to see how implementation of Industry 4.0 technologies could transform the German textile industry as Germany has been a big player in this industry among the other EU countries (Fromhold-Eisebith et al., 2021). The empirical findings showed that the German textile industry has suffered for a long time due to deindustrialization, rationalization and global relocation but in order to meet the challenges of global competition, they have kept innovating; new technological tools like Industry 4.0 have been introduced, which have turned the fortune of their textile industry. If they can manage their human resources and labour relations properly by 2030, the German textile industry will be a digitized, institutionally supported technical textile production industry (Fromhold-Eisebith et al., 2021).

Similarly, Masood and Sonntag (2020) identified that there has been very little research regarding adoption challenges and benefits of Industry 4.0 technologies based on the SMEs of the United Kingdom. So, they researched on these topics and found out that using Industry 4.0 technologies in the SMEs of the United Kingdom have increased their manufacturing quality of products, manufacturing flexibility, operational efficiency and reduced operation cost significantly. However, high implementation cost, technology knowledge and implementation time have been the major challenges identified to adopt Industry 4.0 technologies in the SMEs of the United Kingdom (Masood & Sonntag, 2020).

Moreover, research has been conducted on several SMEs in Thailand to understand how Industry 4.0 technologies can improve the sustainability of business performance in SMEs in Thailand. Result outcome showed that due to lack of human and capital resources and

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technological infrastructure, it was hard for the SMEs in Thailand to cope in competition with big companies in different industries but after adopting different Industry 4.0 technologies in their SMEs in 2017, there was a huge increase in their annual revenue, business savings, production efficiency and decrease in debt (Haseeb, Hussain, Ślusarczyk, & Jermsittiparsert, 2019).

Furthermore, faulty production process and maintenance of machines are crucial concerns in the industrial landscape and thus, a previous study has been done on how Industry 4.0 technologies can be helpful in running predictive maintenance of machines. Study findings outlined by Dalzochio et al. (2020) shows that when Machine Learning (ML) technology is integrated into the machines designed by the CPS and IoT system in the production facility, then predictive maintenance of machines can be successfully operated.

However, not only in manufacturing, Industry 4.0 technologies have also been important in health care service, port and maritime industry and worldwide. Recent study outlined by Aceto et al. (2020) showed that six technologies of IoT which are sensors, wireless sensor network (WSN), machine to machine (M2M), network communication technology, handheld mobile terminal and vehicle terminal are used to build an intelligent port. Research results also showed that IoT, big data, cloud computing and blockchain are also used for port equipment condition monitoring, engineering equipment, asset management and international digital trade transactions at ports. On the other hand, in health care industry, previous study shows that Industry 4.0 technologies like IoT, big data and cloud computing have been successful in monitoring physiological and pathological signals monitoring, telemedicine, telepathology, rehabilitation, cloud-based health information system and personalized health care services (Aceto et al., 2020).

CONCEPTUAL MODEL

Maturity Model

This report covers six different Industry 4.0 maturity models. They focus on the interoperability of systems, information systems, digitalisation, vertical integration, and horizontal integration, as well as cyber-physical development. Additionally, Schumacher et al. (2016) has a more holistic model that takes into consideration both internal and external factors; these factors are the ingredients for assessing maturity level: Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, and Technology.

Since Industry 4.0 is still in the initial stages of its development, it is essential to clearly define the structure and methodology of implementation guidelines for Industry 4.0 specifically. Therefore, there is a fundamental need to assist Polytechnics in their transitions to utilization of Industry 4.0 technologies/practices, and to guide them for improving their capabilities in a standardized, objective, and repeatable way. Structural approaches assist organizations by providing comprehensive guidance and introducing a road map.

It is also noticeable that there have been very few research works regarding Industry 4.0 and other concepts related to it in Nigeria. After going through previous empirical studies regarding Industry 4.0 implementation, no research works were possible to find as this sector is one of the most critical sectors in technological innovation of the country. This study tried

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to find out how mature the polytechnic sector is for 4IR. Therefore, in this paper, attempts have been made to fill these lacunae by identifying the position of Nigerian Polytechnic in the face of their level of maturity and 4IR.

MATURITY MODEL

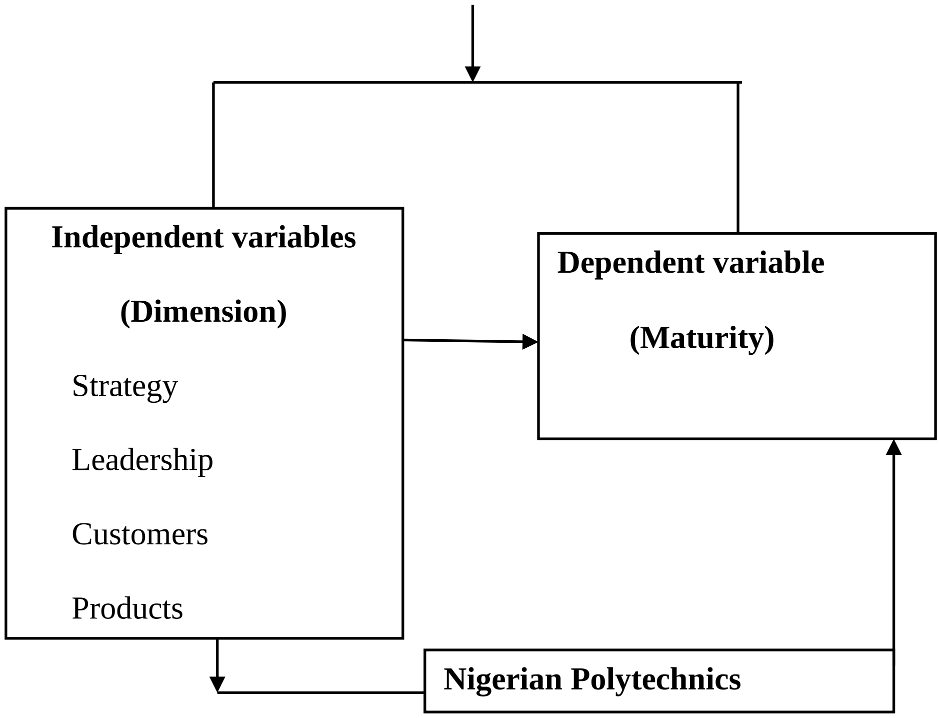

Figure 2: *Conceptual model, Authors' Formulation, 2023.*

Aim and Objective

The aim of this study is to appraise the maturity status of Nigerian polytechnics in Industry 4.0 using Optimal Categorical Scaling Regression (Catreg), while the objective is to assess the significant status of maturity of Nigerian polytechnics in Industry 4.0.

Hypothesis

H_0: Maturity status of Nigerian polytechnics in Industry 4.0 is not positively significant.

H_1: Maturity status of Nigerian polytechnics in Industry 4.0 is positively significant.

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METHODOLOGY

The study adopted Bryman (2012) method of data collection by conducting qualitative structured interviews as well as literature review using abductive research design (merged inductive and deductive approach). Primary data were collected with the aid of structured questionnaires shared to staff of selected polytechnics. Online questionnaires were also shared to complement the hardcopy as well as Focus Group Discussion (FGD) via Zoom meeting. However, the collection was cross-region-based (South-West, South-South, North-West, North-East and North-Central) in Nigeria. This research used the stratified sampling method to ensure a proper spread; the study was designed in line with descriptive survey as it systematically examined the maturity status of their institution on 4IR through the data collected from the stakeholders in private and public Nigerian polytechnics, sourced from 18 Polytechnics (1 federal, 1 state and 1 private in each zone). Rector, Chief, Principal and Senior lecturers constitute the 18 selected participants in data gathering from the polytechnics contacted for the data collection.

Table 1: Sampled Polytechnics

Zone	Polytechnics
South-West	1. The Federal polytechnic, Ede, Osun State 2. Osun State Polytechnic, Iree 3. Igbajo Polytechnic, igbajo, Osun State
South-South	1. Auchi Polytechnic, Auchi, Edo State 2. Edo State Polytechnic Usen, Edo State 3. Kings Polytechnic, Ubiaja
South-East	1. Federal Polytechnic Nekede, Imo State 2. Imo State Polytechnic, Owerri 3. Marist Polytechnic, Emene, Enugu State
North-West	1. Kaduna Polytechnic, kaduna 2. Nuhu Bamalli Polytechnic, Zaria, Kaduna State 3. St. Marry Polytechnic, Kwamba, Suleja, Niger State.
North-East	1. Federal Polytechnic Bauchi 2. Abubakar Tatari Ali Polytechnic, Bauchi 3. Al-Hikma Polytechnic Karu, Nasarawa State
North-Central	1. Federal Polytechnic Offa, Kwara State 2. Kwara State Polytechnic, Ilorin 3. Graceland Polytechnic, Offa, Kwara State

Source: *Authors' Compilation, 2023.*

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METHOD OF DATA ANALYSIS

Descriptive statistics of mean and standard deviation as well Inferential statistics of Optimal Scaling Regression analysis (ORS) of Ordinary Least Square (OLS) analysis for categorical data (Catreg) were employed, in which level of importance and ANOVA were used in the analysis and testing of hypothesis arose from the research questions formulated on the appraisal of maturity status of Polytechnic education in 4th industrial revolution

Maturity Model

$Y_M = f(M_1, M_2, M_3, \ldots M_8)$ ….……....eq(i)

However, the linear function of the above notation is stated as:

$Y_M=\beta_0+\beta_1M_1+\beta_2M_2+\beta_3M_3+\beta_4M_4+\beta_5M_5+\beta_6M_6+\beta_6M_7+\beta_6M_8+U_t$ ….….……eq (ii)

U_t □ $idd(0,\sigma^2)$

Table 2:Variables and their Notations

Notation	Variable
M_1	Strategy
M_2	Leadership
M_3	Products
M_4	Operation
M_5	Culture
M_6	People
M_7	Governance
M_8	Technology
Y_M	Maturity

With the Catreg, R-square and ANOVA were used to affirm the reliability and fitness of the model used. The values of coefficients (βs) and p-values are used to test the level of impact and significance respectively. However, the tolerance and level of importance were also depicted.

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ANALYSIS

Based on the responses from respondents, the mean values of the responses were employed for inference and affirmation was done with a test of hypothesis using Catreg regression analysis.

Objective: *Assessing the Maturity status of Nigerian polytechnics in Industry 4.0.*

Table 3: Descriptive Statistics						
	N	Minimum	Maximum	Mean	Std. Deviation	Remark
M1	18	1	2	1.44	.511	Not Implemented
M2	18	2	3	2.50	.514	Fully implemented
M3	18	1	2	1.61	.502	Partially Implemented
M4	18	1	2	1.17	.383	Not Implemented
M5	18	1	3	1.39	.698	Not Implemented
M6	18	1	2	1.61	.502	Partially Implemented
M7	18	1	2	1.17	.383	Not Implemented
M8	18	2	3	2.56	.511	Fully Implemented
N	18					

Comment: Table 3 shows that Leadership (eagerness of leaders and competence M2) and Technology (modern ICT and mobile devices M8) are fully available in terms of maturity for 4IR. Others are either not implemented or partially implemented as indicated in Table 3. This indicates that the maturity status of Nigerian Polytechnic in Industry 4.0 amidst pandemic was partially implemented.

Test of Hypothesis

H_{01}: Maturity status of Nigerian polytechnics in Industry 4.0 is not positively significant.

H_{11}: Maturity status of Nigerian polytechnics in Industry 4.0 is positively significant.

Table 4: Coefficients

	Standardized Coefficients		df	F	Sig.
	Beta	Bootstrap (1000) Estimate of Std. Error			
M1	.257	.333	2	.597	.626
M2	**.118**	**.491**	**2**	**.057**	**.046**
M3	-.137	.499	2	.076	.929
M4	.537	.628	2	.730	.578
M5	.189	.451	1	.175	.716
M6	.045	.340	2	.017	.983
M7	.164	.376	2	.191	.839
M8	**-.242**	**.427**	**2**	**.322**	**.007**

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Conclusion: It is shown that Leadership (eagerness of leaders and competence, M2) and Technology (modern ICT and mobile devices, M8) among the maturity dimensions evaluated are positively significant at 0.05 level of significance.

Table 5:ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression Residual Total	14.642 3.358 18.000	15 2 17	.976 1.679	.581	.008

Dependent Variable: Maturity
Predictors: M1 M2 M3 M4 M5 M6 M7 M8

Decision: P-value for Analysis of Variance (ANOVA) = 0.008 which is less than 0.05 level of significance. H_1 is therefore accepted.

Conclusion: It is hereby concluded, that Maturity status of Nigerian polytechnics in Industry 4.0 is positively significant but partially implemented.

Table 6:Correlations, Importance and Tolerance

	Correlations			**Importance**	Tolerance	
	Zero-Order	Partial	Part		After Transformation	Before Transformation
M4 (Decentralization, modelling and simulation)	.791	.630	.351	**.522**	.427	.436
M1 (Implementation of 4IR road-map and resources)	.395	.458	.222	**.125**	.747	.747
M8 (Modern ICT and mobile devices)	-.395	-.457	-.222	**.118**	.841	.841
M5 (Sharing knowledge and open innovation)	.438	.368	.171	**.101**	.820	.801
M3 (Individualization and digitalization)	-.443	-.223	-.099	**.075**	.518	.517
M7 (Labour regulations for 4IR)	.316	.273	.122	**.064**	.554	.556
M2 (Eagerness of leaders and competence)	.000	.203	.090	**.000**	.580	.580
M6 (ICT competence,openness to new technology)	-.081	.090	.039	**-.004**	.758	.750

Dependent Variable: Maturity

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Table 6 depicts the level of importance of Maturity status of Nigerian Polytechnics in Industry 4.0. The level of importance is arranged in order of their weight to the dependent variable (Maturity). First to be recognized is M4 (Decentralization, modelling and simulation), followed by M1 (Implementation of 4IR road-map and resources) in that order as shown in Table 6. The last but not the least is M6 (ICT competence and openness to new technology).

CONCLUSION

The study has exposed the perspectives of people on the lingering issue of maturity of Nigerian Polytechnics in terms of 4th industrial revolution which comprises strategy, investment, innovation management, digital modelling, infrastructure, data IT system, cloud, security, autonomous processes, sharing of information, data analytics, ICT add-on functionalities, share of data and revenues, data-driven services, as well as skill acquisition and sets, which are partially implemented. Conversely, resources, eagerness of leaders and competence as well as modern ICT and mobile devices are fully mature but implementation of 4IR road-map, decentralization, modelling and simulation, sharing knowledge and open innovation, ICT competence and openness to new technology are still maturing.

RECOMMENDATIONS

Based on the critical study of related literatures and field work analysis, it is therefore recommended that:

1. The impact of technology, locally and globally, needs to become a central consideration in the long-term decision-making process, especially when addressing issues of innovation and creativity in Nigerian polytechnics.
2. For creating successful technological solutions, having empathy for the user is a key element. In order to engage people, align strategic objectives and obtain new resources for technological investments, leadership, communication and interpersonal skills are needed. However, these efforts should involve evaluation of the ethical implications concerning the development and use of new technologies.
3. The findings are recommended to be used as inspiration for co-creating the final outcome of the polytechnics maturity for the future project: a blueprint of education for Industry 4.0.

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Questionnaire

Section A

General Questions

1 Institution Name: ______________________________________

2. Ownership: Federal (   ) State (   ) Private ( )

3. Regional base: South West ( ) South East ( ) South South ( ) North East ( ) North West (   ) North Central (   )

4. State of location of your institution ....

5. Position Held ....…

6. Staff Status: Academic (   ) Non-Academic (   )

Section B

Thick as appropriate:

1=Not implemented, 2 = Partially Implemented 3 =Fully Implemented

Questions related to Maturity Status of Industry revolution 4.0

	Dimension	**Items**	**1**	**2**	**3**
14	Maturity	Does your institution matured in term of industrial revolution 4.0?			
15	Strategy	Implementation of 4IR road-map and resources			
16	Leadership	Eagerness of leaders and competence			
17	Products	Individualization and digitalization			
18	Operation	Decentralization, modelling and simulation			
19	Culture	Sharing knowledge and open innovation			
20	People	ICT competence and openness to new technology			
21	Governance	Labour regulations for 4IR			
22	Technology	Modern ICT and mobile devices			

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