An evaluation of the fourth industrial revolution adoption in manufacturing industries: An African context

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Abstract

Manufacturing industries across the globe continuously seek for best practices and technologies in ensuring sustainability, competitiveness and improving business performance. Self-Monitoring Analysis and Reporting Technology (SMART) is a strategic best practice approach with capabilities to integrate, automate and operate business functions independently. A SMART manufacturing enterprise is ensued intended to add value in the manufacture and execution of corporate functions. The SMART context aligns with standards of the fourth industrial revolutions (4IR). Effective SMART implementations in manufacturing sectors are essential for ensuring optimal corporate inputs and outputs. This research focuses on SMART 4IR implementations in manufacturing industries. Manufacturing industries in Nigeria a western Africa country is specifically selected to investigate the influence of identified SMART 4IR implementations. Best practice questions relative to 4IR implementations obtainable from literature are defined, empirically tested, which aims at proposing solutions and recommendations relative to enhancing manufacturing efficiency. The document serves as a tool for manufacturing industries relative to improving business performance.

Keywords
The fourth industrial revolutions, Manufacturing industries, SMART implementations.

1. Introduction
Manufacturing industries are continuously developing and implementing sustainable practices aimed at ensuring optimal productivity. The SMART context is a corporate terminology aligned with the evolving 4IR implementations (Chen, et al., 2018). 4IR is the current trend for data exchange and automation (Dolgui, et al., 2018). 4IR implementations result in a SMART manufacturing enterprise (Kang, et al., 2016). The implications of effectively aligning manufacturing industries with the 4IR implementations related to ensuring business sustainability cannot be overstated. The 4IR implementations support the full digitization and automation of manufacturing processes. The 4IR implementations promote sustainability, competitiveness, and improvements in business performance and value. A search in literature details “Cyber-Physical Systems (CPS)”, “SMART factory”, “Internet of Things (IoT)”, and “Internet of Services (IOS)” as four fundamental components of the 4IR implementations (Roblek, et al., 2016). Emerging literature establishes the importance of developing a SMART enterprise with significant impact on business productivity, effectiveness, performance and sustainability (Wang, et al., 2016). A SMART structure provides value added for capturing, evaluating high-value data and integrating business functions. Several SMART enablers premise on the 4IR implementations enhances and contribute significantly to the execution of business functions. This research discusses the SMART context based on 4IR implementations with significant impacts on corporate productivity, efficiency, competitiveness, and sustainability. Best practice questions relative to 4IR implementations obtainable from literature are defined and empirically tested aimed at addressing the research objectives. The empirical testing results in an evaluation structure for effective adoption of the 4IR implementations in manufacturing industries specifically Nigeria a western Africa developing country.

This research commenced with identifying, selecting and defining important SMART 4IR enablers and strategies premised on literature (Chen, et al., 2018; Kang, et al., 2016; Roblek, et al., 2016; Wang, et al., 2016). This research assesses existing relationships obtainable between the important SMART 4IR enablers and strategies defined relative

to improving corporate productivity, efficiency, competitiveness, and sustainability. Corporate goals, objectives, productivity, efficiency, competitiveness, sustainability and strategies are key management issues in a business (Hursman, 2010). This research reviews literature, which elaborates on SMART 4IR implementations. The evaluation seeks for innovations and SMART 4IR implementations, which focus on addressing this research objective. The information collected from an extensive literature review results in best practice questions effective to test the current status of SMART adoption within the Nigeria manufacturing industries.

Secondly, the research reviews literature which elaborates on developing a questionnaire and addressing global standards related to the design of questionnaires. Questionnaire design facilitates an investigative framework in assessing a research limitation (Cronin, 2016 and Telukdarie, 2016). The investigative framework is effective for gathering and analysing data collected (Simons, 2009). The questionnaire comprises best practice questions sufficient for collecting data in addressing the research objectives. The questions aim for a consolidated structure of standard data valuable for manufacturing industries to focus on implementing, improving and optimising SMART 4IR enablement. The research concludes by evaluating data, propose solutions, and recommendations relative to enhancing manufacturing efficiency.

2. Methodology

A questionnaire is designed and employed as the core methodology for data collection and addressing defined research objectives. Questionnaires serve as an effective source for gathering data in research (Easton, 2010). The designed questionnaire is effective for investigating the research objectives in the Nigeria manufacturing business space. Cooper and Schindler (2008), described questionnaires as an inexpensive research tool consisting of sets of response prompts and questions for gathering data via respondents. A conceptual methodology is presented in Figure 1 relative to this research defined objectives. The proposed methodology facilitates the effective gathering, analysis, and understanding of numerous sources of research data (Cronin, 2016 and Simons, 2009). The designed questionnaire is circulated among the management team in each Nigeria manufacturing business space identified for investigation. The questionnaire construct is defined premise on each SMART 4IR enabler identified. The questions and response prompts are constructed in a standardized approach based on best practice benchmarks detailed in (Cooper & Schindler, 2008 and Siniscalco & Auriat, 2005). This ensures the effective, efficient together with easier gathering, and assessments of research data collected. Information premised on the current status of SMART adoption and implementation at the manufacturing business space in Nigeria is investigated. Recommendations are suggested facilitating the enhancement of SMART enablement.

Manufacturing industries relative to the Nigeria context are investigated. Business size of Nigeria manufacturing industries with a minimum of 100 employees is considered for investigation. Statistical data from a database relative to the Nigeria manufacturing context is reviewed to collect information on the total sample size of Nigeria Manufacturing industries (Proshare, 2014). A total of 355 questionnaires are designed and circulated, which accounts for a superior percentage of manufacturing industries registered related to the Nigeria business hub (Sola, et al., 2013; Ojo & Ololade, 2013; Onuoha, 2012; Anyanwu, 2000).

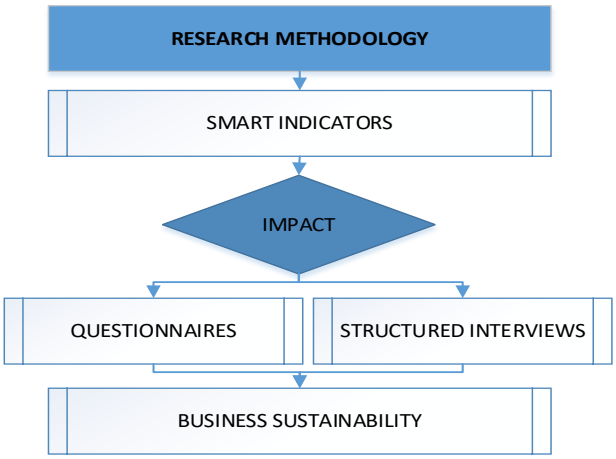

Figure 1. Research methodology

A total of 355 questionnaires are distributed via a Google web-based platform. A total of 285 employees returned the questionnaires during the research data compilation. The 285 questionnaires collected are analysed after a series of follow-up reminders on specific timelines. The analysed questionnaires account for a larger representative of the questionnaires distributed relative to registered manufacturing hubs in Nigeria and considered sufficient for analysis. The total questionnaires reviewed for data analysis are approximately 80% of the initially distributed questionnaires. This is more than a minimum response sufficient for analysing data in research (Greenlaw & Brown-Welty, 2009 and Brynard, et al., 2014). The 285 questionnaires are analysed for data analysis employing quantitative techniques.

Quantitative technique is a statistical descriptive research approach based on formal measures of objectives, actions, and theories. This research analysed data collected based on quantitative techniques. Questionnaires and systematic observations are techniques of data collection supported by the quantitative research method (Siniscalco and Auriat, 2005). Both research methods allow for comprehensive quantification in the collection and assessments of research data (Babbie, 2010). The closed survey approach is employed in the questionnaire construct. The closed survey approach is a technique supported by the quantitative research method (Stangor, 2011). This research aggregates the 355 questionnaires developed as a closed-ended Likert scale constituted with a set of ratings. The responses expected are dependent on a defined set of option ratings. Respondents are obligated to select from the developed ratings. The data collected from the questionnaires is supported by systematic observations and structured interview sessions. The questions though close-ended are exhaustive and mutually exclusive. The closed-ended set of questions enhances the reliability of the responses, less expensive to develop and easily analysed statistically (Reja, et al., 2003). The close-ended questionnaire approach is quick to respond, which aligns with the research timeline. The interviews, systematic observations and research survey are conducted from December 2018 to January 2019.

The questionnaire is structured into three sections (A to C) designed on the basis of three 4IR progress points established in literature (Roblek, et al., 2016; Almada-Lobo, 2016; Schlechtendahl, 2015). A synopsis of these progress points is presented.

- Digitization: SMART enablers for manufacturing planning, execution, and management ensuring the virtualization and decentralization of the manufacturing facilities.
- Automation: SMART enablers for data acquisition and enablement ensuring real-time capability of the manufacturing facilities.
- Integration: SMART enablers facilitating effective linking of manufacturing facilities in a holistic supply chain ensuring interoperability and auto interchange of data.

3. Results and Analysis

The questionnaire construct is constituted premise on the description, strategies, and significance of 4IR SMART implementations (Yannakakis, and Togelius, 2018; Miller, 2018; Medoh and Telukdarie, 2018; Ertel, 2018; Kang, et al., 2016; Wang, et al., 2016; Roblek, et al., 2016; Almada-Lobo, 2016; Schlechtendahl, 2015).

- **Description:** This benchmark in the questionnaire construct seeks for respondents' perceptions and understanding of the 4IR implementations, which includes tools relative to business digitization, automation, and integration. The importance of 4IR implementations in relation to digitization, automation, and integration of manufacturing industries is extensively discussed in literature (Yannakakis, and Togelius, 2018; Miller, 2018; Kang, et al., 2016).
- **Significance:** This benchmark in the questionnaire construct seeks for respondents' perceptions and understanding of the implications of implementing the 4IR protocols relative to ensuring business sustainability in manufacturing industries. Insights to strategic timelines in relation to effective implementations is are also tested. The implications of 4IR implementations in relation to ensuring the sustainability of manufacturing industries is extensively discussed in literature (Medoh and Telukdarie, 2018; Ertel, 2018; Wang, et al., 2016).
- **Strategies:** This benchmark in the questionnaire construct seeks for respondents' perceptions and understanding of the availability and accessibility of corporate measures relative to 4IR implementations. Insights to availability of effectively defined innovation, development, advancement, and implementation strategies in the manufacturing industries are tested. The importance of effectively developed strategies in business sectors is highlighted in literature (Bakkari and Khatory, 2017).

The questions are constituted based on the description, significance and strategies of 4IR SMART implementations premise on the fundamentals of the three 4IR progress points (digitization, automation, integration) discussed.

SMART enablement is a relatively new technology concept in business units relative to the African context (Fwaya and Kesa, 2018). The three sections in the designed questionnaire are detailed as follows.

- Section A investigates the description of 4IR implementations.
- Section B aims if the implications of implementing the 4IR understood.
- Section C explores on the availability and accessibility of corporate measures relative to 4IR implementations.

The data collected and analysed based on the three sections developed in the questionnaire construct aim at contributing to the existing body of knowledge. This is specific to adoption of 4IR implementations in the Nigeria manufacturing corporate space. The questionnaire design and distribution is web-based via google online platform, which facilitates swift feedback and collection of the research data. Google online approach for the design and distribution of questionnaires is a quicker medium for collecting data (Powell and Connaway, 2004). An overview of the developed questionnaire is detailed in Table 1. Direct links of the questionnaires supported with a cover letter are sent to the e-mails of respondents. The researchers assured the respondents of strict confidentiality and explained the research results is purely for academic purposes. The questionnaire comprises questions analysed to obtain demographic data on the existing state of 4IR implementations within Nigeria manufacturing corporate space. The demographic data presents a document, which becomes a significant tool for manufacturing industries facilitating business assessment, productivity, sustainability and implementations of the SMART benchmarks.

The data collected via the structured interview and questionnaires are analysed employing the Statistical Package for Social Science (SPSS) tool. The SPSS tool is effective for analysing a large collection of data (Fowler, 2002). The results are illustrated graphically via bar charts, tables, scatter plots, pie charts. Etc. The validity and reliability of the data collected are obtained via the SPSS tool. Reliability ensures for consistency of the comprehensive data collected via probabilistic estimates based on the mean and standard deviations of the numerical data significant in understanding the research results (Cooper and Schindler, 2011). The average variations and perceptions are obtained validating the reliability or homogeneity of the data gathered. Validity tests if the comprehensive data collected addresses the objectives defined in this research. Results are analysed based on each section defined and presented in subthemes.

Table 1: An overview of the questionnaire construct

SECTION	CLASSIFICATIONS	QUESTIONS
A	Description	(a) Respondents understand the definition of 4IR related to the 4IR progress points (digitization, automation, and integration) detailed in the methodology section of this research. (b) The effective tools to measure and drive digitization, automation, and integration as a 4IR SMART implementations are understood. (c) Who is responsible for effectively aligning with 4IR implementations?
B	Significance	(a) Respondents understand the implications of linking digitization, automation and integration as a 4IR SMART enablers with business sustainability. (b) What is the timeline for reviewing 4IR implementations?
C	Strategies	(a) Effective strategies for innovation and advancements are available. (b) Respondents are interested if 4IR benchmarks are implemented in the manufacturing facility.

Section A: Description and adoption of 4IR implementations

(a) Respondents understand the definition of 4IR.

Figure 2 illustrates from a total of 285 feedbacks analysed related to respondents understanding the definition of 4IR. “100 respondents (35%) do not understand the definition”, “43 respondents (15%) misunderstood the definition”, “88 respondents (31%) partially understood the definition, “40 respondents (14%) understand the definition”, and “14 respondents (5%) remained neutral”.

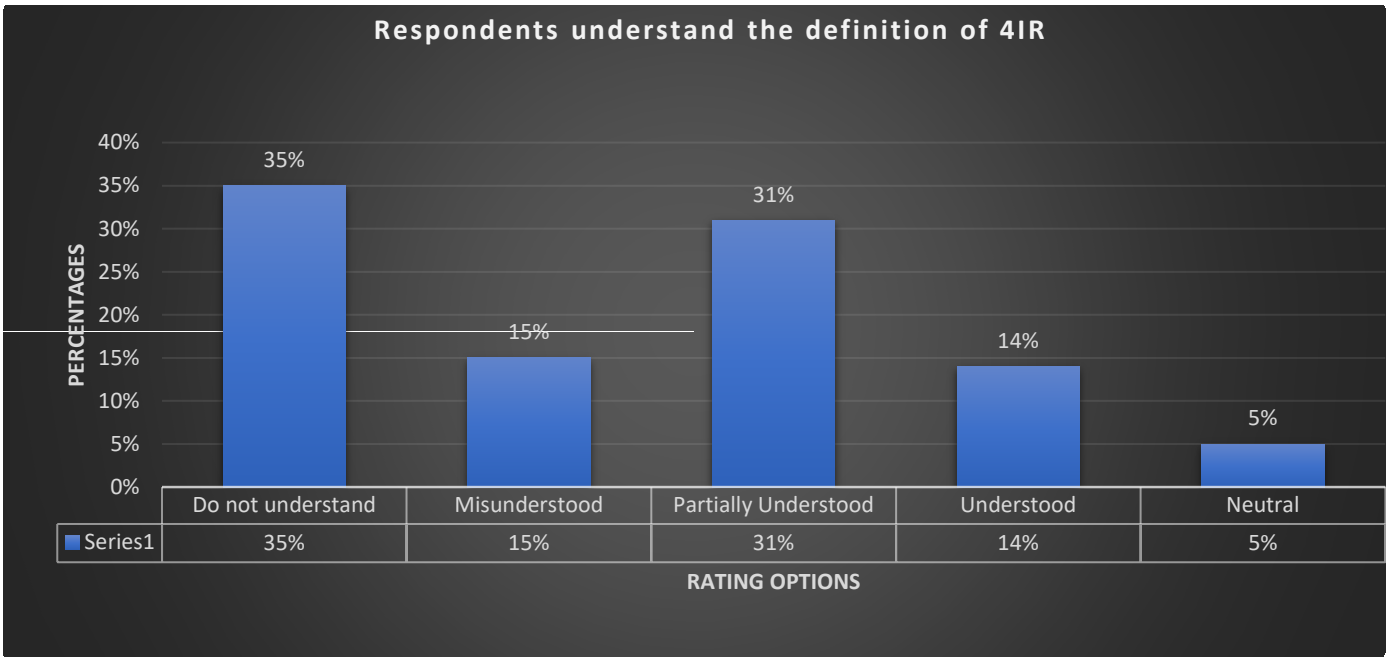

Figure 2. Respondents understand the definition of 4IR

(b) The effective tools to measure and drive digitization, automation and integration as a SMART indicator are understood.

Figure 3 illustrates from a total of 285 feedbacks analysed related to respondents understanding tools to measure and drive SMART enablers. "182 respondents (64%) indicates not clear" and "103 respondents (36%) affirms they understood.

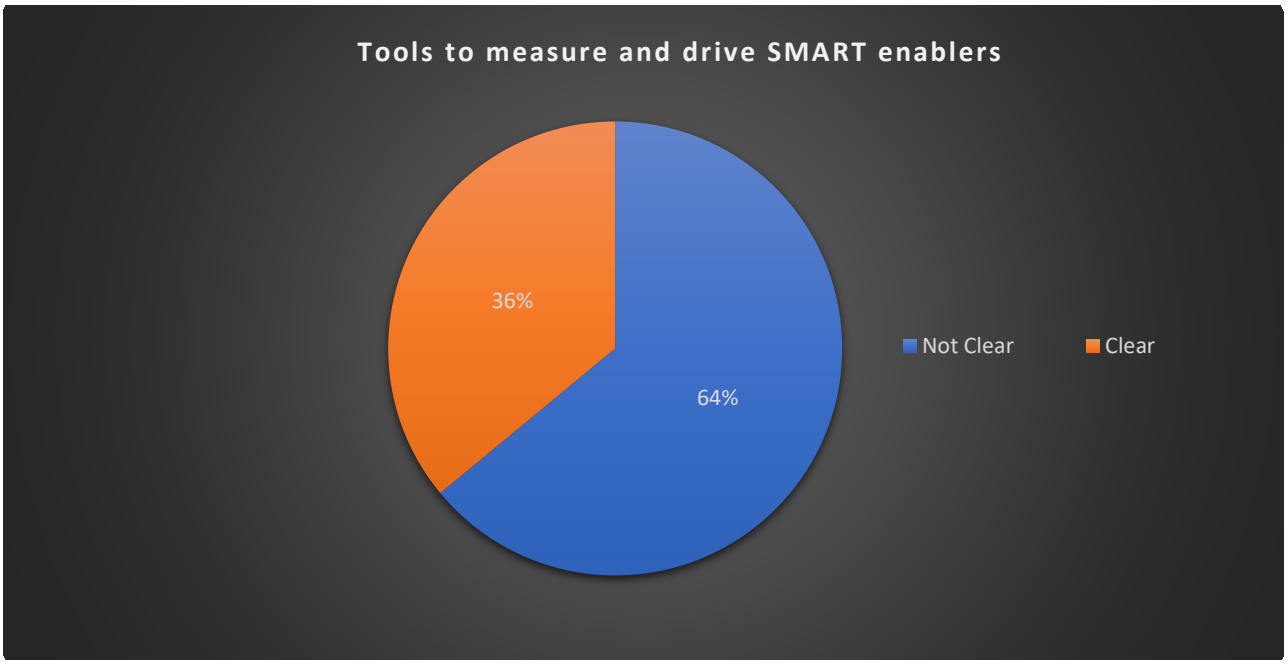

Figure 3. Understanding tools to measure and drive SMART enablers

(c) Who is responsible for effectively aligning with 4IR implementations?

Figure 4 illustrates from a total of 285 feedbacks analysed related who is responsible for effectively implementing 4IR implementations. “88 respondents (31%) indicates employees”, “63 respondents (22%) indicates executive and “134 respondents (47%) indicates manager.

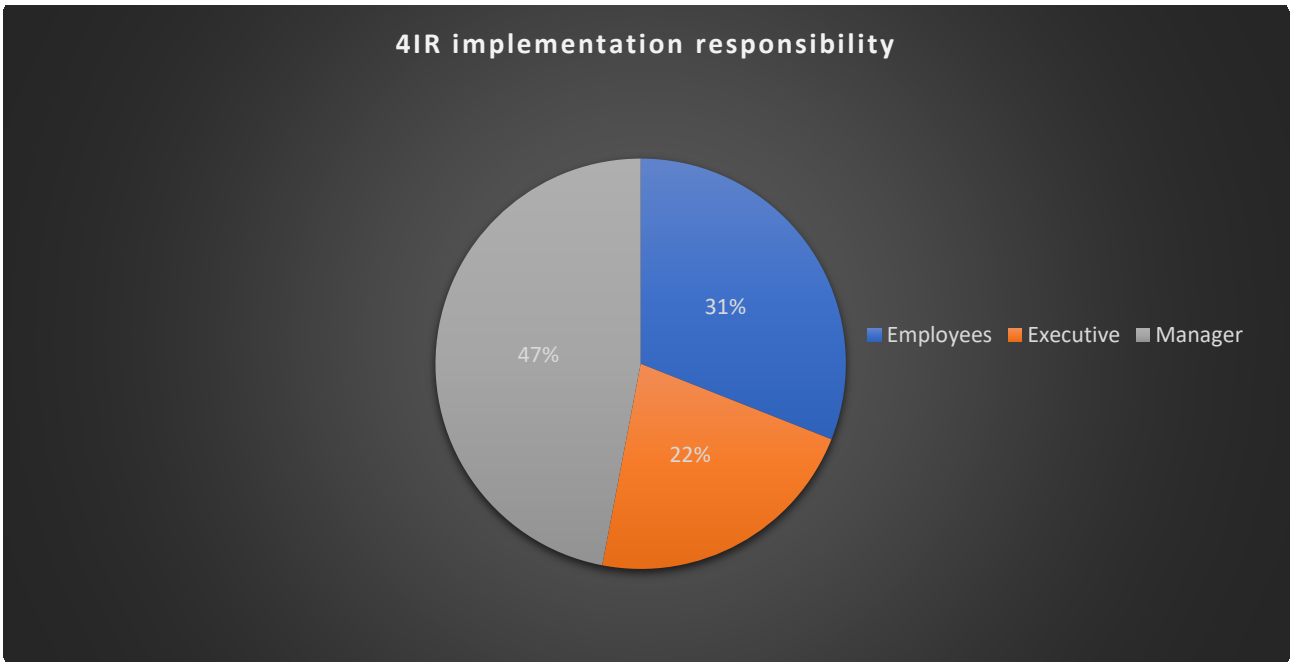

Figure 4. Who is responsible for effectively aligning with 4IR implementations?

Conclusively, section A establishes the concept of 4IR is poorly understood across manufacturing industries resulting in challenges in the effective implementation of 4IR benchmarks. The survey indicates respondents assume most of the responsibilities related to effectively aligning with 4IR implementations lies with managers, this is however false, as the implementations is strictly a communal effort.

Section B: Implications of implementing the 4IR understood

(a) Respondents understand the implications of linking digitization, automation, and integration as SMART enablers with business sustainability.

Figure 5 illustrates from a total of 285 feedbacks analysed related to respondents understanding the implications of linking digitization, automation and integration as SMART enablers with business sustainability. “54 respondents (19%) do not understand”, “69 respondents (24%) not clear”, and “162 respondents (57%) understands”.

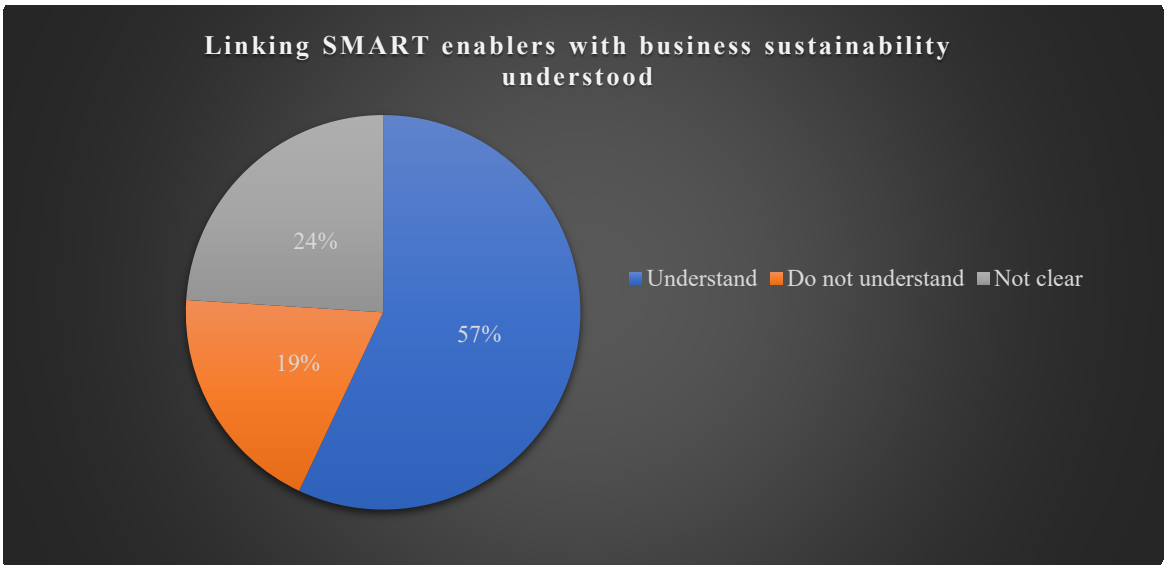

Figure 5. Implications of linking SMART enablers with business sustainability understood

(b) What is the timeline for reviewing 4IR implementations?

Figure 6 illustrates from a total of 285 feedbacks analysed related to respondents understanding the timeline for reviewing 4IR implementations. "180 respondents (63%) indicates quarterly", 68 respondents (24%) indicates bi-annual", and "37 respondents (13%) indicates annually.

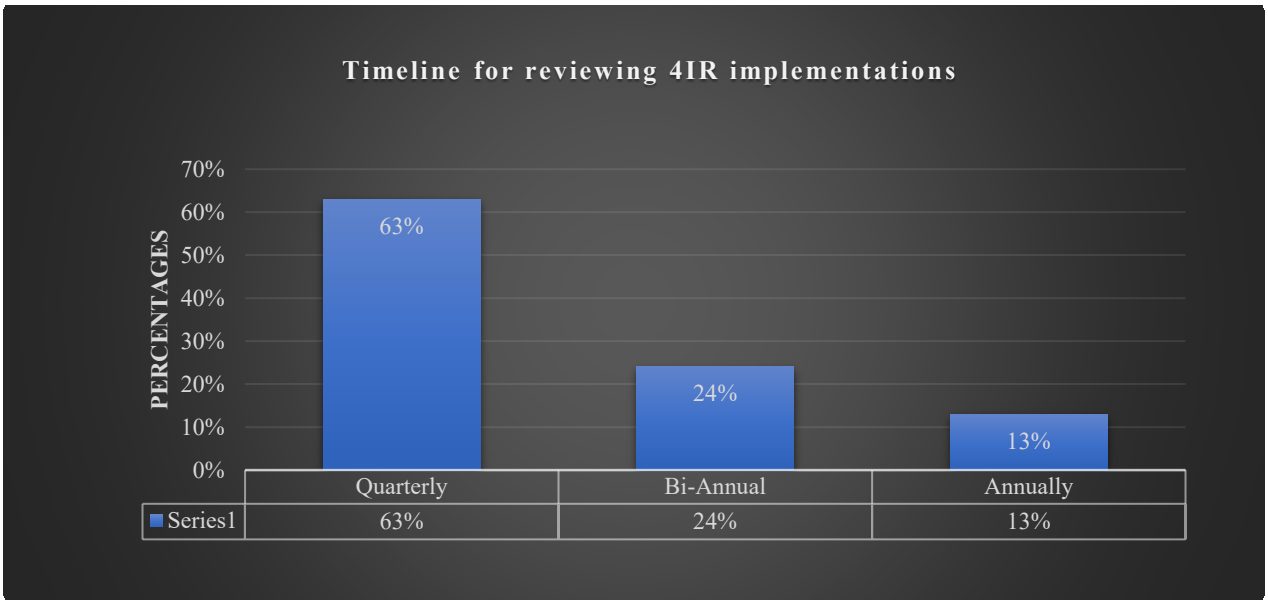

Figure 6. 4IR implementations timeline

Conclusively, section B establishes respondents quite understand the importance of linking SMART enablers with business sustainability, strategies, and philosophies. The survey indicates lots of respondents' supports the quarterly option for effective reviewing of 4IR implementations.

Section C: Availability and accessibility of corporate measures relative to 4IR implementations

(a) Effective strategies for innovation, and advancements are available.

Figure 7 illustrates from a total of 285 feedbacks analysed related to effective strategies for innovation, and advancements. "29 respondents (10%) not available", "168 respondents (59%) available", and "88 respondents (31%) not clear".

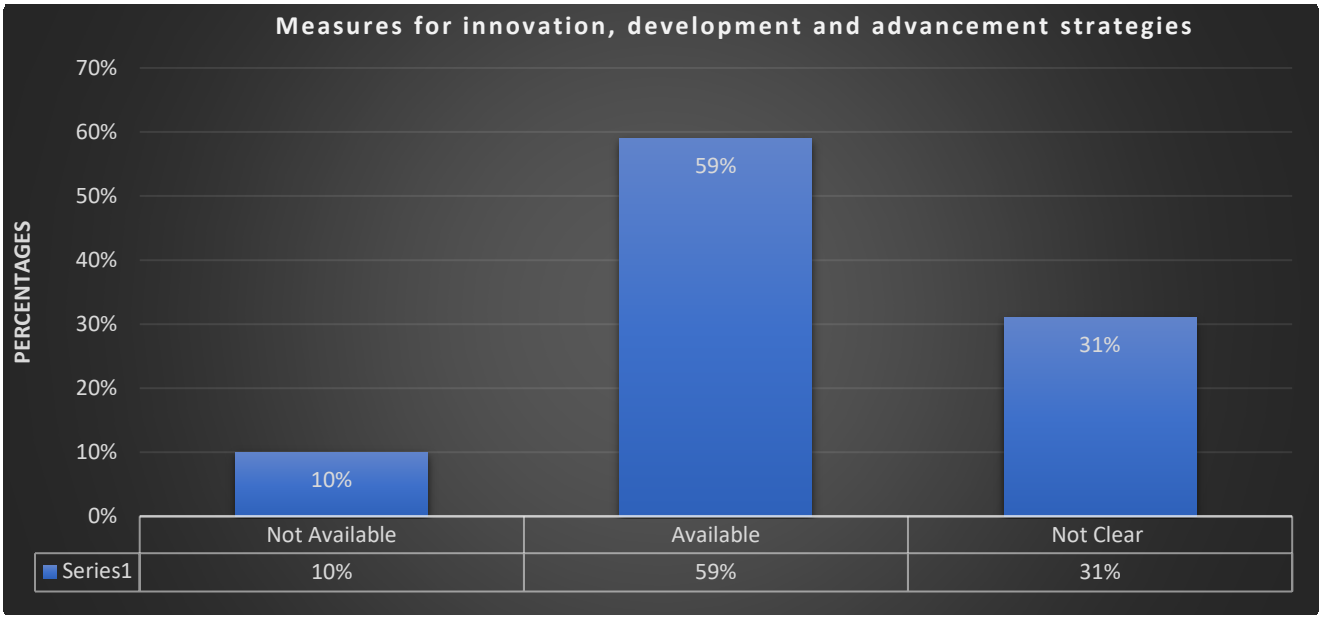

Figure 7. Effective strategies for innovation and advancements are available.

(b) Respondents are interested if 4IR benchmarks are implemented in the manufacturing facility.

Figure 8 illustrates from a total of 285 feedbacks analysed related to interest if 4IR benchmarks are implemented. "103 respondents (36%) indicates interested & not available", 68 respondents (24%) indicates interested, available & effective", "91 respondents (32%) indicates interested, available & not effective", and "23 respondents (8%) remained neutral.

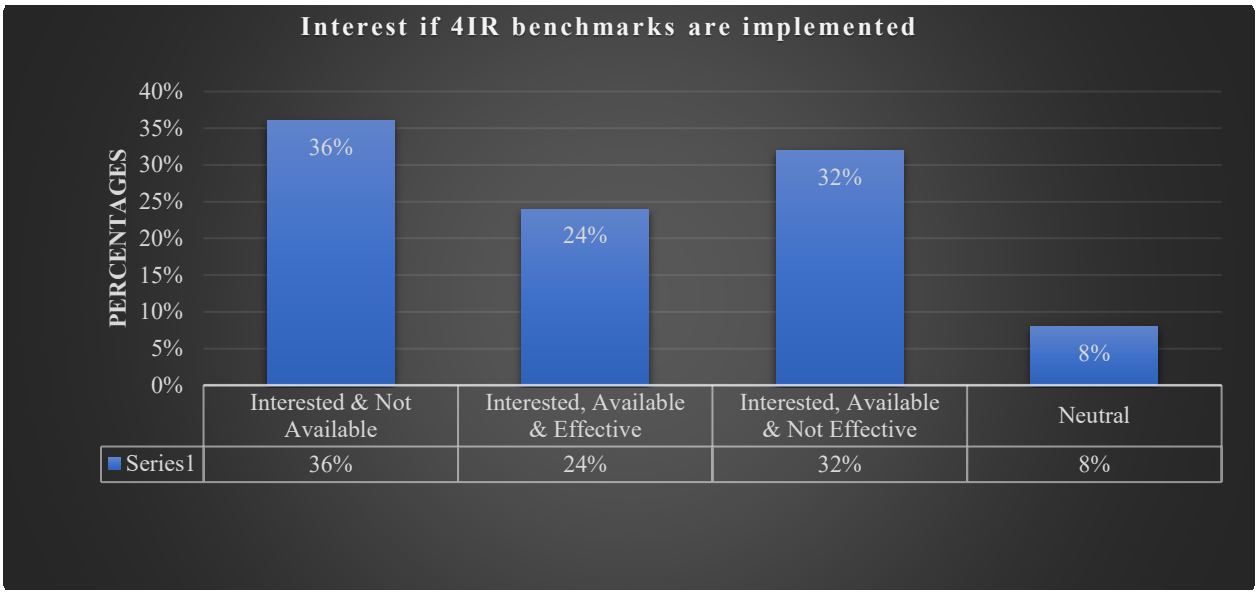

Figure 8. Interest if 4IR benchmarks are implemented

Conclusively, section C establishes despite the availability of effective strategies for innovation, and advancements. A number of respondents remain unclear relative to its importance. The survey indicates a higher percentage of the

respondents are interested in 4IR implementations despite the process not yet integrated into the manufacturing facilities. The survey establishes effective 4IR implementation tools such as stay-interviews, job crafting, awareness educations, and pulse surveys remain unclear.

Conclusion

This research evaluates the existing state of 4IR implementations in manufacturing industries related to an African context specific focus directed to Nigeria as a subset African country. Questionnaires and structured interview are employed as the principal methodology for collecting and analysing data. The data analysis is executed deploying SPSS tool. The results obtained validate the objectives defined in this research, which seeks to present an evaluation structure for effective adoption of the 4IR implementations. The outputs indicate many manufacturing sites still require education or training on the description, implications, and importance of 4IR implementations. The sensitizations include awareness of the tools to measure and drive 4IR implementations. Greater innovative and awareness drives related to 4IR implementations, tools combined with an effective structure facilitating business innovations and advancements are recommended to address gaps, priorities, and strengths essential for 4IR implementation improvements. Based on existing literature, this is inclusive but not limited to the effective application of digitalization, automation and integration strategies. This enhances sustainability, productivity, and competitiveness of manufacturing industries, also supporting a holistic structure for aligning business objectives with multiple stakeholders.

Emerging literature establishes the importance of constantly enhancing business functions in manufacturing facilities (Fosso Wamba & Mishra, 2017 and Arsanjani, et al., 2012). This research presents an evaluation tool via decision-support structure promoting the importance of integrating 4IR implementations with business functions in manufacturing facilities. The results aim at assisting manufacturing facilities to compare the existing state of its business relative to 4IR implementations. Conclusively, the comprehensive results establish inadequacies in developing and implementing 4IR strategies and the need to urgently define measures to address this limitation. Future studies might focus on extensively exploring the influence of 4IR implementations based on manufacturing industries with a fully integrated 4IR benchmarks.

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