Research Journal of Finance and Accounting
ISSN 2222-1697 (Paper) ISSN 2222-2847 (Online)
Vol.15, No.6, 2024

A Review on the Integration of Industry 4.0 Technologies in Management Accounting: Exploring Challenges and Opportunities for Enhancing Business Performance

Kudzai Chuma[1*] Dr Abubaker Qutieshat[2]

1. Doctoral Student, Institute of Distance Education, University of Zambia, PO Box 50110, Lusaka, Zambia
2. Institute of Distance Education, University of Zambia, PO Box 50110, Lusaka, Zambia

* E-mail of the corresponding author: kudzichuma@yahoo.com

Abstract

This literature review critically delves into the symbiotic relationship between Industry 4.0's technologies and management accounting, accentuating challenges and opportunities in the dual facets of pursuing enhanced business performance in the Fourth Industrial Revolution era. The key research problem revolves around effectiveness in harnessing the technologies of Industry 4.0 to management accounting. The review takes the shape of introducing readers through a comprehensive overview of the technologies of Industry 4.0, presenting theoretical framework and methodological rigour to ensure integrity. The core section contains the findings and discussion, for, as emerging challenges of adaptation and privacy are reviewed with some carefulness and some exciting new possibilities for automation, for data-driven decision-making, and innovation in business models. The paths of collaboration and strategic alignment then arise as conduits to efficiency and growth and so take their place in the unsurpassed record of business performance. Free writing in terms of business performance implications, the manuscript defends that exploring challenges and opportunities serve as a platform for attaining financial gains. And these are just not claims but are backed with real-time case discussions and application to authenticate the context. This concludes the review synthesising points of contentions and pointing out knowledge gaps by presenting a robust research agenda for any future scholar setting stage going forward in this dynamic field. Basically, this manuscript does not just synthesize the intricate intersection of Industry 4.0 and management accounting but accentuates the paramount significance in such interfaces. It leads the organizations to a promising future with improved business performance among the landscape of Industry 4.0 and management accounting with practical insights and recommendations.

Keywords: Industry 4.0, Management Accounting, Fourth Industrial Revolution, Internet of Things (IoT), Artificial Intelligence (AI), Automation, Data-driven Decision Making, Business Performance, and Technology Integration

DOI: 10.7176/RJFA/15-6-01

Publication date: June 30th 2024

1.0 Introduction

1.1 Introduction to Industry 4.0 and its impact on management accounting.

Among the continuing scenario of industrial evolution where the fourth phase in progress called 'Industry 4.0', yet stands true to the nature of a transforming revolution proportional characteristic to the anterior eras. This era encapsulates the combination of cyber-physical systems, Internet of Things (IoT), artificial intelligence (AI), and other such technologies that lead to a remodelled environment for manufacturing, decision-making, and business performance. It is a synergy between the physical and the digital that makes Industry 4.0 automate processes with precision, and use data to an extent of strategic sculpting that has not been experienced before.

But beneath the veneer of financial reports and management decisions, there is a quiet revolution rippling through in the world of management accounting, the discipline keeping up the financial pulse of organizations inconspicuously. As the Industry 4.0 progresses, its impact on management accounting extends way beyond the shop floor and right along all those old lines of decision-making, resource allocation, strategy formulation.

This review uncovers the nuanced relationship between Industry 4.0 and management accounting, a range of challenges from grappling with how to adapt to such enormous change through to how to ensure data quality and privacy. On the contrary, it identifies many business opportunities in automated potentials, decision-making driven through data, and innovative business model. The central question of the manuscript touches on the manner that in the 21st century an organization would optimize business performance by effectively assimilating Technology of Industry 4.0 within the sphere of management accounting.

Using real-world examples, analytic insights, and effective journal articles, this work attempts to unfold the common description of financial performance while trying to unravel the concrete influence that mingling management accounting with Industry 4.0 unfolds. Within that narrative, enterprises face complex challenges while at the same time they encounter an array of opportunities to establish within it dynamic weave of the business ecosystem. The manuscript serves to be the compass guiding organizations through the dark forest of both Industry 4.0 and management accounting, specifying a way for enhanced business performance.

2.0 Industry 4.0 Technologies in Management Accounting: Concepts and Theoretical Framework

2.1 Definition and components of Industry 4.0 technologies.

Definition

The Fourth Industrial Revolution, or what is commonly known as Industry 4.0, in simple terms, means a transformation concerned with the integration of digital technologies with conventional industrial abilities. It marks an enormous shift in the industrial operations, making use of contemporary advanced technologies for better efficiencies and productivity and innovations.

Examples of Components include but not limited to the following.

1. Internet of Things (IoT)

The internet of things uses connections of physical devices, sensors, and machines through the internet enabling them to collect data real time and engage in an exchange. This connectivity gives unprecedented insights into industrial operations working out basis of smart decision making.

2. Big Data and Analytics

Industry 4.0 produces vast datasets. Big Data and its associated tools are used to mine, analyze, and make sense of that data, and derive insights that are essential for strategic moves, product quality improvements, and efficiency in supply chain operations.

3. Artificial Intelligence (AI) and Machine Learning

The learning becomes artificial through the machine learning algorithms as well as the artificial learning to result in automation, predictive analysis as well as the cognition computing. Implementation of these functionalities enables the system to learn as well as adapt enhancing the operational efficiency thus resulting in autonomous decision makes.

4. Cyber-Physical Systems (CPS)

Cyber Physical Systems, concerning the systems integrating the physical and digital world through sensors, software, and hardware, form a major segment of the industrial arena. These play an important role in monitoring, control, and coordination of the various industrial process in real time so that it is synchronization along the production line.

5. Cloud Computing

Cloud computing allow data storage and computation scaling with cheaper costs. This way, users can access their critical system and data from remote locations, hence ensuring collaboration and accessibility.

2.2 Explanation of how these and other such technologies can be integrated into management accounting.

The incorporation of the technology involved in Industry 4.0 in the management accounting marks an entire step forward to modernize the financial and accounting practice. This is incorporated through various strategies that include,

Real-time Data Collection and Analysis

In all stages of the production process, data is collected by Internet of Things sensors and Cyber Physical Systems. This real-time data is then integrated in the management accounting systems, enabling continuous tracking for both operations and financials.

Predictive Analytics

Second, Artificial Intelligence and machine learning algorithms would be able to predict cost variances, income forecasts, and future financial trends. These predictive insights then can be used proactively by the management accountants in decision-making.

Automation of Administrative Tasks

Artificial Intelligence along with robotics process automation (RPA) automatically processes time-consuming and routine-like jobs of data entry, transaction processing, and report generating to reduce time and avoid errors.

Cost Allocation and Activity based Costing

The technologies of the industry 4.0 can follow to the product or service cost very precisely. Moreover, real-time data on manufacturing processes can improve activity-based costing models.

Better Reporting and Visualization

Augmented and virtual reality advancements facilitate immersive financial data visualization. Through the interactive 3D environments, the management accountants are capable of perusing the available financial data to make decisions or for analysis in the performance of any organization.

2.3 Theoretical models and frameworks relevant to the integration.

These include theoretical models and frameworks guiding the integration of Industry 4.0 technologies to management accounting:

Resource-Based View (RBV)

Resource-Based View focuses on digital resources for competitive advantage. In the context of management accounting, this theory sees the incorporation of Industry 4.0 technologies to exploit resource allocation towards improved performance (Barney, 2000).

Technology Acceptance Model (TAM)

Models of technology acceptance assess what is the nature of impacts that would allow the dissemination of new technologies (Davis, 1989). Applied to management accounting, Technology Acceptance Model describes the way how people accept and use tools of Industry 4.0 functioning in organizations.

Balanced Scorecard (BSC)

The Balance Score Card provides a framework in which strategic goals can be matched with key performance indicators (KPIs) as touchpoints to Industry 4.0. It makes the measurement and evaluation of extremely differing characteristics of both financial and non-financial aspects as performance components easier and possible (Kaplan, 2005).

Activity-Based Costing (ABC)

The real-time data in the technologies of Industry 4.0 extends the Activity-Based Costing so as to improve the allocation and enhance the decision-making process (Kaplan, 1998). It helps the management accountant identify the cost drivers and allocate the resources effectively.

3.0 Methodology

3.1 Explanation of the literature review methodology (e.g., databases, search criteria, inclusion/exclusion criteria).

The methodology part will describe the systematic approach that was taken in looking for, choosing, and synthesizing the relevant literature on the integration of Industry 4.0 technologies in management accounting. This is in a bid to have a strong and credible literature review.

Databases and Data Sources

The searches were comprehensive from broad scholarly databases and repositories.

Search Criteria

Precise search criteria had to be predetermined in order to identify key articles, including the use of journal articles below five years. In narrowing and broadening the search, the primary keywords and phrases used included "Industry 4.0," "management accounting," "digital technologies," "integration," "challenges," and "opportunities" using the appropriate Boolean operators (AND, OR) in Google Scholar and all the other databases mentioned above.

Inclusion/Exclusion Criteria

All the articles reviewed were scholarly publications and industry reports on integrating Industry 4.0 technologies in management accounting. The exclusion criteria were literature that either did not directly deal with the research topic or did not cut to be exceptional quality standards already set.

3.2 Description of the search process and data collection.

The search process was conducted in a structured and systematic manner so as to access all the literature pertaining to the subject. The process consisted of the following steps,

Initial Search

A preliminary search based on the defined keywords and criteria was made using the selected databases. The literature search aimed to provide more variety in the material to elaborate on the topic.

Screening and Selection

Articles were reviewed based on their titles, introduction, abstracts, and conclusion after the initial search. At this point, irrelevant off-topic articles were discarded. Full texts of possibly suitable articles were pursued for further evaluation.

Full-Text Review

After selecting the articles, all the articles were reviewed for data extraction by way of an annotated bibliography to ascertain their relevance in light of the research. All other articles whose content did not relate to the objectives of the literature review were expunged from qualitative synthesis.

Data Extraction

Key findings, challenges, opportunities, suggested research gaps and theoretical frameworks of relevance to the study were systematically harvested from the articles selected. Organisation of data relevant to the study for further analysis is outlined next.

3.3 Data analysis and synthesis techniques.

Some of the techniques used were within the synthesis of findings and insights from these literatures,

Thematic Analysis

Data that was extracted from these literature was grouped thematically (Braun, 2006). Most common themes identified were on challenges in integration, opportunities on business performance, conceptual frame work, lastly technological components.

Comparative Analysis

Comparative analysis was conducted to identify variations and similarities across different studies. This approach facilitated a comprehensive understanding of the subject matter (Weber, 1949).

Synthesis of Findings

The findings from selected articles have been synthesized, and a coherent overview of the current status of knowledge on the topic has been produced. This synthesis also provided the base for identification of research gaps and drawing conclusions. This methodology made relevant literature selected and analyzed systemically, facilitating that the comprehensive and credible review of the articles on the integration of Industry 4.0 technologies in the management accounting.

4.0 Literature Review Results

4.1 Findings on Challenges of Integrating Industry 4.0 Technologies in Management AccountingChallenges of Change Management and Adaptation

The digitalization requirement from the Industry 4.0 demanded exacting adaptation to facilitate intricate and expensive integration of new advanced technologies into the existing management accounting systems (Ahmad, 2019). The challenges relate to transforming the traditional way into digital data, complex manipulation of data as well as shifts of management control (Yu, 2020). Industry 4.0 transition brings challenges connected with adaptation of the new accounting systems including time-consuming, need for retraining and investments (Azcarate-Aguerre, 2022). Culture change and operations in particular, most especially within SMEs, are facing a tendency toward a circular economy and sustainable practices (Allioui, 2023). During the implementation of the Industry 4.0, lack of a clear strategic intent might create sub-optimized results (Cai, 2022). Challenges are also in the form of lack of regulator support to Blockchain adoption and inadequate disclosure impacting information flows (Jiang, 2022).

Data Quality and Integration Challenges

Managing massive amount of data from the Industry 4.0 technologies is the challenge as it impacts on data accuracy, reliability, and integration (Zolkifli, 2022). Issues may arise including data de-contextualization, centralization of 'truth,' and associated challenges in managing complicated and unstructured information (Wijethilake, 2018). Incorporation of digital technologies may culminate in disruptions and issues related to maintaining operational efficiency (Buer, 2021). Challenges also involve difficulties in the smooth integration more so in the Internet of Things and lack of sufficient information on disclosure affecting the flows of information (Van Dung, 2019).

Privacy and Security Challenges

Enhanced connectivity appropriate to data-sharing in industry 4.0 refuels worries over the privacy and security of data (Butler-Adam, 2018). For example, challenges include cyber threats and data breaches, as well as ensuring that the large amounts of data are kept confidential, integral, and authentic (Fähndrich, 2023). Other challenge is compliance with increasingly complex sustainable practices regulations and standards that increases

costs (Bian, 2022). From the discussion, further to the outsourcing of accounting functions, a major issue that was highlighted is trust and privacy through the Internet of Things data collection (Abdelhalim, 2023).

No Skill or Competency Gaps

For the integration of Industry 4.0 technologies, the workforce needs advanced digital skills (Hahm, 2018). Challenges would entail the costs and time that are associated with upskilling the current workforce or even bringing in a new one (Akanmu, 2021). The main challenge is the resistance of professionals from this technology especially in developing countries (Allioui, 2023). Fast-paced technological changes and constantly evolving landscapes pose challenges in ensuring, accountants have such skills (Cugno, 2021).

Challenges to Cost and Investment

Significant initial costs of technologies, software, and infrastructure are required if the organization is not only to adopt but also be successful with Industry 4.0 technologies (Joshi, 2023). There is a significant financial commitment in implementing sustainable practices as well as the technologies brought out by Industry 4.0 (Inam, 2020). There are huge amounts of initial costs incurred for infrastructure setup associated with electronic invoices (Alkaraan, 2022) (Anshari, 2022). The challenges that come with it is high initial costs and experiencing financial strain including concerns over profit reduction (Heller, 2019).

4.2 Findings on Opportunities Arising from the Integration of Industry 4.0 Technologies in Management Accounting

Automation and Efficiency Opportunities

These technologies under Industry 4.0 open the doors toward automation and streamline of financial processes (Frederico, 2021) (Nankervis, 2021). With automation, manual effort is eliminated and errors are reduced whereas better efficiencies lead to saving as well as reflected in financial performance (Manesh, 2020). Higher operational efficiency facilitates saving on wastages to an extent, and it may help as a net loss even if there is no savings over operational costs of the manufacturing system but qualitative enhancements for such operations (Nørreklit, 2023).

Opportunities in Data-Driven Decisions

The rolling out of technologies in Industry 4.0 offers the integration of financial data in real-time, accuracy and dependability which is a prerequisite in making data-driven decisions (Piosik, 2022). The data greatly helps in resource allocation, and strategic financial planning through analytics, and real-time flows at all stages thus cost savings or growing income (Oleiwi, 2023).

Business Model Innovation Opportunities

Improved control and predictability over the management accounting and construction projects enhance the financial performance (Varaniūtė, 2022).

Industry 4.0 technologies open ways to business model innovation, diversification in the offerings, and find out new revenues to fund the ventures (Kriz, 2018) (Kumar, 2020). Innovation in products and services result in the surge in market share, revenues, and profitability (Tsiligiris, 2021) (Török, 2022).

Opportunities for Collaboration and Integration

Effective coordination of resource management and breaking of silos in information guarantees efficient collaboration and data integration across the departments in an organization (Karmańska, 2021). Breaking of silos in organizations also assures better operational efficiency and enhances more financial outcomes (Tran, 2023).

Strategic Alignment Opportunities

Strategic alignment of management accounting and financial performance (Singaram, 2022) (Naciri, 2023). Financial strategies may be accurately aligned with broader objectives that optimize resources for sustainable value creation using Industry 4.0 technologies (Seshadrinathan, 2021) (Sroufe, 2019).

Opportunities Arising With A Customer-Centric Approach

The technologies of industry 4.0 would allow businesses to easily gather and analyze customer-related data (Mariani, 2019) (Sokolenko, 2020). The satisfaction, loyalty, sales, and revenue of customers would become reinforced through the customer-centric approach (Rutherford, 2020).

Sustainability and Social Responsibility Prospects

This enhances social responsibility and reputation of the organization through this sustainability practices integration. It is a way of attracting socially responsible investors with positive impacts on financial performance (Mhlanga, 2020) (Mian, 2020).

Opportunities to enhance employee skills

Improving skills for accountants therefore involve addressing skill weaknesses and exploiting the potential of 4IR technologies (Mbizi, 2022). Accountants who are trained professionals offer enhanced financial decision-making in addition to value-added services (Reis, 2021) (Sartal, 2022) (Pramono, 2023).

4.3 Findings on Implications for Business Performance, how addressing challenges and capitalizing on opportunities can lead to improved financial performance.

Integration of Industry 4.0 Technologies in Management Accounting

Challenges involved in integrating Industry 4.0 technology would be resistance to change, skills gaps as well as cyber risks (Mohd Faizal, 2022). Succeeding integration comes with the cost-saving approach, enhanced revenue stream, and better profits from efficiency (Mohd Faizal, 2022). Better or improved customer relationships and satisfaction through technology will also mean increased sales and customers frequent business more often (Alsughayer, 2023).

Internet of Things (IoT) in Accounting

Internet of Things in accounting implementation also enables access to data in real-time, better decisions and reduced cost (Bhimani, 2020). It boosts revenue with the aid of data-driven marketing efforts and sales while reducing financial risks as a result of detection for fraud (Manesh, 2020). Its minimization of operation costs makes it able to attract more customers hence, more business by increasing competitiveness within the market (Heller, 2019).

Changing Role of Management Accountants

The interpretation of data and usage of technology by management accountants for strategic decisions are reportedly a part of the changing role of management accountants (Karmańska, 2021). Technologies under industry 4.0 offer real-time access to data and efficiency gains as well as insights from data to enable better financial strategies (Ahmad, 2019) (Bhimani, 2020). Strategic decision support will enhance the resource allocation and the market positioning in which the organization will gain competitive advantage (Anshari, 2022).

African accountants and the Fourth Industrial Revolution (4IR)

The opportunities of boosting the financial performance associated with 4IR in Africa will be addressed (Fähndrich, 2023). The revenue generation and profit improvements associated with data-driven insights, efficiency gains, and global connectivity among others will be realized (Jiang, 2022). Financial performance sustainability through challenges in addressing elements such as technology preparedness in the African context will be realigned (Mbizi, 2022) (Mhlanga, 2020).

Accounting and Sustainability in Developing Economies

Sustainability embraced in the developing economies improve financial performance (Mbizi, 2022). Market differentiation brings positive influence towards financial outcomes, cost reduction, innovation, and access to capital (Mhlanga, 2020). Rejuvenating reputation, partnership, and collaboration create new business opportunities and revenue streams (Mbizi, 2022).

5.0 Literature Review discussion of the Results

5.1 Discussion on Challenges of Integrating Industry 4.0 Technologies in Management Accounting

Adaptation and Change Management Challenges

The adaptation and change management challenges underline as being the most urgent among the imperatives that organizations need to address including barriers such as resistance to change, unpreparedness on the work force, as well as the imperative of strategic intent. These implications highlight effective change management strategies, focus on investment in training of employees along with the alignment needs as being imperative towards Industry 4.0 implementation (Alkaraan, 2022).

Challenges in Quality and Integration of Data

The management should therefore be proactive in addressing these challenges for any organization that wishes to derive value from the data. Challenges such as data quality and integration have indicated the relevance of investment in different integration solutions, policies on data governance, as well as strong data management systems (Horváth, 2019). The demand for reliable, complete, and timely data has affirmed the need for accurate financial insights and effective decision-making at the heart of management accounting.

Challenges of Privacy and Security

It requires robust privacy frameworks, encryption protocols, and cybersecurity measures to overcome challenges pertaining to privacy and security. Management accountants should work with IT and security teams to protect financial data as it could bring in heavy penalties and damage the reputation if not handled properly while practicing privacy regulations.

Skill and Competency Gaps

Skill and competency gaps encompass continuous training, development, and adaptiveness. Organizations have to invest in preparing employees to use Industry 4.0 technologies, acknowledging that the skills required in the digital landscape are shifting (Hahm, 2018).

Cost and Investment Challenges

Effective financial planning, risk assessment, and resource allocation hence become of great importance in the management of the sizeable costs involved in the adoption of Industry 4.0. It will be important for the management accountants to assess the economics of technologies, and align strategic investments (Hahm, 2018).

5.2 Discussion on Opportunities Arising from Integrating Industry 4.0 Technologies in Management AccountingAutomation and Efficiency Opportunities

Indeed, with incorporation of technologies that powers Industry 4.0, there is a means of improved efficiency in automation that ultimately will tremor down costs and eventually improve financial outcomes (Mian, 2020). In the context of the manufacturing processes, adoption to these technologies is efficient for creating opportunities within organizations in obtaining operational efficiencies, with increased resource optimisation.

Opportunities for Data-Driven Decision Making

The establishment caused from Industry 4.0 technologies would create an opportunity in terms of making data-driven decisions to assist in capitalizing real-time data to enhance resource management and reduce the cost associated with the business process. The proper implementation of data analytics would be significant enough in contributing considerably toward better decision-making for improving financial results.

Business Model Innovation Opportunities

Opportunities for business model innovations suggest the technologies of Industry 4.0 can radically transform the business, argue for the novel methods of revenue generation such as open-source and begin its journey of digital transformation to enhance financial performance (Joshi, 2023).

Collaboration and Integration Opportunities

Collaboration and integration opportunities show the importance of breaking down organizational silos, enhancing coordination, and achieving better operational efficiency. This has a positive influence on financial performance.

Strategic Alignment Opportunities

Strategic alignment opportunities bring the need for integrating Industry 4.0 technologies to align the financial strategies with organizational goals and objectives. Such an alignment promotes sustainable value creation and better financial result.

Customer Engagement Opportunities

Customer-centric approach facilitated by Industry 4.0 technologies enables organizations to enhance customer experiences ensuring higher satisfaction levels, thus translating into better sales and revenues. Improves overall financial performances.

Sustainability Prospects

Opportunities in sustainability and social responsibility underline the connection of business ethics with financial performance. Implementation of Industry 4.0 technologies gives birth to reputation enhancement and attraction of investments from organizations focused on social responsibility.

Opportunities for Enhancing Employees' Skills

Investment in workforce capabilities and provision of opportunities to improve employee skills highlight the necessity for employing well trained accountants. Such professional employees may materially contribute to financial decision-making processes and add value to organizational processes (Marsintauli, 2021).

5.3 Discussion on Implications for Business Performance, how addressing challenges and capitalizing on opportunities can lead to improved financial performance.

Integration of the Technologies in Industry 4.0 within Management Accounting

The way forward is overcoming challenges and grasping opportunities for integration in Industry 4.0. Derived concepts can help in an improvement of a company's financial performance through utilization of technology for innovation, cutting operational cost, as well as focusing on customer satisfaction (Mohd Faizal, 2022). Instead of using Big Data Analytics, real-time access to data, empirical research, and Industry 4.0 literature updates are employed for better decision making that, in return, promotes operational efficiency with financial growth.

Internet of Things (IoT) in Accounting

Firms that successfully respond to the challenges and capitalizes on opportunities offered by IoT are likely to improve the financial performance. The transformative impact expresses better decision making, increased profitability as well as competitive differentiation among entities playing in the same market (Karmańska, 2021). By integrating IoT to accounting practices has proven to be an improved effect on the financial stability and performance of an organization in terms of ensuring better flow of data and operation is efficient.

Adapting Opportunities in Financial Performance

The changing role of management accountants in the context of Industry 4.0 provides a set of opportunities for enhancing financial performance. The strategic use of real-time data, automation, and decision support has impacts on cost control, customer satisfaction, and overall financial outcomes.

Accountants in Africa and the Fourth Industrial Revolution (4IR)

Effectively navigating such challenges and leveraging this wave of the 4IR in Africa could significantly improve financial performance. This would entail addressing issues such as technological readiness gaps, skills gaps, as well as embracing automation for cost savings, revenue growth, and being competitive globally.

Accounting and Sustainability in Developing Economies

Adopting sustainability within accounting practices in the emerging economies offer opportunities for better financial-firm outcomes. Where firms contribute to Sustainable Development Goals (SDGs), they become differentiated within the market, saved cost, growing revenues, and earning reputational gains that culminate into better financial outcomes (Piosik, 2022).

6.0 Case studies of real-world examples demonstrating the impact on business performance, classified in accordance with the themes above.

Leading global examples have concretely demonstrated financial gains that could come with the application of Industry 4.0 technologies to associated industries. Bosch Rexroth, in particular, applied the smart sensors into its operations resulting in real-time data analysis, condition monitoring as well as predictive maintenance while depicting more excellent throughput together with efficiency at notably lower costs than before (Rexroth, 2023). Similarly, Siemens implemented Industry 4.0 technologies including sensors which were IoT-enabled thus enhancing efficiency in production, reducing downtime and optimizing on resources, with related outputs in the dimension of cost reduction as well as increasing returns (Siemens, 2023).

In a scenario of accounting in an IoT context, General Electric (GE) used IoT sensors for real-time monitoring of aircraft engines to develop predictive maintenance and work cost-effectively. This development allowed reliability improvement that enhanced customer satisfaction developing growth in revenue and profitability (Electric, 2023). Maersk Line embedded the sensors of IoT in its shipping containers to enhance its visibility within a supply chain, leading to cost reduction and enhancing customer service that impacted the company's financial performance positively (Maersk, 2023).

An example of the changing role of management accountants involves PricewaterhouseCoopers (PwC) which entailed accountants, armed with better skills in data analytical, led to clients achieving improved financial performance that translated into enhanced profits and informed decisions (PricewaterhouseCoopers, 2023).

Unilever accentuated ethical and sustainable accounting strengthening its reputation to draw attention from the socially responsible investors who invest for long-term financial performance (Unilever, 2023).

In light of the Fourth Industrial Revolution (4IR) in Africa, Sasol's adoption of the Industry 4.0 technologies lifted its operation by notching-up operational efficiency, cost management, as well product quality hence getting aligned with the 4IR principles while making contribution towards improved financials for Sasol (Sasol, 2023). Equity Bank in Kenya, however, welcomed both mobile banking as well as digital financial services that align with 4IR principles which have greatly expanded customer base while recording increased revenue and experiencing national and international expansion (EquityBank, 2023).

The sustainable accounting practices of Nestlé Nigeria optimized the resources usage, minimized waste generation and sustained on sustainability helped in cost savings, enhancement of reputation, and increase in sales (Nestle, 2023). Eskom, electricity utility player of South Africa, undertook sustainable accounting practices for realizing the cost saving, compliance towards regulatory, and better financial performance along with addressing the sustenance issues (Eskom, 2023).

7.0 Knowledge Gaps identified in the existing literature related to the integration of Industry 4.0 in management accounting

7.1 The identified knowledge gaps were also classified per the running themes identified in the previous sections of this literature review.

Integration of Industry 4.0 in Management Accounting

(Yaqub, 2023) outlines some of the focal points of challenges in the integration of Industry 4.0 in management accounting methods highlighted, including small sample sizes and the fact that the focus was on Polish context calls for future research to look into motives for underutilization among management accounting systems among firms vine genuine high financial performance in Industry 4.0. (Ciliberto, 2021) Highlights the theoretical perspective while suggesting empirical validation of proposed frameworks, throwing light on optimal strategies that should be used for adopting digital technologies to foster sustainable development.

(Ramadan, 2022) recommends future research on the manner information regarding Industry 4.0 is communicated in the annual reports of the firms, specifically its impact on financial performance that is associated with ESG practices. (Thuan, 2022) also stresses more research on accounting information systems used for operational efficiency amidst the environment of Industry 4.0.

Changing Role of Management Accountants

(Mbizi, 2022) Points out that the organizations of professionals, universities, and employers need to make preparations regarding the changing role of management accountants for Industry 4.0. (Bhimani, 2020) Says issues in relationships among the technologies of FIR and HRM theories, challenges on integrating digitalization and lean manufacturing and what is the real meaning of Industry 4.0 to change particularly attitudes and performances of workers. PwC and Unilever both typify the shifting mandate of accountants towards data analytics, insights-oriented decision-making along with an agenda of sustainability and ethics (PricewaterhouseCoopers, 2023)

Accountants in Africa and the Fourth Industrial Revolution (4IR)

Within the context of Africa's Fourth Industrial Revolution (4IR), (Mbizi, 2022) posits digital skills and data management, demonstrated with Sasol and Equity Bank, who adopted Industry 4.0 technologies. Research gaps in literature include empirical-based research, investigation of causality as well as understanding how the

Industry 4.0 will affect different typologies of companies (Bhimani, 2020); (Fähndrich, 2023); (Marsintauli, 2021); (Möller, 2020).

Accounting and Sustainability in Developing Economies

Sustainability and accounting in the emerging economies demonstrated in Nestlé Nigeria, and Eskom, reveal sustainable practices of cost minimization leading to financial performance (Eskom, 2023); (Nestle, 2023). Literature reveals that accounting plays a role in advancing sustainability objectives within Africa and other emerging economies (Bhimani, 2020).

The existing works show, above all the gaps in knowledge management, impact of changes caused by Industry 4.0 on knowledge management, bad consideration on human interactions in design of Cyber-Physical Production Systems (CPPS) among other which require further research on managerial impacts, role of service industries, and impacts of manuscript access on results.

7.2 Unanswered questions, and suggestions for potential areas for future research

Unanswered Questions

How does communication of information about Industry 4.0 in the annual reports lead to increased financial performance of the companies? How is this moderated by ESG (environmental, social, governance) practices?

What practices and frameworks specifically make up the integration of lean manufacturing with digitalization? In what way does the combination of these two paradigms change operational performance and sustainability among industries?

What attitudes, skills, competences that should be put in place for HR professionals to be able to respond efficiently towards the challenges of FIR technologies? What are the sections of HRM theories and models that should be revised and adapted to the needs of the Industry 4.0 period?

7.3 Potential areas of research

A research that investigates and compares the adoption and benefit from Industry 4.0 technologies for management accounting - manufacturing versus service industries across the countries.

Secondly, differences in industry will be explored for the management accounting integration of Industry 4.0 technologies. Also, how specific sectors like manufacturing, services or healthcare adapt and benefit differently of it.

Thirdly, gain insights on ways through which impacts of changes within Industry 4.0 affects the decision making processes at various levels in organization by exploring strategies towards optimization and performance enhancement.

The fourth area of the possible research is a development of a framework towards integration of lean manufacturing principles with Industry 4.0 technologies effectively and analyse its implications to efficiency and sustainability.

Number five is exploring the gap between present skills of HR professionals and what will be required for them in future in context to FIR technologies. For seeking innovative systems, processes, programs which may pave a way towards technology architecture and bridge this gap.

Number six to examine the unique challenges and opportunities that face service industries in the integration of Industry 4.0 technologies to management accounting practices.

Number seven explains the challenges of industry 4.0 adaption for SMEs in developing countries outlines and the strategies that will help to overcome the barriers of this adaptation such as cost, skills, and technology adoption.

Eight will also inquire about the effects of changes that relate to Industry 4.0 across levels of organization, that is, strategic, tactical, as well as operational. This would include collecting invaluable insights for comprehending ways by which these changes affect decision making processes and metrics of performance.

Number nine should conduct a multinational study to analyze ways of different countries for implementing Industry 4.0 in managerial accounting. Perform investigations about cultural influences and regulatory frameworks as well as their impacts on acceptance of Industry 4.0 in management accounting and its performance.

8.0 Conclusion

8.1 Summarizing Key Findings

The literature shows a dynamic landscape in opportunities and challenges transforming towards the integration application Industry 4.0 in management accounting. Such a task points at the dynamic role management accountants take owning to the Fourth Industrial Revolution (4IR) where among other things, digital skills are the most crucial need. The research raises international implications as sustainability effects regarding the development of economies due to industry 4.0 adoption. Interaction of digitalization with corporate governance and the challenges met by SMEs during the process of digital technologies in place are important features. Overall, the integration of Industry 4.0 technologies is outlined to be a driver for corporate transformation determining financial performance through environmental, social, and governance practices.

8.2 Reiterating the Importance of Addressing Challenges and Embracing Opportunities

In the era of Industry 4.0, advanced technologies should be incorporated in the approach of management accounting for competitiveness. While grabbing opportunities, organizations need to solve challenges such as eliminated digital skills and secured data. Despite of the challenges, the benefits such as increased efficiency and improved financial performance outweigh the hurdles and put the organizations on a position of innovation and adaptability in the every changing land of business.

8.3 Summarizing Identified Research Gaps and Potential Areas for Future Research

Consequently, adaptation and benefits availed to varied sectors out of Industry 4.0 need to be extensively studied through cross-industry comparative in the research. In this respect, differences at a global front with respect to adoption of Industry 4.0 for management accounting including cultural and a regulatory framework should be explored. Therefore, future research will be required to examine changes in Industry 4.0 on different organizational levels, having their impact on strategic, tactical and operational decision-making processes. This research has also explored the preparedness of HR for FIR technologies, challenges and opportunities faced by service industries, and strategies for SMEs' in developing countries towards readiness of Industry 4.0 technologies.

8.4 Practical Insights and Recommendations for Organizations

Implementation of Industry 4.0 technologies in management accounting has to consider and take into account organizational and industry specifics. It must focus on developing digital skills that bridge the gaps for effective adoption. The organizations need to invest in such secure technologies to yield a high-level data protection, and across industries collaboration is pivotal for a circular economy. The sustainability practices must be embedded in management accounting helping in aligning Industry 4.0 with ESG metrics and financial goals. Ongoing tailored strategies focusing on SMEs, addressing cost barriers and skills training should be. Indeed, overcoming

the barriers and embracing opportunities in Industry 4.0 contributes to performance enhancement of businesses, as well as to sustainable development in the digital age.

References

Abdelhalim, A. M. I. N. &. A. M., 2023. The Moderating Role of Digital Environmental Management Accounting in the Relationship between Eco-Efficiency and Corporate Sustainability.. *Sustainability, 15(9), 7052..*

Ahmad, M. U. &. M. J., 2019. Understanding the connect between digitalisation, sustainability and performance of an organisation.. *International Journal of Business Excellence, 17(1), ,* pp. 83-96.

Akanmu, A. A. A. C. J. &. O. O. O., 2021. Towards next generation cyber-physical systems and digital twins for construction.. *Journal of Information Technology in Construction, 26..*

Alkaraan, F. A. K. H. K. &. V. V. G., 2022. Corporate transformation toward Industry 4.0 and financial performance: The influence of environmental, social, and governance (ESG).. *Technological Forecasting and Social Change, 175, 12.*

Allioui, H. &. M. Y., 2023. Exploring the Full Potentials of IoT for Better Financial Growth and Stability: A Comprehensive Survey.. *Sensors, 23(19), 8015..*

Alsughayer, S. A. &. A. N., 2023. Expectations gap, market skills, and challenges of accounting education in Saudi Arabia.. *Journal of Accounting, Finance and Auditing Studies.*

Anshari, M. S. M. &. F. N. L., 2022. Fourth industrial revolution between knowledge management and digital humanities.. *Information, 13(6), 292..*

Azcarate-Aguerre, J. F. K. T. K. T. &. V. M., 2022. Facades-as-a-Service: the role of technology in the circular servitisation of the building envelope.. *Applied Sciences, 12(3), 1267..*

Barney, J. B., 2000. Firm resources and sustained competitive advantage. In Economics meets sociology in strategic management. *Emerald Group Publishing Limited.,* pp. 203-227.

Bhimani, A., 2020. Digital data and management accounting: why we need to rethink research methods.. *Journal of Management Control, 31(1-2), ,* pp. 9-23.

Bian, W. &. B. W., 2022. Construction of Application Model of Accounting Framework Platform for Industry-Finance Integration Management under the Background of Multimedia Technology.. *Mobile Information Systems, .*

Braun, V. &. C. V., 2006. Using thematic analysis in psychology.. *Qualitative research in psychology, 3(2), ,* pp. 77-101.

Buer, S. V. S. M. S. J. O. &. S. F., 2021. Buer, S. V., Semini,The complementary effect of lean manufacturing and digitalisation on operational performance.. *International Journal of Production Research, 59(7), ,* pp. 1976-1992.

Butler-Adam, J., 2018. The fourth industrial revolution and education.. *South African Journal of Science, 114(5-6),,* pp. 1-1.

Cai, C., 2022. Training mode of innovative accounting talents in colleges using artificial intelligence.. *Mobile Information Systems, .*

Ciliberto, C. S. K. T. M. R. A. &. I. G., 2021. Enabling the Circular Economy transition: A sustainable lean manufacturing recipe for Industry 4.0.. *Business Strategy and the Environment, 30(7),,* pp. 3255-3277.

Cugno, M. C. R. &. B. G., 2021. Openness to Industry 4.0 and performance: The impact of barriers and incentives.. *Technological Forecasting and Social Change, 168, 120756..*

Davis, F. D. B. R. P. &. W. P. R., 1989. User acceptance of computer technology: A comparison of two theoretical models.. *Management science, 35(8),,* pp. 982-1003.

Electric, G., 2023. *General Electric.* [Online] Available at: https://www.ge.com/

EquityBank, 2023. *Equity Bank Kenya.* [Online] Available at: https://equitygroupholdings.com/ke/

Eskom, 2023. *Eskom.* [Online] Available at: https://www.eskom.co.za/

Fähndrich, J., 2023. A literature review on the impact of digitalisation on management control.. *Journal of Management Control, 34(1),,* pp. 9-65.

Frederico, G. F. G.-R. J. A. K. A. &. K. V., 2021. Performance measurement for supply chains in the Industry 4.0 era: a balanced scorecard approach.. *International journal of productivity and performance management, 70(4),,* pp. 789-807.

Hahm, S., 2018. Attitudes and performance of workers preparing for the fourth industrial revolution.. *KSII Transactions on Internet and Information Systems (TIIS), 12(8),,* pp. 4038-4056.

Heller, C. H., 2019. Near-term applications of artificial intelligence.. *Naval War College Review, 72(4), ,* pp. 73-100.

Horváth, D. &. S. R. Z., 2019. Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?.. *Technological forecasting and social change, 146,,* pp. 119-132.

Inam, G. U. I. S. J. &. A. T., 2020. Diversification, Innovation, and Digitalisation: An Effective Vaccine for Survival of Pakistan's SMEs Amidst COVID'19.. *Electronic Journal of Business & Management, 2, ,* pp. 35-45.

Jiang, J. C., 2022. Regulating Blockchain? An Ex-Post Regulatory Impact Assessment of the US Blockchain Regulatory Regime.. *Journal of Law & Cyber Warfare, 8(2), ,* pp. 5-58.

Joshi, P. L., 2023. A Survey of the Influence of Skill Sets on the Performance of Professional Accountants.. *Journal of Accounting, Finance and Auditing Studies, 9(3), ,* pp. 162-196.

Kaplan, R. S. &. C. R., 1998. Cost & effect: using integrated cost systems to drive profitability and performance.. *Harvard Business Press..*

Kaplan, R. S. &. N. D. P., 2005. The balanced scorecard: measures that drive performance. *Harvard Business Review. Vol 70,* pp. 71-79.

Karmańska, A., 2021. Internet of Things in the accounting field–benefits and challenges.. *Operations Research and Decisions, 31(3), ,* pp. 23-39.

Kriz, A. &. W. C., 2018. Innovation and internationalisation processes of firms with new-to-the-world technologies.. *Journal of International Business Studies, 49, ,* pp. 496-522.

Kumar, R. S. R. K. &. D. Y. K., 2020. Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges.. *Journal of cleaner production, 275, 124063..*

Maersk, 2023. *Maersk.* [Online] Available at: https://www.maersk.com/

Manesh, M. F. P. M. M. M. G. &. D. M., 2020. Knowledge management in the fourth industrial revolution: Mapping the literature and scoping future avenues.. *IEEE Transactions on Engineering Management, 68(1),,* pp. 289-300.

Mariani, M. &. B. M., 2019. Industry 4.0: A bibliometric review of its managerial intellectual structure and potential evolution in the service industries.. *Technological Forecasting and Social Change, 149, 119752..*

Marsintauli, F. N. E. S. R. &. D. F., 2021. An analysis on the implementation of cloud accounting to the accounting process.. *Accounting, 7(4),,* pp. 747-754.

Mbizi, R. S. O. G. F. T. D. G. E. M. S. .. &. S. K., 2022. Accountants in Africa and the evolving fourth industrial revolution (4IR): Towards a competency framework.. *Cogent Business & Management, 9(1), 211715.*

Mhlanga, D. &. M. T., 2020. COVID-19 and the digital transformation of education: What are we learning on 4IR in South Africa?.. *Education sciences, 10(7), ,* p. 180.

Mian, S. H. S. B. A. W. M. K. &. A. H., 2020. Adapting universities for sustainability education in industry 4.0: Channel of challenges and opportunities.. *Sustainability, 12(15), 6100..*

Mohd Faizal, S. J. N. &. M. N. A. S., 2022. Integrate the adoption and readiness of digital technologies amongst accounting professionals towards the fourth industrial revolution.. *Cogent Business & Management, 9(1), 2122160..*

Möller, K. S. U. &. V. F., 2020. Digitalization in management accounting and control: an editorial.. *Journal of Management Control, 31, ,* pp. 1-8.

Naciri, L. G. M. S. A. M. S. &. D. N. M., 2023. Digital Technologies' Risks and Opportunities: Case Study of an RFID System.. *Applied System Innovation, 6(3), 54..*

Nankervis, A. C. J. C. R. M. A. &. P. V., 2021. 'Are we there yet?'Australian HR professionals and the Fourth Industrial Revolution.. *Asia Pacific Journal of Human Resources, 59(1), ,* pp. 3-19.

Nestle, 2023. *Nestle Nigeria.* [Online] Available at: https://www.nestle.com/

Nørreklit, H. &. C. L., 2023. Introduction to the special issue:"Performance, management and governance in the digital age".. *Journal of Management and Governance, 27(3),,* pp. 689-693.

Oleiwi, R., 2023. The Impact of Electronic Data Interchange on Accounting Systems.. *International Journal of Professional Business Review: Int. J. Prof. Bus. Rev., 8(4), 11..*

Piosik, A., 2022. The intensity of the use of management accounting systems under Industry 4.0 conditions. Confirmation from Poland.. *Procedia Computer Science, 207, ,* pp. 1598-1610.

Pramono, A. J. S. A. F. &. F. R., 2023. Sustainability Management Accounting in Achieving Sustainable Development Goals: The Role of Performance Auditing in the Manufacturing Sector.. *Sustainability, 15(13), 10082..*

PricewaterhouseCoopers, 2023. *PricewaterhouseCoopers.* [Online] Available at: https://www.pwc.com/gx/en.html

Ramadan, M. A. T. S. B. &. R. M., 2022. The Impact of Integration of Industry 4.0 and Internal Organizational Forces on Sustaining Competitive Advantages and Achieving Strategic Objectives.. *Sustainability, 14(10), 5841..*

Reis, J. S. D. M. E. M. N. T. V. S. N. A. D. S. I. R. C. F. C. D. &. O. O. J. D., 2021. Reis, J. S. D. M., Espuny, M., Nunhes, T. V., Sampaio, N. A. D. Striding towards sustainability: A framework to overcome challenges and explore opportunities through industry 4.0.. *Sustainability, 13(9), 5232..*

Rexroth, B., 2023. *Bosch Rexroth.* [Online] Available at: https://www.boschrexroth.com/en/dc/

Rutherford, T. D. &. F. L., 2020. Is Industry 4.0 a good fit for high performance work systems? Trade unions and workplace change in the Southern Ontario Automotive Assembly Sector.. *relations industrielles/industrial relations, 75(4), ,* pp. 751-773.

Sartal, A. L. J. &. L.-M. F., 2022. Do technologies really affect that much? Exploring the potential of several industry 4.0 technologies in today's lean manufacturing shop floors.. *Operational Research, 22(5),,* pp. 6075-6106.

Sasol, 2023. *Sasol.* [Online] Available at: https://www.sasol.com/

Seshadrinathan, S. &. C. S., 2021. Exploring factors influencing adoption of blockchain in accounting applications using technology–organization–environment framework.. *Journal of International Technology and Information Management, 30(1), ,* pp. 30-68.

Siemens, 2023. *Siemens.* [Online] Available at: https://www.siemens.com/global/en.html

Singaram, S. &. M. C. H., 2022. The influence of the Fourth Industrial Revolution on organisational culture: An empirical investigation.. *Frontiers in psychology, 13, 919157..*

Sokolenko, L. E. T. K. O. A. O. &. K. O., 2020. Use of cloud-based accounting technologies in the information security system.. *Academy of accounting and financial studies journal, 24(2), ,* pp. 1-8.

Sroufe, R. &. G.-R. V., 2019. Management, social sustainability, reputation, and financial performance relationships: An empirical examination of US firms.. *Organization & Environment, 32(3), ,* pp. 331-362.

Thuan, P. Q. K. N. V. A. N. D. C. H. N. T. X. T. V. H. A. T. T. N. B. &. H. C. G., 2022. Thuan, P. Q., Khuong, N. V., Anh, N. D. C., Hanh, N. T. X., Thi, V. H. A., Tram, T. The determinants of the usage of accounting information systems toward operational efficiency in industrial revolution 4.0: Evidence from an emerging economy. *Economies, 10(4),* p. 83.

Török, R. M., 2022. Artificial intelligence algorithms applied in business and accounting.. *Journal of Economics and Business, 15(1), ,* pp. 73-90.

Tran, P. T. K. T. I. W. K. N. T. H. &. T. H. T. M., 2023. Determinants of management accounting application use in Vietnamese telecommunications companies: The moderating role of organisational culture.. *Sustainability, 15(19), 14419..*

Tsiligiris, V. &. B. D., 2021. Exploring the impact of 4IR on skills and personal qualities for future accountants: a proposed conceptual framework for university accounting education.. *Accounting Education, 30(6), ,* pp. 621-649.

Unilever, 2023. *Unilever.* [Online] Available at: https://www.unilever.com/

Van Dung, N., 2019. DETERMINANTS INFLUENCING THE APPLICATION OF ELECTRONIC INVOICE ON ACCOUNTING SOFTWARES IN THE FOURTH INDUSTRIAL REVOLUTION ERA.. *Management Accounting Research, 13,,* pp. 379-400.

Varaniūtė, V. Ž. I. &. Ž. A., 2022. The changing role of management accounting in product development: directions to digitalization, sustainability, and circularity.. *Sustainability, 14(8), 4740..*

Weber, M., 1949. " Objectivity" in social science and social policy.. *The methodology of the social sciences, ,* pp. 49-112.

Wijethilake, C. M. R. &. A. R., 2018. Environmental innovation strategy and organizational performance: Enabling and controlling uses of management control systems.. *Journal of Business Ethics, 151,,* pp. 1139-1160.

Yaqub, M. Z. &. A. A., 2023. Industry-4.0-Enabled Digital Transformation: Prospects, Instruments, Challenges, and Implications for Business Strategies.. *Sustainability, 15(11), 8553..*

Yu, F. &. S. T., 2020. Industry 4.0 technology implementation in SMEs–A survey in the Danish-German border region.. *International Journal of Innovation Studies, 4(3), ,* pp. 76-84.

Zolkifli, N. L. A. Z. &. J. D., 2022. Accounting Education in the Era of IR 4.0: Exploring the Market Relevance of Auditing Courses in Malaysian Public Universities.. *Global Business and Management Research, 14(3s), ,* pp. 1307-1319.

Biodata of the authors

1. **Kudzai Chuma (Corresponding Author)**
   Botho University Gaborone Botswana
   Born at Chegutu Zimbabwe
   Doctoral Student-University of Zambia (UNZA)
   Master in Business Administration – Zimbabwe Open University
   Master of Higher Education-Botho University Botswana
   Bsc Accounting Honors- Botho University Botswana
   Associate Chartered Management Accountant (ACMA) and Chartered Global Management Accountant (CGMA) with the Chartered Institute of Management Accountant (CIMA UK).
   Chartered Public Finance Accountant member of CIPFA (The Chartered Institute of Public Finance and Accountancy)
2. **Dr Abubaker Qutieshat is an Associate Lecturer at University of Zambia**