

The Effects of Industry 4.0 Technologies on Supply Chain Management Performance: A Case Study of DHL Zambia

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Abstract

Technological advancements related to the fourth industrial revolution are causing disruptive changes that are widely felt at national, industry, and company level. Hence, this mixed methods study aimed to assess the effects of industry 4.0 technologies on supply chain management performance at DHL Zambia. The 50 employees selected out of 56 employees at DHL Zambia through Simple random sampling technique resulted in 50 valid responses translating in 100% response rate. Empirical data was derived from both the Likert Scale questionnaire and interview guide distributed through Google Forms. Quantitative data was analyzed using descriptive statistics, and inferential statistics such as regression analysis, and correlation analysis. While qualitative data was analyzed using thematic approach. The study revealed that Internet of Things, block chain, Big Data Analytics and AR and VR as industry 4.0 technologies used at DHL Zambia. The study also found that on-time delivery, order cycle time, inventory turnover, perfect order rate, supply chain cost, lead time, and forecast accuracy, are the supply chain management metrics adopted at DHL Zambia. The multiple regression test results found significant effect of industry 4.0 technologies on supply chain management metrics ($P > 0.05$). The study recommended that managers at DHL Zambia need to prioritize training and skill development initiatives aimed at equipping the workforce with the technical competencies required for leveraging Industry 4.0 technologies effectively. This will ensure that the workforce is prepared to embrace digital transformation and adapt to the changing demands of the industry. This study proposed increasing the number of companies in Zambia in order to get the views of employees from other companies.

Keywords: Industry 4.0, Supply Chain Management, DHL Zambia

1. Introduction

The technological advancements related to the fourth industrial revolution are causing disruptive changes that are widely felt at national, industry, and company level. (Maisiri et al., 2019). Industry 4.0 is a concept that focuses on automation, digitalization, and networking in companies (Abdirad and Krishnan, 2021). Its goal is to achieve a smart factory to reduce lead time to respond to the customers' demand or to unforeseen events and improve productivity in the system (Abdirad and Krishnan, 2021).

The idea and background of Industry 4.0 came from the grounding in previous industrial revolutions. Thus, the First Industrial Revolution (Industry 1.0) began first in Britain in the 1700s and focused primarily on textile manufacturing and steam power, iron production and development in transportation system (Beck, 2022). The revolution lasted to sometime between 1820 and 1840. During this period human and animal labour technology transformed into machinery, such as the steam engine, the spinning jenny, coke smelting, puddling and rolling processes for making iron (Mohajan, 2019). However, the first industrial revolution had a number of side effects which include; a general sense of alienation, poor working conditions, and overcrowded cities which resulted in high poverty drunkenness, unemployment, sexual exploitation, child labor and lassesze faire (Mohajan, 2019).

As a result, Industry 2.0 (second industrial revolution) began. It started at the end of the 19th century, with massive technological advancements in the field of industries that helped the emergence of a new source of energy namely, electricity, gas, and oil (Mohajan, 2019). In industry 2.0 brought the division of labor mass production via electrical energy around the turn of the 20th century. This type of production is illustrated best by the assembly line used by Henry Ford (Beck, 2022). However, the systematic production developed during industry 2.0 (Second Industrial Revolution) had as a consequence the acceleration of production, achieving greater competitiveness in the market which, in turn, increased unemployment due to the replacement of employees by machinery (Beck, 2022).

However, the third industrial revolution integrated electronics and IT technology into production. Industry 3.0 began with the first computer era. These early computers were often very simple, unwieldy and incredibly large relative to the computing power they were able to provide, but they laid the groundwork for a world today that one is hard-pressed to imagine without computer technology. Around 1970 the Third Industrial Revolution involved the use of electronics and IT (Information Technology) to further automation in production. Manufacturing and automation advanced considerably thanks to Internet access, connectivity and renewable energy. In addition, industry 3.0 introduced more automated systems onto the assembly line to perform human tasks, i.e. using Programmable Logic Controllers (PLC). Although automated systems were in place, they still relied on human input and intervention (Xiong et al., 2022). However, in 2011 the industry 4.0 term first appeared at Hannover Messe in Germany when Professor Wolfgang Wahlster, Director and CEO of the German Research Centre for Artificial Intelligence, addressed the opening ceremony audience. The context of the term usage was how companies can be successful in a high wage region with global competition. He suggested that we must be in shape for the 4th Industrial Revolution that is being driven by the Internet (Pek, 2022). In addition, the fourth industrial revolution is bringing digital processing into the production process. This involves wireless communication between devices, wireless sensing and data reports, and modelling and simulation of physical models to make decentralized decisions (Dalenogare et al., 2018). Figure 1 demonstrates the evolution of industry 4.0.

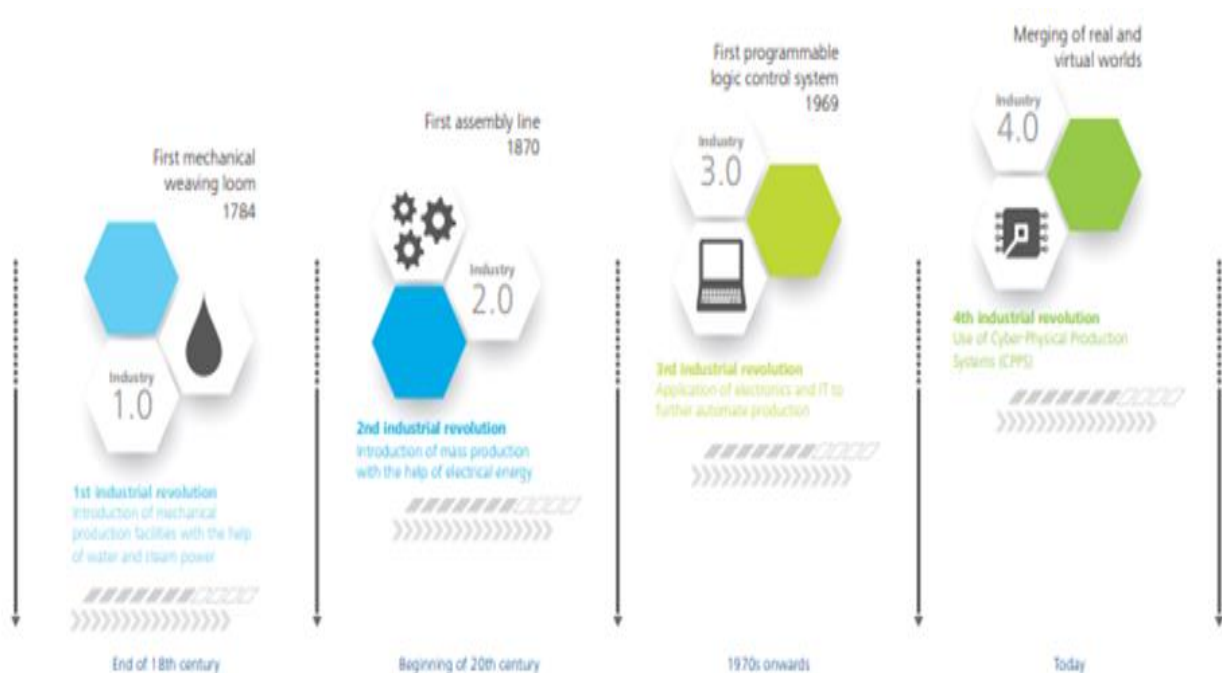


Figure 1: Evolution of industry 4.0 (Deloitte, 2016)

However, Industry 4.0 can be defined as the comprehensive introduction of information and communication technology (ICT) as well as their connection to an internet of things, services and data, which enables a real-time production. Industry 4.0 means a higher degree of digitalization for products, value creation chain, and business models. Industry 4.0 supports digitalization by IT solutions and connections to improve productivity and reduce costs (Abdirad and Krishnan, 2021). In the supply chain industry this means that in order to satisfy people and companies' needs, it is essential to carry out a more efficient and intelligent way of production, maximizing the profitability of all the processes involved, radically reducing costs and marginal manufacturing times. In short, optimizing production. The term 'industry 4.0' also refers to the next developmental stage in the organization of the entire value chain process in the manufacturing industry. It is also known as the 'fourth industrial revolution' (Zhu and Zhou, 2016). Figure 1.2 demonstrates framework for industry 4.0 and contributing technologies adopted from PWC, (Ustundag et al., 2018).

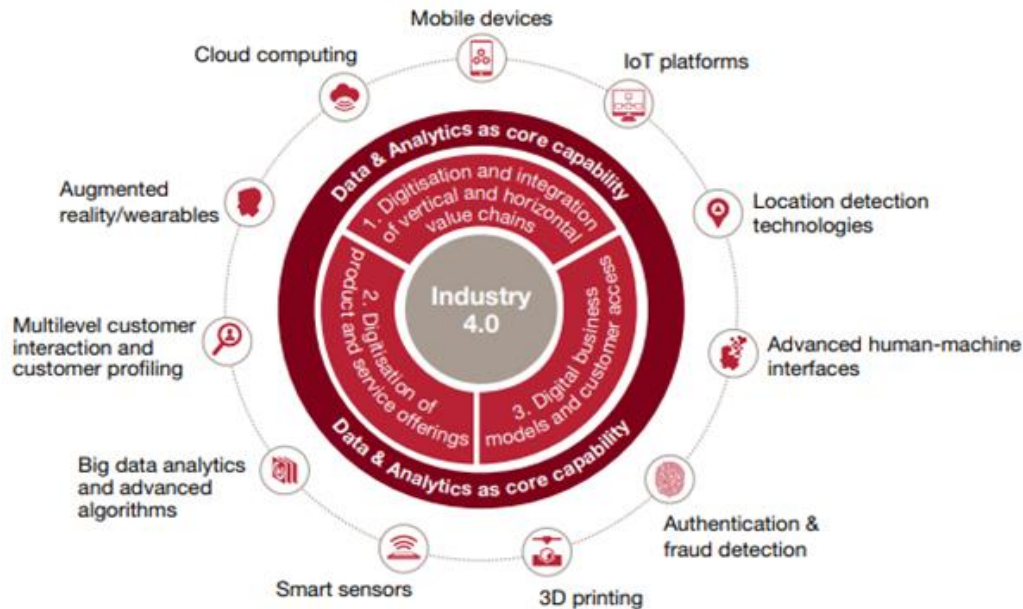


Figure 2: Framework for Industry 4.0

Source: Adopted from PWC (2016)

Thus, the Industry 4.0 is characterized by the creation of intelligent factories that implement and integrate state of the art technologies such as cyber physical systems (which combine tangible assets with digital twins), IIoT (Industrial Internet of Things), data analytics, additive manufacturing, 3D printing and artificial intelligence. Similarly, the technologies used in industry 4.0 are internet of things (IoT), big data, smart factory, cyber physical system (Patil et al., 2020).

However, global empirical studies have revealed that bringing supply chains online can help enterprises reach the next level of operational effectiveness and realize significant cost reductions. Digital supply chain can lower operational costs by more than 30 percent, reduce lost sales opportunities by more than 60 percent, and even reduce inventory requirements by more than 70 percent, all while making companies faster, more agile, granular, accurate, and efficient (Patil et al., 2020). An empirical study conducted in Poland by Szozda concluded that the idea of Industry 4.0 is not foreign to contemporary companies and has an influence on the organization of physical and information flows in supply chains. Managers are aware of the changes occurring in the organization of production, procurement, and distribution processes in the entire supply chains. However, they are concerned about transferring processes into the virtual world, due to data security issues and capacity of long-distance wireless networks (Szozda, 2017). However, empirical studies have found that there are a number of factors affecting industry 4.0 which are Software Infrastructure (SI), System Flexibility (SF), Operational Accuracy (OA), and the Technical Capabilities (TC) which play a dominant role in the successful adoption intentions of Industry 4.0 in India (Szozda, 2017).

However, regional empirical studies have revealed that although noticeable progress has been made in the use of Industry 4.0 technologies, systems, and processes in developed countries, there is uncertainty about the preparedness of businesses and industries in developing countries, including South Africa, to adopt Industry 4.0. Another study conducted in South Africa found that there is lack of awareness concerning Industry 4.0 both in academia and in industry (Maisiri et al., 2019). In Zambia, the Zambia Science Technology and Innovation policy review showed that Zambia has made significant progress in its digital infrastructure. There is growth in the number of digital tech start-ups, entrepreneurs and hubs, while digital technology has seen application in solar energy, agriculture, public service delivery, and financial inclusion (Tošović-Stevanović, 2022). However, it was revealed that Zambia's score of 116 indicates a need for greater effort in improving the country's digitalization prospects (Tošović-Stevanović, 2022). As a result, the report by World Bank Group also showed that Zambia is one of the first 17 African countries to implement the Digital Economy for Africa (DE4A).

In this study, Dalsey, Hillblom and Lynn (DHL) is the case study. It was founded by Adrian Dalsey, Larry Hillblom and Robert Lynn founded DHL in 1969. It is an international team of over 380,000 shipping professionals, united by a passion for logistics. DHL is as innovative as a start-up, with the power of an international organization (Altman and Bastian, 2022). With regards to Industry 4.0 technologies, DHL uses AR (Augmented Reality) and IoT (Internet of Things) for picking, sorting, and tagging the products in the warehouse. All are done with the help of Vuzix smart glasses, their workers harnessed the goodness of AR to work hands-free in warehouses (Patil et al., 2020). In addition, DHL Logistics Company explores many uses of AR in various supply chain functions such as warehousing operations, transportation optimization, last-mile delivery, and enhanced value-added services.

1.2 Statement of the problem

There is still a significant knowledge gap regarding the successful integration of Industry 4.0 (I4.0) in major industries such as global supply chain management. In recent literature this gap has been pointed out as a major concern. [Bellantuono et al. \(2021\)](#) reviewed the failure aspect of the I4.0 integration in Forbes magazine and mentioned that according to the Cap Gemini report (year), 68% of more than 1000 manufacturing companies with the revenue of one billion dollars and more have ongoing smart manufacturing initiatives and only 14% of these companies are succeeding.

DHL faces various supply chain management challenges in Zambia including infrastructure limitations, regulatory complexities, and diverse market conditions. Developing tailored solutions for efficient transportation, navigating regulatory hurdles, and adapting to regional nuances are key aspects to address in enhancing their supply chain operations. These challenges at DHL Zambia have been compounded by the lack of dedicated studies that can identify the main metrics that are needed to bring about the change that DHL has to attain to be competitive.

According to Gavyn at DHL, customers view green logistics as an additional cost. It is a highly cost-oriented market and customers are reluctant to additional logistic costs. Gavyn Symons has never before met any customer who wants to pay extra for green logistics in Zambia. In other parts of the world, there is an incentive of being green and using green services due to annual and quarterly environmental reports ([Mukupo, 2019](#)). In Zambia, this is not a case and that is great in trying to manage green logistics. When it comes to the roads and infrastructure, the highways ways such as Great East Rd, Great North Rd and the Lusaka Livingstone Roads are good. However, when you leave the highways and especially in rural areas, the condition of the roads become challenging. Main routes as mentioned is not a challenge for DHL, but the condition in the rural areas is definitely a challenge.

Despite the growing body of global and regional research exploring the intersection of Industry 4.0 and supply chain management, a noticeable gap exists in addressing the specific effect of Industry 4.0 on the supply chain performance at DHL Zambia. Prior studies, such as those by [Pfohl et al. \(2015\)](#), [Abdirad and Krishnan \(2021\)](#), [Patil et al. \(2020\)](#), [Dalenogare et al. \(2018\)](#), [Maisiri et al. \(2019\)](#), and [Asongu and Odhiambo \(2020\)](#) have primarily focused on different facets of Industry 4.0 within manufacturing, logistics, procurement processes, and readiness assessments in various regions. However, a dedicated investigation into the implications of Industry 4.0 technologies on supply chain management within DHL Zambia remains conspicuously absent. This study is an attempt to address this gap and provide some possible solutions to some of the challenges highlighted in this research.

1.3 Objectives of the Study

1. To establish the industry 4.0 technologies used at DHL Zambia.
2. To determine the Supply Chain Management metrics used to measure performance at DHL Zambia.
3. To evaluate the effects of the established Industry 4.0 technologies on the supply chain management performance metrics at DHL Zambia.

1.4 Research question

The study was guided by the following research questions:

RQ1. What are the Industry 4.0 technologies used at DHL Zambia?

RQ2. What supply chain management metrics are used to measure performance at DHL Zambia?

RQ3. What are the effects of the established Industry 4.0 technologies on the supply chain management performance metrics at DHL Zambia?

2. Literature review

2.1. Overview of Industry 4.0

The concept of Industry 4.0 has gained large popularity and importance since it was first introduced by the German government at the Hannover Fair in November 2011. Nowadays, Industry 4.0 is creating a new industrial field which will depend on data acquisition and sharing along the entire supply chain ([Olsson and Yuanjing, 2018](#)). At the same time, Industry 4.0 is a new method to connect the digital world with the physical world. Industry 4.0 can be understood as the comprehensive introduction of information and communication technology (ICT) as well as their connection to an internet of things, services, and data, which enables a real-time production. Industry 4.0 means a higher degree of digitalization for products, value creation chain, and business models.

Industry 4.0 supports digitalization by IT solutions and connections to improve productivity and reduce costs ([Abdirad and Krishnan, 2021](#)). In the supply chain industry this means that to satisfy people and companies' needs, it is essential to carry out a more efficient and intelligent way of production, maximizing the profitability of all the processes involved, radically reducing costs and marginal manufacturing times. In short, optimizing production. The term 'industry 4.0' also refers to the next developmental stage in the organization of the entire value chain process in the manufacturing industry. It is also

known as the 'fourth industrial revolution' (Ross and Maynard, 2021).

By implementing Industry 4.0 in the supply chain systems, four main SC elements; integration, operations, purchasing, and distribution are affected and can increase the productivity of companies as well (Barreto et al., 2017). The main benefits of Industry 4.0 in the SC are to reduce the lead time for delivery of products to customers, reduce the time to respond to an unforeseen event, and to prompt a significant increase in decision making quality (Barreto et al., 2017).

2.2. The effects of industry 4.0 technologies on Supply Chain Management

A supply chain is a network that links technology, activities, resources and organisations involved in the manufacturing and distribution of product and services. Supply Chain Operations Reference model (SCOR) defines basic processes of the supply chain (SC) into five categories as Plan, Source, Make, Delivery and Return (Tjahjono et al., 2017). The search for a more sustainable production and consumption system is so relevant today that the United Nations (UN) have selected it as one of their paramount societal objectives for sustainable development (Nagy et al., 2018). The implementation of sustainability in production and consumption processes aims to mitigate negative pressures on the ecosystem generated by products, services, and transportation. Industry 4.0 (I40) technologies have sparked interest in recent years (Hofmann and Rüsçh, 2017). The advanced digital technologies of I40 such as big data analytics (BDA), artificial intelligence (AI), machine learning (ML), internet of things (IoT) and sensors, block chain technology (BCT), robotic systems (RS), cloud computing (CC), cyber-physical system (CPS), additive manufacturing (AM) /3D printing (3D), virtual reality (VR), augmented reality (AR), autonomous vehicles (AV), and drones have found applications in many processes of manufacturing, logistics and SC. The benefits are sustainability, efficiency, cost reduction, transparency, traceability, and collaboration. In addition to benefits, I40 implementation is not free from challenges (Luthra and Mangla, 2018).

The Industry 4.0 technologies used at DHL Zambia.

The logistics industry in Zambia, like in other regions, is increasingly adopting Industry 4.0 technologies to improve operations. DHL Zambia is taking a lead in adopting some of the industry 4.0 technologies to enhance its performance (Mukupo, 2019). Common technologies being used by DHL Zambia include:

1. Internet of Things (IoT): Sensors and devices for real-time tracking of shipments and monitoring conditions like temperature and humidity.
2. Artificial Intelligence (AI): AI is used for route optimization, demand forecasting, and predictive maintenance to enhance efficiency.
3. Blockchain: Employed for secure and transparent supply chain management, reducing fraud and errors in transactions.
4. Robotics and Automation: Automated systems for sorting, packing, and even autonomous vehicles for transportation are becoming more prevalent.
5. Big Data Analytics: Analyzing large datasets helps in making informed decisions, optimizing routes, and managing inventory effectively.
6. Cloud Computing: Enables access to data and applications remotely, facilitating collaboration and scalability.
7. Augmented Reality (AR) and Virtual Reality (VR): Used for training, maintenance, and improving overall warehouse efficiency.

These technologies are being used in the day-to-day operations of DHL Zambia to improve efficiency and provide a seamless logistics process to its clients.

The Supply Chain Management metrics are used to measure performance at DHL Zambia.

DHL Zambia, like many logistics and supply chain companies, employs various key performance indicators (KPIs) to measure its supply chain management performance (Mukupo, 2019). Common metrics include:

1. On-time Delivery (OTD): Measures the percentage of deliveries that are made on time as per the agreed-upon schedule.
2. Order Cycle Time: The time it takes from order placement to delivery, providing insights into overall efficiency.
3. Inventory Turnover: Indicates how quickly inventory is used and replenished, reflecting supply chain agility.
4. Perfect Order Rate: Measures the percentage of orders that are delivered without errors, including accurate documentation, undamaged goods, and on-time delivery.
5. Supply Chain Cost: Evaluates the overall cost efficiency of the supply chain process, including transportation, warehousing, and order fulfillment costs.
6. Lead Time: The time it takes for an order to be fulfilled, from initiation to delivery, highlighting efficiency and responsiveness.
7. Customer Satisfaction: Through surveys or feedback, assessing customer satisfaction can be a crucial metric in understanding the overall supply chain experience.
8. Forecast Accuracy: Measures how well the company predicts demand, helping in optimizing inventory levels and preventing overstock or stockouts.

It's important to note that specific metrics vary based on the nature of the products being handled and the specific goals of DHL in a particular region or sector.

The effects of established industry 4.0 technologies on the supply chain management performance metrics at DHL Zambia. DHL's current performance metrics influenced by Industry 4.0 technologies and the integration of these technologies in supply chain management have generally lead to several positive effects (Mukupo, 2019). Some impacts include:

1. Improved Visibility: IoT and real-time tracking technologies enhance visibility across the supply chain, reducing uncertainties and providing accurate data for decision-making.
2. Enhanced Efficiency: Automation and AI-driven processes optimize workflows, reducing lead times, and improving overall supply chain efficiency.
3. Predictive Analytics: Advanced analytics enable better forecasting, reducing the likelihood of stockouts or overstock situations, thus improving inventory management.
4. Cost Reduction: Efficient use of resources streamlined processes, and reduced errors can contribute to overall cost savings in the supply chain.
5. Increased Customer Satisfaction: Faster and more accurate order fulfillment, along with improved communication enabled by Industry 4.0 technologies, can positively impact customer satisfaction.
6. Agile Response to Changes: The flexibility provided by Industry 4.0 technologies allows companies like DHL to respond quickly to changes in demand, supply chain disruptions, or other variables.
7. Data-Driven Decision Making: Leveraging big data analytics allows for data-driven insights, leading to informed and strategic decision-making in supply chain management.

It's worth noting that the specific effects vary based on how these technologies are implemented and integrated into DHL's operations.

2.3. Key Principles of Industry 4.0

As with most other phenomena, Industry 4.0 is underpinned by a collection of key principles that revolutionize the status quo of business operations. Industry 4.0 is concentrated around the role of modern technology in shaping the landscape of business operations, while reshaping the future of manufacturing and supply chain management. These principles serve as guiding tenets, driving the paradigm shift towards intelligent, interconnected systems (Canas, et al., 2021).

Interoperability

Interoperability refers to the ability of computer systems or software to exchange and make use of information (Oxford Languages, 2024). In the context of Industry 4.0, these principles create avenues for the creation of interconnected networks where data flows freely. This fosters collaboration and synergy between various components within the manufacturing ecosystem (Rosin, et al., 2019).

Interoperability presents several unique advantages, especially in the context of supply chain management. For example, interoperability facilitates for seamless communication between various components of the supply chain, including suppliers, manufacturers, distributors, and retailers (Canas, et al., 2021). This real-time flow of information contributes a level of efficiency otherwise almost unattainable. This translates into reduced delays, the eventual elimination of miscommunication, and the reduction of the costs associated with these issues.

Interoperability also facilitated enhanced visibility by connecting diverse systems and data sources, interoperability provides a comprehensive view of the entire supply chain (Habib & Chimsom, 2019). By doing this, managers and supply chain professionals alike are given a comprehensive perspective of the entire supply chain. With this increased visibility comes with provision to track the movement of goods, monitor inventory levels, and identify potential bottlenecks more efficiently (Rosin, et al., 2019). This translates into better decision-making, increased profitability, and more business longevity.

Decentralization

Decentralization is the process by which the activities of an organization or process, particularly those regarding planning and decision-making, are distributed or delegated away from a central, authoritative location or group and given to smaller factions within it (Merriam-Webster, 2024). Currently, most systems are characterized by traditional hierarchical structures that are often marred with operational inefficiencies and tedious procedures that lead to backlogs and bottlenecks. On the contrary, Industry 4.0 advocates for decentralization where decision-making is distributed across the system, empowering individual components with the autonomy to make intelligent choices (Dikhanbayeva, et al., 2020).

The primary benefit of decentralization is faster decision-making. However, there are a plethora of equally potent advantages that advantages that this element provides supply chain management. One of these is improved responsiveness to emergence of challenges and opportunities. With decision-making dispersed across the supply-chain, organizations can respond more swiftly to shifts in demand, supply chain disruptions, or other operational challenges (Dikhanbayeva, et al.,

2020). Additionally, decentralization facilitates for more adaptability to changes in the business environment. Since decisions are not concentrated on one group of individuals who can only be reached at particular times, smaller entities in the organization can adjust their operations, inventory levels, and distribution strategies based on local market conditions, customer preferences, and other factors (Habib & Chimsom, 2019).

Decentralization also acts as a potent tool for managing and mitigating risks by distributing the impact of disruptions. If one part of the supply chain faces challenges, other decentralized units may continue their operations, reducing the overall vulnerability of the supply chain to single points of failure (Rosin, et al., 2019). Moreover, it helps avoid communication bottlenecks, allowing for smoother information exchange and faster resolution of issues. Further, local decision-makers can optimize inventory levels based on local demand patterns, reducing risks for excessive stock, and associated carrying costs eating away at company profitability (Dikhanbayeva, et al., 2020). This helps prevent overstocking or stockouts, further contributing to efficiency and supply chain sustainability.

Real-Time Data

Real-time data acquisition and processing are at the core of Industry 4.0. By leveraging advanced sensors and connectivity, manufacturers gain access to instantaneous insights into their operations (Canas, et al., 2021). This real-time data not only facilitates proactive decision-making but also enables predictive maintenance, reducing downtime and optimizing overall efficiency (Rosin, et al., 2019).

In the context of supply chain management, real-time data is a holy grail in its potential for revolutionizing efficiency. Real-time data enables a level of responsiveness that pales in comparison to traditional data management systems currently employed. Supply chain participants can proactively address issues such as stockouts, delays, or quality concerns, minimizing the impact on operations and customer satisfaction (Canas, et al., 2021).

Real-time data facilitates more accurate demand forecasting by providing up-to-the-minute insights into customer behaviours and market trends. This allows for more efficient anticipation of changes in demand trends, leaving the organization better equipped to serve the needs of their customers and increasing their customers goodwill (Hermann, et al., 2016). This, coupled with reduced lead times, translates into improved delivery accuracy, logistical efficiency, and more cost effectiveness. Moreover, real-time data allows organizations to provide better customer service by offering accurate and timely information on order status, delivery times, and product availability, contributing to improved customer satisfaction and loyalty (Habib & Chimsom, 2019).

Virtualization

Virtualization in Industry 4.0 involves creating digital representations of physical entities, commonly referred to as "Digital Twins" (Thuemmler & Bai, 2017). These virtual replicas allow businesses to simulate and analyse processes, products, or systems in a risk-free digital environment (Hermann, et al., 2016). By mirroring the real world in a virtual space, companies can optimize performance, troubleshoot potential issues, and refine operations before implementation.

Digital Twins provide a detailed digital representation of physical assets in the supply chain, including machinery, equipment, and inventory (Hermann, et al., 2016). This allows for more efficient asset management, predictive maintenance, and better utilization of resources. Digital Twins enable a continuous improvement mindset by providing a platform for ongoing analysis and optimization (Hermann, et al., 2016). Supply chain managers can iterate on processes, experiment with changes, and continuously enhance efficiency and effectiveness.

Virtualization enables the use of predictive analytics by analysing data from digital twins to anticipate future trends and potential issues (Dikhanbayeva, et al., 2020). This capability enhances decision-making by providing insights into future demand, operational challenges, and performance optimization opportunities. It fosters collaboration by providing a shared digital environment where stakeholders across the supply chain can collaborate in real-time (Thuemmler & Bai, 2017). This shared space enhances communication, coordination, and decision-making among different entities in the supply chain.

Virtualization supports the entire lifecycle management of products and processes. Organizations can track and manage the entire journey of a product, from design and production to distribution and end-of-life considerations (Hermann, et al., 2016). It allows organizations to assess and optimize the environmental impact of their supply chain operations. By analysing digital twins, companies can identify opportunities to reduce waste, energy consumption, and overall environmental footprint (Thuemmler & Bai, 2017).

2.4. Impact on Supply Chain Industry

With the evolution of Industry 4.0 has come technological advancements and the integration of digital innovations, there is room to suggest that it has had a profound impact on supply chain management. The impact of the phenomenon had reshaped traditional practices and paved the way for a more interrelated, efficient, sustainable, and resilient ecosystem in the supply chain industry.

Enhanced Visibility and Transparency

The technologies that Industry 4.0 has ushered in provide unprecedented visibility into every aspect of the supply chain. The tools provided by real-time data enhance transparency that lend to a more effective and trustworthy supply chain network. This enhanced transparency allows stakeholders to track inventory in real-time, monitor production processes, and gain insights into the entire supply chain network (Ghadge, et al., 2020).

Through the deployment of Internet of Things (IoT) devices (to be elaborated on in the sections below), supply chain stakeholders stand to gain real-time insights into all the multiple facets of their operations. From the movement of raw materials on the factory floor to the status of shipments in transit, real-time data analytics provide a comprehensive and up-to-the-minute view of the entire supply chain ecosystem (Fatorachian & Kazemi, 2021). This level of visibility enables managers to make quick, agile decisions while empowering the organization to identify and eliminate inefficiencies and bottlenecks promptly.

Industry 4.0 also sets the precedent for data-driven decision-making. The wealth of data at the disposal of managers using tools like visualization and real-time data are a potent tool for managers looking to track performance metrics, identify patterns, and analyse historical trends (Habib & Chimsom, 2019). This tool empowers decision makers to optimize processes and allocate resources more effectively. Additionally, it acts as a catalyst for continuous improvement, driving the supply chain towards higher levels of efficiency and competitiveness.

Moreover, the ability to access real-time data, trace products seamlessly, leverage digital twins, and make informed decisions based on comprehensive insights is pivotal in creating a supply chain that is not only efficient but also resilient in the face of evolving challenges (Tjahjono, et al., 2017). Organizations that embrace this find themselves better equipped to navigate the complexities of the modern supply chain ecosystem with unprecedented clarity and precision. This means, in essence, the enhanced visibility and transparency facilitated by Industry 4.0 redefine how stakeholders perceive and navigate the supply chain landscape (Fatorachian & Kazemi, 2021).

Risk Management and Resilience

Industry 4.0 equips supply chain managers with tools that are cardinal for proactive risk management. The real time monitoring tools that are commonplace in the framework are a potent tool in enabling the early detection of anomalies and potential disruptions (Proful, et al., 2015). These tools allow for the detection of fluctuations in demand, supply chain bottlenecks, or geopolitical uncertainties. It also equips managers with the ability to identify risks in their infancy, which empowers organizations to take pre-emptive measures and fortify their supply chain against potential pitfalls (Ghadge, et al., 2020).

Virtualization and digital twins form a significant contribution to risk management as a tool of scenario simulations (Tjahjono, et al., 2017). These technologies give organizations to create virtual replicas of their supply chain processes and simulate different scenarios. By modelling potential disruptions or changes, supply chain managers can assess the impact on operations and devise effective contingency plans (Ivanov, et al., 2019). This proactive approach, grounding in digital foresight, allows for a more resilient supply chain that can navigate uncertainties with strategic preparedness.

Industry 4.0 also fosters collaborative risk management by facilitating communication and information sharing among supply chain partners (Fatorachian & Kazemi, 2021). Through shared platforms and digital ecosystems, stakeholders can collaboratively assess and address risks. This collaborative approach not only strengthens relationships within the supply chain but also ensures that the collective intelligence of the network is harnessed for effective risk mitigation (Tjahjono, et al., 2017).

Challenges and Risks

While Industry 4.0 stands to benefit and enhance the realm of supply chain management, it is not without its risks and challenges. These include concerns surrounding cybersecurity, data privacy and compliance, investment costs, and integration complexity.

Cybersecurity Concerns

There is a heavy reliance on technology that comes with integrating Industry 4.0 technologies. While the internet has truly been a vehicle of industry development, especially for the supply chain industry, it does expose organizations to cybersecurity vulnerabilities. These vulnerabilities can expose sensitive supply chain data to unauthorized access, leading to potential disruptions, data breaches, and compromise of critical information (Kumar & Mallipeddi, 2022).

One potent threat to businesses operating under Industry 4.0 tools exposure to data breaches and intellectual property theft. The vast amount of data generated and shared with an Industry 4.0-enabled supply chain contains sensitive information, trade secrets, and intellectual property (Melnyk, et al., 2022). Cyber adversaries may target this valuable data

through various means, including unauthorized access, data breaches, or corporate espionage, posing a direct threat to a company's competitive advantage (Sofla, 2022).

Data Privacy and Compliance

Industry 4.0 entails the collection and utilization of innumerable amounts of data. However, this poses significant challenges concerning compliance with regulations surrounding data protection. This is worsened for organizations operating on a multinational scale as regulations vary from region to region. Moreover, there is a rising sentiment surrounding data management and the practices of businesses in managing the personal information of their customers, which poses another risk (Sofla, 2022). Organizations must navigate these complexities of data privacy laws, such as the General Data Protection Regulation (GDPR) in the United States and the Cyber Security Act in Zambia, to avoid any legal consequences and maintain the trust of their customers (Pandey, et al., 2020). As organizations begin to integrate Industry 4.0 more and more, it becomes increasingly more difficult to adhere to these regulations, exposing them more to litigation risks.

High Initial Investment

The adoption of Industry 4.0 technologies requires a significant upfront investment in infrastructure, technology upgrades, and employee training. Smaller businesses or those with limited financial resources may find it challenging to make the initial investment required to fully embrace Industry 4.0. To fully transition to Industry 4.0, businesses require substantial upgrades to their existing infrastructure (Prause, 2019). This includes investments in advanced hardware such as sensors, devices for IoT, automation equipment, all to enable real-time data collection and connectivity across the supply chain. Moreover, these businesses would have to sink even more funds into software and platform costs, employee training and skill development, and data security measures (Thames & Schaefer, 2017). This means that businesses that cannot spare that level of investment remain out of the loop, losing their competitive edge and being slowly etched out of the market.

Internet of Things

Internet of things in the context of supply chain management is defined as a network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes (Ben-Daya, et al., 2019). As one of the latest IT developments, Internet of Things (IoT) fundamentally changed communication in SCM by providing human to things communication (Ben-Daya, et al., 2019).

However, Lee and Lee (2015) defined five key Internet of Things technologies which include; Radio-frequency identification (RFID) which allows identifying, tracking and transmitting information, Wireless sensor networks (WSN) which is composed of a set of sensors to monitor and track the status of different devices like their location, movements or temperature, middleware a service-oriented software layer that allows software developers the possibility to communicate with heterogeneous devices like sensors, actuators or RFID tags, cloud computing an internet-based computing platform where a pool of different computing resources (computers, networks, storage, software, etc.) can be shared and accessed on demand and IoT applications which enable device to device and humans to device interactions. IoT applications constitute the interface between the user and the devices (Lee & Lee, 2015).

Augmented Reality

AR is one of the key technologies for Industry 4.0, and the field of computer science that is concerned with merging the real world with the computer-generated data. AR devices digitally process images received from the environment and augment this data by adding supplementary computer-generated graphics (Sääski, et al., 2008). AR systems combine real and virtual objects in real-time and align these objects with each other in a real environment. An AR application usually consists of a display, a camera, and a computer with application software. AR applications can be run using different devices such as camera phones, handheld computers, laptops, and head-mounted displays (Sääski, et al., 2008).

AR is not a new technology since the idea of AR has been used in many applications such as virtual mirrors and mobile applications on mobile devices and tablets. Virtual mirrors are AR devices that are commonly used in the fashion retail industry. These devices film customers with the integrated cameras and superimpose the selected clothes on a customer's body displayed on the virtual mirror, hence assist a customer to judge which garment suits and fits best on him/her. Besides, mobile AR applications are widely used by many people on smartphones and tablet computers to reach information instantaneously. For instance, the Cyclopedia AR application provides information about nearby buildings or historic places, when an app user takes a picture of the mentioned building with the smart device (Ro, et al., 2018).

Augmented Reality Smart Glasses (ARSGs) are another innovative AR devices that recently draw growing attention both in industry and academia, and they offer great opportunities for development soon. ARSGs are wearable AR devices (e.g., Google Glass and Microsoft HoloLens) that capture and digitally process the objects in an environment and augment them with computer-generated data. Physical information is captured by the add-on technologies on ARSGs such as

camera, GPS, or microphones, then the virtual information gathered from the internet and/or memory device is used to augment this physical information. The user can see the virtual information that is superimposed on the physical world on the screen of an ARSG (Ro, et al., 2018). The characteristics of AR system include; combining real and virtual objects in a real environment, running interactively, and in real-time and aligning real and virtual objects with each other (Ro, et al., 2018).

Concept of Supply Chain Management

Supply chain management is a critical aspect of conducting any business. Therefore, a supply chain is the set of entities that are involved in the design of new products and services, procuring raw materials, transforming them into semifinished and finished products and delivering them to the end customers (Lu & Swaminathan, 2015). Supply chain management is efficient management of the end-to-end process starting from the design of the product or service to the time when it has been sold, consumed, and finally disposed of by the consumer. This complete process includes product design, procurement, planning and forecasting, production, distribution, fulfillment, and after-sales support (Lu & Swaminathan, 2015).

Effects of Internet of Things on Supply Chain Management

According to Cisco's economic analysis, IoT will generate \$ 8 trillion in worldwide revenues over the next decade, with revenue of \$ 1.9 trillion for supply chains and SC activities. According to Cisco's report, the number of devices connected to the IoT is estimated to be 3.47 million in 2015, while the number of devices connected per capita is expected to be 6.58 million in 2020 (Cisco, 2015). With the IoT, SC operators, corporate customers, and end consumers can be provided with remote access. Thus, problems arising in operational services, transportation safety, customer satisfaction, and new business models can be easily detected.

Together with the IoT, companies will have a low-cost opportunity in storage, transportation, and all other SC activities. In following the storage, pallets, and vehicles in communication with each other, there can be a smaller, more efficient storage policy. International transport, tracking, and monitoring of products can be faster, more precise, more reliable, and errors can automatically be detected with the product tracking system. The material flows within the SC are monitored instantaneously, making transportation and handling processes easier, minimizing the risks in transportation. However, one of the most significant tasks of logistics is the delivery function. Logistics includes: plan, storage and control of goods and services flow. In supply chain, the delivery process is concerned with warehouse, inventory and order management, and transportation (Ben-Daya, et al., 2019). The main effect of IOT on SC delivery process include; Warehousing function: the IOT enables time saving of joint ordering via using smart RFID tags. Internet of Things also achieve collaborative warehousing via using smart things and multi-agent systems. It also increases safety and security of supply chain. In order and inventory management: the Internet of Things enables sharing of information, inventory accuracy via using RFID tags. In transportation function: the Internet of Things achieve accurate and timely delivery via using sensors and networks. It also saves scanning and recording times via using smartphones (Ben-Daya, et al., 2019).

The smart devices of Internet of Things enable supply chain companies to reduce cost which results from acquisition process of knowledge. Applying Internet of Things in supply chain management will make it smarter and have the following characteristics: (1) Instrumented: information in supply chain being machine generated. (2) Inter-connected via using smart objects and IT systems. (3) Intelligent: optimize performance via making a large-scale of optimal decisions. (4) Automated: all processes must be automated to substitute low efficiency resources. (5) Integrated: collaboration between supply chain stages. Innovative: the evolution of new values via solutions for meeting new requirements.

The new technologies of RFID tags enable recording process of all types of information such as production and expire date, warrant period and this will achieve effective management of supply chain. Maximize transparency of logistics: all transport information (transport condition, destination, etc.) will be available to the entire supply chain through using smart objects. This increases the chance of monitoring and saving goods. It also minimizes cost of return and has a great impact on customer satisfaction (Abdel-Basset & Mohamed, 2018).

Effects of Augmented Reality on Supply Chains Management

AR is one of the newly emerging technologies that will take an important part in warehouse management. The potential use of AR in warehouse operations can be classified into four main areas: receiving, storing, order picking, and shipping. Among these areas, order picking accounts for more than 50% of the warehousing cost (Stoltz, et al., 2017). Order picking is one of the logistics operations that AR technology can be effectively used. Since order picking operation requires flexibility, workers cannot be replaced by machines. However, a worker equipped with an HMD can improve his information visualization. These pick-by-vision systems allow workers to act faster and work with fewer errors (Reif & Günthner, 2009). The development and implementation of AR software solutions rely on robust AR hardware platforms. These AR platforms appear in many forms such as handheld devices, stationary AR systems, spatial augmented reality (SAR) systems, HMDs, smart glasses, and smart lenses. AR applications allow logistics providers to access significant information easily and rapidly. This information is crucial for planning and executing delivery and load optimization

operations. Smart glasses are wearable computers which offer human-computer interface solution between CPS and factory workers. These devices are capable of displaying information proactively and enable workers to interact with the information hands-free during work because of its capability to communicate with other information systems using wireless communication technology such as Wi-Fi or Bluetooth (Hobert & Schumann., 2016).

2.5. Empirical Review

Global Perspective

Sharma, et al. (2022) examined the mediating effect of Industry 4.0 technologies on supply chain management practices and supply chain performance measures. Using a survey-based approach, they studied manufacturing organizations across India using the Structural Equation Modelling (SEM) to analyse data. One of their key findings revealed that there is a significant influence of supply chain management practices on the adoption of Industry 4.0 technologies. Specifically, Industry 4.0 technologies that were explored by the researchers exhibited a positive influence on the varying performance metrics analysed in the study. The findings of the study also highlight the mediating role played by these technologies in the relationship between supply chain management practices and performance measures to be significant.

However, the study does little to demonstrate its the robustness of its data analysis. While the researchers do outline their design and the data analysis techniques, their report does not demonstrate the key metrics used to ensure the reliability of the data. The study emphasizes the need for a holistic model but does not explicitly outline the theoretical framework guiding the study. moreover, the study's primary focus on three manufacturing organizations in India limits the generalizability of the results. Cultural nuances, economic variations, and industry-specific factors unique to India and to those specific companies limit the scope of their results' applicability, especially in the context of Zambia.

Karmaker, et al. (2023) studied the mediating role of green supply chain management practices and circular economy. In the wake of the COVID-19 pandemic, the researchers sought to understand the unexplored terrain of the integrated effects of Industry 4.0 technologies and sustainable practices. Their central objective was to uncover the mediating role played by green supply chain management and circular economy practices in shaping sustainable supply chain performance. To do this, the study employed a second-order hierarchical component model, with partial least square-based structural equation modelling employed for testing.

The findings of the study reveal that there is a positive link between Industry 4.0 technology adoption and sustainability in the sector. Specifically, the researchers highlighted the mediating influence of green supply chain management and circular economy practices. These integrated practices play a crucial role in translating the adoption of Industry 4.0 technologies into tangible contributions to sustainable supply chain performance (Karmaker, et al., 2023). The study provides unique context for the Bangladeshi ready-made garment industries while placing a significant and crucial emphasis on environmental sustainability and how it can be harnessed for longevity, profitability, and the efficiency of the supply chain.

However, the study falls short in terms of demonstrating causality due to its cross-sectional design. While the survey methodology does do well to capture the multitude of factors that need to be captured from a plethora of respondents, there is a lack of control variables into the analysis, which could introduce confounding factors affecting the internal validity of the analysis. Moreover, the lens through which the study was conducted – which is the pandemic and the onset of the Russo-Ukraine war – limit the applicability of the study.

Pfohl et al. (2015) researched the impact of industry 4.0 on the supply chain. The study found that structural changes to the organization are to be expected mainly in manufacturing processes. Impacting technologies are the M2M-communication, and Smart Factory including Smart Logistics. According to Patra (2018), the combined implementation of Smartphone Apps and Smart Data tools, the interaction of people within the supply chain will face a huge impact in the sales departments of companies, where the customer can be integrated, and organizational borders are eliminated (Patra, 2018). However, a quantitative analysis to validate the results must be performed to confirm the hypotheses. In addition, the summarizing model did not weigh the factors with which the specific challenges or potentials are operationalized in the framework. Thus, this study will be validated by making it a quantitative study so that hypotheses can be confirmed. In addition, the specific challenges will be investigated and validated.

Abdirad and Krishnan (2021) study on industry 4.0 in Logistics and Supply Chain Management: a systematic literature review found that 4.0 is seen as a concept that has an important role in the MSC. By applying this concept, human interaction would be minimized, and productivity would be increased in companies. However, the findings of this study were too general. The reviewed study did not show the role it plays specifically in logistics and supply chain management. Thus, the new study will specifically focus on the effects of industry 4.0 technologies on supply chain management.

Patil et al. (2020) researched the industry 4.0 and its impact on supply chain management in India which found that industry 4.0 gives the greater transparency and accuracy between the all suppliers, manufactures, logistics, warehouse, and

fulfilment are overcome unnecessary cost. Advance machine learning help to predict the demand of different products at high accuracy. High interconnection and collaboration between all the supply chain levers which taking supply chain on next level. The study also found that digitization increases the warehouse capabilities like sensor track the flow of goods and feed the relevant information in real time. It also improves the agility by using integrate data from procurement to consumer end in 'supply chain cloud' it ensures that all stockholders having the way to take decision by considering all the factors. However, the new study will specifically aim at assessing the effects of industry 4.0 technologies on supply chain management at DHL Zambia.

Dalenogare et al. (2018) researched the application of industry 4.0 in the procurement processes of supply chains. The study found that applicable technologies such as CPSs, BDA, and IoT under the term P4.0 have represented substantial values in the supply chains. These added values consist of performance improvement in the operations associated with procurement management in supply chains such as pricing, supplier selection and evaluation, cost-efficacy, data gathering and analysis, and purchasing management. However, the reviewed study used secondary data while the new study will use both primary and secondary data.

Regional Perspective

Bag, et al. (2023) studied how Industry 4.0 tools and applications have been harnessed to achieve sustainability in supply chain operations. They focused on manufacturing enterprises based in South Africa, investigating the ways these tools have impacted sustainability outcomes. Their central goal was to shed light on the effectiveness of industry 4.0 tools in improving resource consumption rates and reducing waste and pollution – a critical yet underexplored fact in the broader discourse on Industry 4.0 (Bag, et al., 2023).

The study was anchored on the Organization Information Processing Theory (OIPT), a framework that is commonly used in organizational studies and information systems research to understand how organizations process information and make decisions (Fatorachian & Kazemi, 2021). It focuses on how information is collected, processed, and utilized within an organization, emphasising the role of information processing in organizational behaviour and outcomes (Ghadge, et al., 2020). In the context of the study, it provides a foundation to guide investigation into how Industry 4.0 tools enhance operational capabilities within South African manufacturing enterprises.

The results of the study are quite compelling. The foremost being that Industry 4.0 tools can be leveraged to enhance resource consumption rates and mitigate waste and pollution is most likely to bolster sustainable supply chain operations (Bag, et al., 2023). The results also demonstrates that both the control orientation and the flexible orientation of production teams play pivotal roles in generating positive sustainable outcomes from Industry 4.0 use. By emphasizing the improvement of resource consumption and the reduction and the reduction of waste and pollution, the study offers actionable insights for South African manufacturing enterprises seeking to align their practices with sustainability goals (Bag, et al., 2023).

However, the study established associations but not causality. While the associations are significant findings, a longitudinal approach would have been more potent in enhancing the study's ability to infer causation over time. There is also little evidence demonstrating the external validity of the results which limits the applicability of the results outside of the specific context of the manufacturing industry in Zambia (Surajit, et al., 2018).

Maisiri et al. (2019) explored the readiness of South African industry. A questionnaire instrument with quantitative criteria compiled by the Impulse Foundation of Verb and Deutscher Maschinen- und Anlagenbau was used in this study. The exploratory study revealed that South African industry is faced with significant challenges in Industry 4.0 strategy formulation and equipment infrastructure to support Industry 4.0 requirements. However, the reviewed study was about readiness while the new study will focus on the effects industry 4.0 technologies have on supply chain management at DHL Zambia.

A book by Banga and te Velde (2018) on the impact of industry 4.0 on Africa's manufacturing sector found that Industry 4.0 brings with it a multitude of other benefits for industrialists such as cost, productivity, profitability, and operations that manufacturers are striving to control, streamline, optimize or enhance. Similarly, these opportunities extend to small and medium businesses to establish new business models and assimilate into international value chains (Banga and te Velde, 2018).

3. Methodology

3.1. Research Design

The decision to study a topic involves choosing a suitable research design. A roadmap to achieving the intended objectives of a research in trying to answer the research questions is referred to as research design (Creswell, 2013). Based on

pragmatic philosophy, convergent (parallel or concurrent) design was adopted. A convergent (parallel or concurrent) design is a mixed methods design in which quantitative and qualitative data are collected simultaneously but analyzed separately, and the results are merged or integrated. The convergent parallel design consists of taking qualitative and quantitative data collection and analysis and comparing or relating the two and then interpreting them. In this design, areas of convergence or divergence between the qualitative and quantitative results were discussed. This type of design allowed the researcher for the collection of rich, detailed data and provided a comprehensive understanding of the research problem (Rosenkranz, Wang and Hu, 2015). In this convergent parallel mixed methods study, the quantitative data was collected via a survey and qualitative data via semi-structured interviews. Data were analyzed separately, and the results were compared and merged.

3.2. Study Population and Sampling Strategy

A target population is a group of individuals the researcher identifies to collect the data from. Bryman and Bell (2015) have defined a target population as a comprehensive set of elements that hold some common characteristics defined by the sampling criteria which is established by the researcher. For this study, the target population were employees in the warehouse, logistics, procurement, IT, and administrative departments at DHL Zambia. Probability sampling was chosen due to the nature of the study. There are 56 employees working with DHL Zambia in Lusaka in the departments that were considered for the study, therefore sample size was derived using the formula Trochim (2007) as follows:

$$n = N / (1 + N \cdot \alpha^2)$$

$$n = 56 / (1 + 56 \cdot [(0.05)]^2)$$

$$n = 56 / (1 + 1.14)$$

$$n = 50$$

DHL Zambia has 56 employees in the warehouse, logistics, procurement, IT, and administrative departments. When this formula is employed, the researcher determined that ideal sample size was 50 respondents for quantitative study. However, 6 key employees in the warehouse department, 6 key employees in the logistics, 6 key employees in the procurement, 6 key employees in IT department made the sample size for qualitative study.

3.3. Data Collection Procedures

The role of instrumentation in research cannot be overstressed. It refers to the tools or means by which the researcher measures the variables or items of interest in the data collection process (Hsu and Sandford, 2010). Based on the objectives of the study, the researcher employed the use of the following data collection instruments:

- i. **Structured Questionnaires:** Surveys require the researcher to standardize the responses of the questionnaire to accurately measure them. This would entail the researcher using standardized predetermined questions and response options. The questionnaires were designed to ensure consistency and comparability in the data collected (Manalo, 2023). This allowed the researcher to identify trends correlations, statistical significance, and any other quantitative relationships. It is recommended that closed-ended questions be adopted in surveys to allow the study to benefit from more generalizable results and recommendations. Using tools like Likert scales, rating scales, and web and paper-based surveys. In this study, the questionnaires were administered 50 respondents in the warehouse, logistics, IT, Operations and admiration department.
- ii. **Key-Informant Interviews:** These are qualitative research tools that allow the researcher to conduct in-depth, semi-structured interviews with individuals who possess specialized knowledge, expertise, or experience relevant to the research topic (Centre for Health Policy Research, 2022). Key informants give the researcher additional insight on the topic at hand, providing the researcher with first-hand knowledge, experience and/or expertise on the subject matter under investigation (Brown, 2021). In this study, the semi-structured interviews were administered to 24 key employees in the warehouse, logistics, IT, operations and administration.

3.4. Data Analysis

The study employed a mixed methods approach to integrate quantitative and qualitative data, offering a thorough exploration of internal and external stakeholder support as well as business analytics adoption. Quantitative analyses, conducted using statistical software (SPSS Version 22), included descriptive statistics, inferential statistics such as regression analysis, and correlation analysis to examine interrelationships between variables. Conversely, qualitative data underwent thematic analysis. This mixed methods strategy facilitated triangulation of data sources, thereby bolstering the validity and reliability of findings concerning the adoption of business analytics in quasi-government institutions. The combined methodologies provided comprehensive insights into how stakeholder support influences the effective use of business analytics, thereby informing evidence-based strategies and policies for organizational decision-making and performance enhancement. Furthermore, the study integrated quantitative and qualitative findings through comparative analysis, identifying convergent or divergent patterns and themes pertaining to industry 4.0 technologies and supply chain management metrics.

4. Results and Discussions

Table 1 presents the study respondents' demographic information for a sound understanding of their background.

Demographic Characteristics	Frequency	Percentage
Department		
Warehouse	15	30%
Logistics	10	20%
Procurement	8	16%
IT	7	14%
Administrative	10	20%
Job Role		
Managerial	10	20%
Supervisory	15	30%
Operational	25	50%
Years of Experience		
Less Than a Year	5	10%
1 to 5 Years	20	40%
6 to 10 Years	15	30%
More Than 10 Years	10	20%

In table 1 above, the majority (30.0%) of respondents belonged to the warehouse department, 20.0% belonged to logistics department, 20% belonged to the administrative department, 16.0% belonged to the procurement department and 14.0% belonged to Information and Technology department. In terms of job role, majority (40%) of respondents held managerial positions, while (30%) were in supervisory roles and the remaining (30%) were in operational positions. As of years of experience, majority (40%) of respondents had 1-5 years of experience, while 30% had 6-10 years of experience. In addition, 20.0% had more than 10 years and 10.0% had less than 1 year of experience.

4.1. Descriptive statistics

Descriptive statistics were used to describe and summarize the data regarding the variables. The primary goal of descriptive statistics analysis was to calculate frequencies, mean, standard deviation, skewness, and kurtosis. Skewness shows a symmetrical distribution of data, while kurtosis provides information about the flatness of the data distribution (Pallant, 2016). In addition, skewness and kurtosis were used to assess the data for violations of normality. According to [George and Mallery \(2010\)](#), skewness and kurtosis values between $+2/-2$ provide evidence that there is no significant deviation from the normal univariate distribution of the data.

Data were collected using a 1-5 Likert scale with 1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, and 5-Strongly agree. Thus, mean values significantly greater than 3.5 mean that, on average, respondents agreed/strongly agreed with the factor statement, while mean values significantly less than 2.5 means that, on average, respondents disagreed/strongly disagreed with the factor statement. Mean values between 2.5 and 3.5 indicate that, on average, respondents neither agreed nor disagreed with the statement about the factor.

Table 2. Descriptive Statistics for variables under Industry 4.0 technologies

	Mean	Std.	Skewness	Kurtosis
	Statistic	Deviation	Statistic	Statistic
Internet of Things (IoT):	4.26	1.139	-1.660	1.803
Artificial Intelligence (AI)	4.68	.471	-.796	-1.425
Block chain:	4.44	.861	-1.806	2.909
Robotics and Automation	4.50	.505	.000	-2.085
Big Data Analytics	4.68	.471	-.796	-1.425
Cloud Computing	4.20	1.229	-1.567	1.294
Augmented Reality (AR) and Virtual Reality (VR)	4.52	.505	-.083	-2.078
Valid N (listwise)				

In table 2 above, the mean scores for the technologies range from 4.20 to 4.68. "Cloud Computing" has the lowest mean score of 4.20, while "Artificial Intelligence (AI)" and "Big Data Analytics" both have the highest mean score of 4.68, indicating variability in perceptions across these technologies. The standard deviations range from 0.471 to 1.229, reflecting the variability or spread of responses around the mean for each technology. "Artificial Intelligence (AI)" and "Big

Data Analytics" have the lowest standard deviation of 0.471, while "Cloud Computing" has the highest standard deviation of 1.229. In addition, skewness values range from -1.806 to -0.083. These values indicated slight to moderate left-skewness in the distributions of responses for the technologies. All skewness values fall within the acceptable range of -2 to +2, suggesting reasonably symmetrical or moderately skewed distributions. Furthermore, kurtosis values range from -2.085 to 2.909. These values indicate distributions that are generally within the acceptable range for normality (between -2 and +2). The distributions are slightly peaked or have heavier tails compared to a normal distribution, but not excessively so. The findings of this study are in agreement with the findings of the study conducted by [Mukupo, \(2019\)](#) which found that DHL Zambia is taking a lead in adopting some of the industry 4.0 technologies to enhance its performance and the common technologies being used by DHL Zambia include: Internet of Things (IoT) which sensors and devices for real-time tracking of shipments and monitoring conditions like temperature and humidity, Artificial Intelligence (AI) which is used for route optimization, demand forecasting, and predictive maintenance to enhance efficiency, blockchain which is employed for secure and transparent supply chain management, reducing fraud and errors in transactions, Big Data Analytics which analyzes large datasets helps in making informed decisions, optimizing routes, and managing inventory effectively, cloud computing which enables access to data and applications remotely, facilitating collaboration and scalability and Augmented Reality (AR) and Virtual Reality (VR) which is used for training, maintenance, and improving overall warehouse efficiency ([Mukupo,2019](#)). The findings of the study are also in line with the TEO framework (theory) which is evident in its applicability to different types of technological innovations. Particularly, shedding light on the adoption behaviour related to applied innovations for technical tasks, innovations in business administration, and innovations deeply embedded in the core business processes of an organization ([Ramdani & Kawalek, 2007](#)). Similarly, [Dalenogare et al. \(2018\)](#) found that applicable technologies such as CPSs, BDA, and IoT under the term P4.0 have represented substantial values in the supply chains. These added values consist of performance improvement in the operations associated with procurement management in supply chains such as pricing, supplier selection and evaluation, cost-efficacy, data gathering and analysis, and purchasing management.

Table 3: Descriptive Statistics for variables under supply Chain Management metrics

	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic
On-time Delivery (OTD):	4.44	.861	-1.806	2.909
Order Cycle Time	4.04	1.277	-1.363	.697
Inventory Turnover	4.34	.917	-1.571	1.869
Perfect Order Rate	4.18	.941	-1.294	1.076
Supply Chain Cost	4.74	.443	-1.128	-.759
Lead Time	4.10	1.298	-1.536	1.178
Forecast Accuracy	4.54	.930	-2.101	3.285
Valid N (listwise)				

In table 3 above, the mean scores for the supply chain metrics range from 4.04 to 4.74. "Order Cycle Time" has the lowest mean score of 4.04, while "Supply Chain Cost" has the highest mean score of 4.74, indicating variability in performance across these metrics. The standard deviations range from 0.443 to 1.298, reflecting the variability or spread of responses around the mean for each metric. "Supply Chain Cost" has the lowest standard deviation of 0.443, indicating less variability, whereas "Lead Time" has the highest standard deviation of 1.298, indicating more variability. In addition, skewness values range from -2.101 to 0.166. These values indicate slight to moderate left-skewness in the distributions of responses for the metrics. All skewness values fall within the acceptable range of -2 to +2, suggesting reasonably symmetrical or moderately skewed distributions. Furthermore, kurtosis values range from -2.057 to 3.285. These values indicate distributions that are generally within the acceptable range for normality (between -2 and +2). "Forecast Accuracy" exhibits the highest kurtosis of 3.285, suggesting a distribution that is more peaked and has heavier tails than a normal distribution. Conversely, "Supply Chain Cost" has a kurtosis of -0.759, indicating a distribution that is slightly flatter and has lighter tails compared to a normal distribution. The findings of the study are in agreement with the findings of the study by [Mukupo \(2019\)](#) which revealed that DHL Zambia, like many logistics and supply chain companies, employs various key performance indicators (KPIs) to measure its supply chain management performance and the common metrics include; On-time Delivery (OTD) which measures the percentage of deliveries that are made on time as per the agreed-upon schedule, Order Cycle Time which measures the time it takes from order placement to delivery, providing insights into overall efficiency, inventory turnover which indicates how quickly inventory is used and replenished, reflecting supply chain agility, perfect order rate which measures the percentage of orders that are delivered without errors, including accurate documentation, undamaged goods, and on-time delivery, supply chain cost which evaluates the overall cost efficiency of the supply chain process, including transportation, warehousing, and order fulfillment costs, lead time which measures the time it takes for an order to be fulfilled, from initiation to delivery, highlighting efficiency and responsiveness and forecast accuracy which measures how well the company predicts demand, helping in optimizing inventory levels and preventing overstock or stockouts.

4.2. Principal Component Analysis

Principal component analysis is a statistical technique used to reduce the dimensionality of a dataset while preserving as much variance as possible (Bai, Bai & Ng, 2021). It achieves this by transforming the original variables into a new set of uncorrelated variables, called principal components. These components are linear combinations of the original variables and are ordered so that the first component explains the maximum variance in the data, the second component explains the second most variance, and so on. Principal component analysis (PCA) is widely used in various fields such as image processing, finance, biology, and social sciences to simplify complex data sets and to identify patterns and relationships between variables. It is particularly useful when dealing with large datasets with many variables, as it helps in visualizing and interpreting data more effectively. Principal component analysis was used to reduce the indicators to components that are easy to interpret. In order to conduct a principal component analysis, the following assumptions were evaluated:

Assumption 1: There are multiple variables measured at the continuous level (ordinal data is also considered). The questionnaire had 14 statements that measured 2 constructs at the ordinal level of measurement (Strongly Disagreed, Disagreed, Neither Agree nor Disagree, Agreed and Strongly Agreed).

Assumption 2: There should be a linear relationship between all variables. This was tested using the correlation matrix. The level of correlation considered worthy of a variable’s inclusion is usually $r \geq 0.3$ (Laerd Statistics, 2015). In this data set, all the variables had correlations greater than 0.3.

Assumption 3: There should be a large sample size - 10 cases per variable was a rule of thumb used to determine this assumption (Tabachnick & Fidell, 2014). There were 14 variables that met the minimum factor loading of 0.6; this translates into a minimum of 140 cases. The data set for the analysis had 140 cases. Thus, this assumption was not violated.

Sampling Adequacy

To test for the sampling adequacy, the data set was tested using the Kaiser-Meyer-Olkin (KMO) index (Kaiser, 1974). The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity are statistical tools commonly used in the context of factor analysis to assess whether a dataset is suitable for this type of analysis. The KMO measure evaluates the sampling adequacy of data for factor analysis and is calculated by considering the partial correlations between variables and then taking into account the sum of these correlations relative to the sum of all correlations. The KMO index ranges from 0 to 1. Higher values close to 1 indicate that the variables in the dataset are suitable for factor analysis. Lower values closer to 0 suggest that correlations between variables are too weak for reliable factor analysis. On the other hand, Bartlett's test evaluates whether the correlation matrix among variables is an identity matrix, which would indicate that variables are not correlated and hence not suitable for factor analysis. The null hypothesis for Bartlett's test is that the correlation matrix is an identity matrix (variables are uncorrelated). If Bartlett's test yields a significant result (typically $p < 0.05$), then the null hypothesis is rejected, indicating that correlations between variables are sufficiently large for factor analysis thus, a non-significant result suggests that the dataset does not have sufficient correlations among variables for meaningful factor analysis. For this data, the KMO was 0.6, which is satisfactory. For the individual items KMO measures, all were above 0.6. The Bartlett's test of sphericity is statistically significant (i.e., $p < 0.05$). Thus, the correlation matrix was not an identity matrix (see Table 18 below). This indicates that the data was suitable for principal components analysis.

Table 4: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	430.954
	df	105
	Sig.	.000

Table 4: KMO Measures for Individual Variables

Variable	KMO Measurement	Variable	KMO Measurement
Internet of Things (IoT):	0.873	On-time Delivery	0.779
Artificial Intelligence (AI)	0.690	Order Cycle Time	0.680
Block chain:	0.819	Inventory Turnover	0.700
Robotics and Automation	0.600	Perfect Order Rate	0.700
Big Data Analytics	0.600	Supply Chain Cost	0.701
Cloud Computing	0.624	Lead Time	0.703

The Result of the PCA

A principal component analysis (PCA) was conducted on a 14-question questionnaire assessing the effects of industry 4.0 on supply chain management metrics. Prior to analysis, the suitability of PCA was assessed. Examination of the correlation

matrix revealed that all 14 variables had correlation coefficients greater than 0.3. The Kaiser-Meyer-Olkin (KMO) measure was 0.602 overall, with individual KMO measures exceeding the minimum acceptable cutoff of 0.6, as recommended by Kaiser (1974). Bartlett's test of sphericity yielded a highly significant result ($p < .0005$), indicating that the data was appropriate for factor analysis. PCA identified two components with eigenvalues exceeding one, Collectively explaining 45.964% of the total variance. The percentages of variance explained by these components were 25.922%, and 20.042% respectively (see Table 3a, Table 3b, Table 3c and Figure 1) for detailed outputs). Visual inspection of the scree plot supported retaining two components (Cattell, 1966). Furthermore, a two-component solution met the interpretability criterion (Cheaper). The retained components were industry 4.0 technologies and supply chain management metrics. Together, these components explained 45.964% of the total variance. A Varimax orthogonal rotation was applied to enhance interpretability, yielding a rotated solution with 'simple structure' (Thurstone, 1947). Interpretation of the data aligned well with the attributes the questionnaire aimed to measure, with strong loadings observed for Industry 4.0 technologies (Component 1), and supply chain management metrics (Component 2). Detailed component loadings from the rotated solution can be found in Tables below (SPSS Output, 2024). The full SPSS outputs are provided in the appendices.

Table 4a: Rotated Structure Matrix PCA with Varimax Rotation

	Component	
	1	2
Internet of Things (IoT):	7.255	.721
Artificial Intelligence (AI)	.777	.160
Blockchain:	.798	.186
Robotics and Automation	.776	-.524
Big Data Analytics	.794	-.109
Cloud Computing	.711	.051
Augmented Reality (AR) and Virtual Reality (VR)	.797	.299
On-time Delivery (OTD):	.160	.815
Order Cycle Time	-.683	.896
Inventory Turnover	-.065	.845
Perfect Order Rate	-.012	.859
Supply Chain Cost	.832	.800
Lead Time	.418	.744
Customer Satisfaction	-.326	.722
Forecast Accuracy	-.328	.707

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4b: Total Variance Explained

Component	Total Variance Explained								
	Initial Eigenvalues			Loadings			Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.888	25.922	25.922	3.888	25.922	25.922	3.357	22.378	22.378
2	3.006	20.042	45.964	3.006	20.042	45.964	2.769	18.460	40.837
3	1.948	12.985	58.948	1.948	12.985	58.948	2.069	13.796	54.633
4	1.601	10.672	69.620	1.601	10.672	69.620	1.822	12.148	66.781
5	1.093	7.286	76.906	1.093	7.286	76.906	1.519	10.126	76.906
6	.964	6.424	83.331						
7	.736	4.904	88.235						
8	.418	2.783	91.018						
9	.362	2.412	93.430						
10	.279	1.863	95.293						
11	.212	1.414	96.708						
12	.182	1.216	97.923						
13	.145	.966	98.889						
14	.089	.595	99.484						
15	.077	.516	100.000						

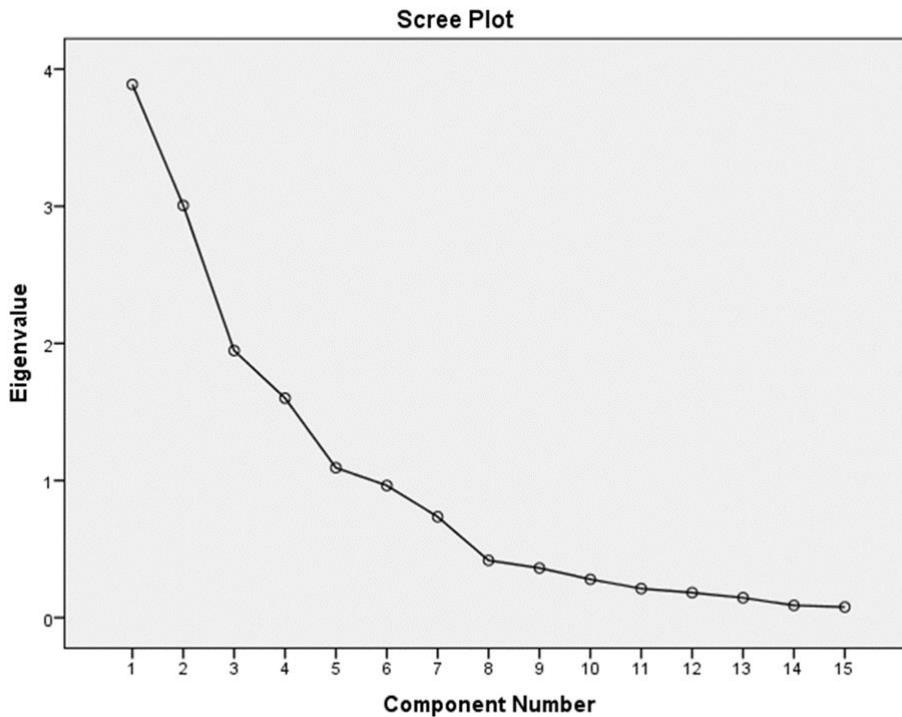
Extraction Method: Principal Component Analysis.

Table 4cc: Anti-Image Matrices

Anti-image Matrices																
	Internet of Things (IoT):	Artificial Intelligence (AI)	Blockchain:	Robotics and Automation	Big Data Analytics	Cloud Computing	Augmented Reality (AR) and Virtual Reality (VR)	On-time Delivery (OTD):	Order Cycle Time	Inventory Turnover	Perfect Order Rate	Supply Chain Cost	Lead Time	Customer Satisfaction	Forecast Accuracy	
Anti-image Covariance	Internet of Things (IoT):	.380	-.029	-.036	.031	-.008	.043	.048	.019	-.011	.016	-.130	.015	.001	.028	-.048
	Artificial Intelligence (AI)	-.029	.329	.127	-.002	.068	-.041	-.020	-.154	-.005	-.051	.002	.039	.104	.123	.038
	Blockchain:	-.036	.127	.213	-.139	.096	-.095	-.053	-.040	.013	-.044	-.006	-.082	.044	.084	.040
	Robotics and Automation	.031	-.002	-.139	.363	-.103	.104	.039	-.089	-.064	.029	.059	.044	-.055	-.011	-.057
	Big Data Analytics	-.008	.068	.096	-.103	.180	-.150	.040	-.030	.072	.056	.007	-.049	.016	.048	.024
	Cloud Computing	.043	-.041	-.095	.104	-.150	.246	-.016	.004	-.009	-.042	-.036	-.008	.046	-.092	-.018
	Augmented Reality (AR) and Virtual Reality (VR)	.048	-.020	-.053	.039	.040	-.016	.202	.056	.118	.210	-.021	-.011	.124	-.033	-.002
	On-time Delivery (OTD):	.019	-.154	-.040	-.089	-.030	.004	.056	.392	-.022	.108	-.091	-.099	-.011	-.101	.083
	Order Cycle Time	-.011	-.005	.013	-.064	.072	-.009	.118	-.022	.192	.123	-.020	-.006	.152	-.056	.029
	Inventory Turnover	.016	-.051	-.044	.029	.056	-.042	.210	.108	.123	.398	-.003	-.034	.101	-.024	-.003
	Perfect Order Rate	-.130	.002	-.006	.059	.007	-.036	-.021	-.091	-.020	-.003	.230	.005	-.053	.098	-.157
	Supply Chain Cost	.015	.039	-.082	.044	-.049	-.008	-.011	-.099	-.006	-.034	.005	.268	-.028	.087	.057
	Lead Time	.001	.104	.044	-.055	.016	.046	.124	-.011	.152	.101	-.053	-.028	.352	-.029	.049
	Customer Satisfaction	.028	.123	.084	-.011	.048	-.092	-.033	-.101	-.056	-.024	.098	.087	-.029	.282	-.022
Forecast Accuracy	-.048	.038	.040	-.057	.024	-.018	-.002	.083	.029	-.003	-.157	.057	.049	-.022	.389	
Anti-image Correlation	Internet of Things (IoT):	.806 ^a	-.081	-.126	.083	-.032	.139	.174	.049	-.041	.041	-.441	.048	.002	.086	-.124
	Artificial Intelligence (AI)	-.081	.618 ^a	.481	-.005	.278	-.144	-.078	-.428	-.022	-.140	.007	.130	.305	.405	.106
	Blockchain:	-.126	.481	.534 ^a	-.498	.489	-.413	-.257	-.139	.063	-.151	-.025	-.344	.160	.342	.138
	Robotics and Automation	.083	-.005	-.498	.544 ^a	-.402	.348	.146	-.236	-.244	.077	.203	.142	-.153	-.033	-.151
	Big Data Analytics	-.032	.278	.489	-.402	.570 ^a	-.713	.210	-.112	.385	.210	.035	-.223	.063	.211	.091
	Cloud Computing	.139	-.144	-.413	.348	-.713	.580 ^a	-.074	.013	-.042	-.134	-.153	-.030	.155	-.349	-.058
	Augmented Reality (AR) and Virtual Reality (VR)	.174	-.078	-.257	.146	.210	-.074	.418 ^a	.200	.598	.742	-.100	-.046	.466	-.137	-.006
	On-time Delivery (OTD):	.049	-.428	-.139	-.236	-.112	.013	.200	.489 ^a	-.079	.273	-.304	-.306	-.030	-.304	.212
	Order Cycle Time	-.041	-.022	.063	-.244	.385	-.042	.598	-.079	.589 ^a	.444	-.096	-.026	.584	-.240	.105
	Inventory Turnover	.041	-.140	-.151	.077	.210	-.134	.742	.273	.444	.249 ^a	-.010	-.105	.271	-.071	-.007
	Perfect Order Rate	-.441	.007	-.025	.203	.035	-.153	-.100	-.304	-.096	-.010	.641 ^a	.021	-.187	.384	-.524
	Supply Chain Cost	.048	.130	-.344	.142	-.223	-.030	-.046	-.306	-.026	-.105	.021	.812 ^a	-.090	.316	.178
	Lead Time	.002	.305	.160	-.153	.063	.155	.466	-.030	.584	.271	-.187	-.090	.463 ^a	-.091	.132
	Customer Satisfaction	.086	.405	.342	-.033	.211	-.349	-.137	-.304	-.240	-.071	.384	.316	-.091	.594 ^a	-.068
Forecast Accuracy	-.124	.106	.138	-.151	.091	-.058	-.006	.212	.105	-.007	-.524	.178	.132	-.068	.719 ^a	

a. Measures of Sampling Adequacy(MSA)

Figure 1: Scree Plot



4.3. Reliability Analysis

In this study, a structured questionnaire served as the primary tool for evaluating several distinct constructs relevant to the research objectives. The questionnaire was meticulously designed to capture key variables related to industry 4.0 technologies and supply chain management metrics. This method ensured that the data collected was comprehensive and aligned with the study's aims. To ascertain the reliability of the constructs measured by the questionnaire, the researcher employed Statistical Package for Social Sciences (SPSS) version 22. This software facilitated a rigorous reliability analysis, specifically using Cronbach's alpha coefficient. Cronbach's alpha is a widely used measure to assess the internal consistency of a set of questionnaire items intended to measure a single construct. It quantifies how closely related a set of items are as a group, providing insights into the reliability and coherence of the constructs being studied. Table below in the study presents the computed Cronbach's alpha coefficients for each variable construct derived from the questionnaire. These coefficients were crucial indicators of the reliability of the measurement scales used in the study. Higher alpha values generally indicate greater internal consistency among the items measuring each construct, suggesting that the items are measuring the same underlying concept effectively. Moreover, detailed outputs from the reliability analysis procedure conducted in SPSS are documented in Table 4 of the study. These outputs include comprehensive information such as item-level statistics, scale-level statistics, and reliability coefficients for each construct. This transparency and thoroughness in reporting the reliability analysis ensured that the study's findings were based on robust and dependable measurement instruments. Table 5.21 below provides an illustration of the reliability analysis utilizing Cronbach's alpha coefficient.

Table 5: Cronbach's Alpha for the Two Constructs

Case Processing Summary			
		N	%
Cases	Valid	50	100.0
	Excluded ^a	0	0.0
	Total	50	100.0
a. Listwise deletion based on all variables in			
Reliability Statistics			
Cronbach's Alpha	N of Items		
.787	7		

George and Mallery (2019) offer a guideline for interpreting Cronbach's alpha. Cronbach's alpha is a measure of internal consistency reliability, used to assess how well a set of items in a questionnaire or scale measures a single construct. The

coefficients can range from 0 to 1, where higher values indicate greater internal consistency among the items. Coefficients less than 0.5 are classified as "Unacceptable." This range suggests that the items in the questionnaire or scale are not measuring the construct reliably. Internal consistency is considered inadequate, indicating that the items may not be sufficiently related to each other to provide a consistent measurement. Coefficients greater than 0.5 but less than 0.7 are categorized as "Poor." While these coefficients indicate some degree of internal consistency, it is still considered less than desirable. The items may be measuring the construct, but with a moderate level of reliability. In this study, all the constructs demonstrated strong to excellent Cronbach's alpha values. That is: values less than 0.5 are categorized as "Unacceptable," indicating poor internal consistency reliability; values greater than 0.5 but less than or equal to 0.6 are classified as "Poor," suggesting weak internal consistency; values greater than 0.6 but less than or equal to 0.7 are labeled as "Questionable," indicating moderate internal consistency; values greater than 0.7 but less than or equal to 0.8 are considered "Acceptable," signifying reasonably good internal consistency; values greater than 0.8 but less than or equal to 0.9 are termed "Good," indicating strong internal consistency; values greater than 0.9 but not exceeding 0.95 fall into the category of "Excellent," suggesting very strong internal consistency. These classifications helped assess the reliability of scales or constructs measured by Cronbach's alpha, providing insights into the consistency of responses within a questionnaire or survey.

4.4. Component-Based Scores

A component-based score refers to a composite score derived by averaging the scores of all items that exhibit strong loadings on a specific component identified through factor analysis (Fincham, 2008). For instance, items such as “Internet of Things (IoT), Artificial Intelligence (AI), Block chain, Robotics and Automation, Big Data Analytics, Cloud Computing, Augmented Reality and Virtual Reality” all demonstrated strong loadings on Component 1. The scores of these individual items were averaged to generate a composite component-based score reflecting the industry 4.0 technologies. These component-based scores, now treated as variables, were subsequently utilized in hierarchical multiple regression analysis (Tabachnick & Fidell, 2014). This method allows for examining the relationship between these composite scores (variables) and other control variables, as well as the dependent variable, which in this context is the supply chain management metrics.

Table 6: Correlation Matrix

		Correlations			
		I4T	SCMM	Depart	Exp
Industry4.0 Technologies	Pearson Correlation	1		.163	
	Sig. (2-tailed)			.259	
	N	50		50	
SupplyChain Management Metrics	Pearson Correlation	.035	1		
	Sig. (2-tailed)	.807			
	N	50	50		
Department	Pearson Correlation	.163	.011	1	
	Sig. (2-tailed)	.259	.939		
	N	50	50	50	
Experience	Pearson Correlation	-.236	-.361*	.663**	1
	Sig. (2-tailed)	.099	.010	.000	
	N	50	50	50	50

*. Correlation is significant at the 0.05 level (2-tailed).
 **. Correlation is significant at the 0.01 level (2-tailed).

From table 6 above, it was observed that department (as a control variable) exhibited a statistically positive correlation with the dependent variable, supply chain management metrics ($r=0.011$, $P<0.05$). However, experience (as a control variable) showed negative correlation with supply chain management metrics. Additionally, industry 4.0 technologies had a positive correlation with supply chain management metrics. These findings suggest that industry 4.0 technologies have a positive effect on the supply chain management metrics. Moreover, the correlation matrix presented in Table above was examined to assess the potential issue of multicollinearity in the context of conducting OLS multiple regression. The matrix revealed that all correlations among the continuous independent variables were less than 0.7, indicating that multicollinearity is not likely to be a significant concern.

4.5. Hierarchical Multiple Regression Analysis

Hierarchical multiple regression analysis is a statistical technique used to explore the relationship between multiple predictor variables and a single outcome variable. It builds upon the basic principles of multiple regression by introducing a systematic approach to entering predictor variables into the regression equation (Tabachnick & Fidell, 2014). To begin

a hierarchical multiple regression analysis, there is need to evaluate several assumptions to ensure the validity and reliability of the findings. These assumptions typically include assessing the linearity of relationships between variables, verifying that residuals are normally distributed, confirming that there is no multicollinearity among predictor variables, and ensuring that residuals exhibit homoscedasticity (equal variance). Once these assumptions are met, the hierarchical multiple regression analysis proceeds. This method involves systematically entering predictor variables into the regression equation in stages or blocks. The order of entry is predetermined based on theoretical or practical considerations. Thus, in order to conduct a hierarchical multiple regression analysis, the following assumptions (eight key) were evaluated thereafter the procedure was run to obtain the results.

Assumption 1: You have one dependent variable that is measured at a continuous level (i.e., the interval or ratio level). In this study, the dependent variable, supply chain management metrics, was considered a continuous variable after the component-based scores were computed.

Assumption 2: You have one or more independent variables that are measured on either a continuous or nominal scale. In this study, the following independent variables were continuous variables after the component-based scores were computed: industry 4.0 technologies. The control variables used were department (nominal) and Experience (ordinal).

Assumption 3: There should be independence of errors (residuals). The Durbin-Watson was .560, which is between 1.5 and 2.5, and therefore, the data is not auto-correlated. There was the independence of residuals as assessed by a Durbin – Watson statistic of .560.

Assumption 4: There should be a linear relationship between the predictor variables and the dependent variable. To establish if a linear relationship exists between the dependent and independent variables collectively, a scatter plot of the standardized residuals against the unstandardized predicted values was plotted using the chat builder in SPSS (see appendix 4) The residuals form a horizontal band as shown in the scatter plot in Appendix IV. Therefore, the relationship between the dependent variable and independent variables is linear. To establish if a linear relationship exists between the dependent variable and each of the independent partial regression plots from SPSS were used. Industry 4.0 Technologies: A partial regression plot in appendix 4 shows a linear relationship between Industry 4.0 Technologies and Supply Chain Management Metrics.

Assumption 5: There should be homoscedasticity of residuals (equal error variances). The assumption of homoscedasticity was checked using the plot for standardized residuals against the unstandardized predicted values (see appendix 4). The residuals appear randomly scattered. On this basis, it appears that the assumption of homoscedasticity has been made.

Assumption 6: There should be no multicollinearity. To check for multicollinearity, correlation coefficient and tolerance/VIF values were inspected. None of the independent variables in Table 4.14 had correlations greater than 4.7. In the coefficient output in appendix 4 none of the variance VIF is greater than 5, so multicollinearity should not be a problem with this data set.

Assumption 7: There should be no significant outliers, high-leverage points, or highly influential points. To check for outliers, standardized residuals, and standardized deleted residuals were inspected from the SPSS output residual statistics. Values greater than ± 3 are an indication of the presence of an outlier. From the residual statistics table, none of the standardized residuals and standardized deleted residuals were outside the ± 3 cutoff criteria for outliers therefore, there was no evidence of outliers in the data set. To The assumptions and statistical results of the regression model indicate robustness and validity. Linearity was confirmed through partial regression plots and a studentized residuals plot against predicted values. Independence of residuals was supported by a Durbin-Watson statistic of .560, suggesting no significant autocorrelation. Homoscedasticity was observed via visual inspection of a plot of studentized residuals versus unstandardized predicted values. Multicollinearity was absent, verified by low correlations and Variance Inflation Factors (VIFs). Further diagnostics showed no studentized deleted residuals exceeding ± 3 standard deviations, leverage values above 0.2, or Cook's distance values exceeding 1, affirming the model's stability. Normality assumptions were met, evidenced by the histogram of residuals and the P-P Plot. Regarding model performance, the correlation coefficient (R) of 0.539 indicated a low to moderate relationship between predictor (industry 4.0 technologies, respondents' experience and respondents' department) and the dependent variable (supply chain management metrics). The R Square value of 0.291 indicated that approximately 2.9% of the variance in supply chain management metrics could be explained by the model's predictors. check whether any cases exhibit high leverage, one general rule of thumb is to consider leverage values less than 0.2 as safe, 0.2 to less than 0.5 as risky, and values of 0.5 and above as dangerous (Huber, 1981). From the residual statistics table in Appendix 4 the maximum leverage point is 0.142 and the minimum leverage point is 0.010. In this data, there are no leverage values above the safe value of .2. Therefore, there is no residual with a high leverage point. To check for influential points cook's Distance values for each case were inspected. As a rule of thumb, if there are Cook's Distance values above 1, they should be investigated. From the residual statistics in appendix 4, the maximum Cook's value is .115 and the minimum value is .000. There were no Cook's distance values above 1, therefore no evidence of an influential case (Cook and Weisberg, 1982).

Assumption 8: Errors (residuals) should be approximately normally distributed. Two methods were used to check for the assumptions of normality of the residuals: A histogram with a superimposed normal curve and a P- P Plot produced by SPSS. From the histogram in appendix 4, the standardized residuals appear to be approximately normally distributed. To confirm this finding, the P-P Plot was examined. From the P-P Plot in appendix 4 although the points are not aligned perfectly along the diagonal line, there are close enough to indicate that residuals are close enough to normal for the analysis to proceed.

4.6. Interpretation of the Findings

A hierarchical multiple regression analysis was conducted to assess the effects of industry 4.0 technologies on supply chain management metrics, while controlling for variables such as experience and department. This method allowed for examining whether the effect of industry 4.0 technologies variable remained significant after accounting for the effects of these control variables. The analysis aimed to determine the hierarchical contribution of industry 4.0 technologies beyond the baseline effects of the control variables. This approach helped in understanding whether industry 4.0 factors independently affect the supply chain management metrics or if their influence was mitigated or enhanced by other demographic or organizational factors. For comprehensive insights into the results of the regression model, including coefficients, significance levels, and model fit statistics, please consult Table 18. This table provides a comprehensive overview of how each variable contributes to explaining the effect of industry 4.0 technologies on supply chain management metrics.

Table 7: Model Summary

Model Summary ^b										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.539 ^a	.291	.244	2.02811	.291	6.281	3	46	.001	.560

a. Predictors: (Constant), Experience, Industry4.0Technologies, Department

b. Dependent Variable: SupplyChainManagementMetrics

The assumptions and statistical results of the regression model indicate robustness and validity. Linearity was confirmed through partial regression plots and a studentized residuals plot against predicted values. Independence of residuals was supported by a Durbin-Watson statistic of .560, suggesting no significant autocorrelation. Homoscedasticity was observed via visual inspection of a plot of studentized residuals versus unstandardized predicted values. Multicollinearity was absent, verified by low correlations and Variance Inflation Factors (VIFs). Further diagnostics showed no studentized deleted residuals exceeding ± 3 standard deviations, leverage values above 0.2, or Cook's distance values exceeding 1, affirming the model's stability. Normality assumptions were met, evidenced by the histogram of residuals and the P-P Plot. Regarding model performance, the correlation coefficient (R) of 0.539 indicated a low to moderate relationship between predictor (industry 4.0 technologies, respondents' experience and respondents' department) and the dependent variable (supply chain management metrics). The R Square value of 0.291 indicated that approximately 2.9% of the variance in supply chain management metrics could be explained by the model's predictors.

The adjusted R Square, slightly lower at 0.291, adjusted for the number of predictors, suggested that some explained variance might be due to chance. The standard error of the estimate (2.02811) gauged the accuracy of predictions made by the model. A change in R Square of 0.291 indicated that the independent variables collectively contributed to 2.9% of the variability in the dependent variable. Finally, the Durbin-Watson statistic of 0.560, close to 2, indicated no significant autocorrelation in the residuals, further validating the model's reliability. The significance value for the model's overall change was 0.01, below the conventional threshold of 0.05, indicating statistical significant effect of industry 4.0 technologies on supply chain management metrics. The findings of this study are consistent with the findings of the study conducted by [Sharma, et al. \(2022\)](#) who examined the mediating effect of Industry 4.0 technologies on supply chain management practices and supply chain performance measures. The study by [Sharma, et al., \(2022\)](#) revealed that there is a significant effect of supply chain management practices on the adoption of Industry 4.0 technologies. In addition, the findings of this study support the findings of the study by [Abdirad and Krishnan \(2021\)](#) which found that 4.0 is seen as a concept that has an important role in the MSC. By applying this concept, human interaction would be minimized, and productivity would be increased in companies. Similarly, a study by [Patil et al. \(2020\)](#) which found that industry 4.0 gives the greater transparency and accuracy between the all suppliers, manufactures, logistics, warehouse, and fulfilment are overcome unnecessary cost. Advance machine learning help to predict the demand of different products at high accuracy. High interconnection and collaboration between all the supply chain levers which taking supply chain on next level. The study also found that digitization increases the warehouse capabilities like sensor track the flow of goods and feed the relevant information in real time. It also improves the agility by using integrate data from procurement to consumer end in 'supply chain cloud' it ensures that all stockholders having the way to take decision by considering all the factors.

5. Conclusion and Recommendations

Technological advancements related to the fourth industrial revolution are causing disruptive changes that are widely felt at national, industry, and company level. Industry 4.0 is a concept that focuses on automation, digitalization, and networking in companies. Its goal is to achieve a smart factory to reduce lead time to respond to the customers' demand

or to unforeseen events and improve productivity in the system. Despite the growing body of global and regional research exploring the intersection of Industry 4.0 and supply chain management, a noticeable gap exists in addressing the specific effect of Industry 4.0 on the supply chain performance at DHL Zambia. As a result, this study assesses the effects of industry 4.0 technologies on supply chain management performance at DHL Zambia.

The study's first objective was to establish the industry 4.0 technologies used at DHL Zambia. The study found that Internet of Things, block chain, Big Data Analytics and AR and VR as technologies are the industry 4.0 technologies used at DHL Zambia. This was affirmed by the specific mean scores of the responses obtained as they were greater than the neutral mean score (3.00). Furthermore, the second objective determined the supply chain management metrics used to measure performance at DHL Zambia. The study found that on-time delivery, order cycle time, inventory turnover, perfect order rate, supply chain cost, lead time, and forecast accuracy, are the supply chain management metrics adopted at DHL Zambia. The third research objective evaluated the effects of the established Industry 4.0 technologies on the supply chain management performance metrics at DHL Zambia. The multiple regression test results found significant effect of industry 4.0 technologies on supply chain management.

Based on the findings provided by the study, the study recommends that managers at DHL Zambia need to adopt this technology to sort, pack the packages and use autonomous vehicles for transportation. Managers at DHL Zambia need to prioritize training and skill development initiatives aimed at equipping the workforce with the technical competencies required for leveraging Industry 4.0 technologies effectively. This will ensure that the workforce is prepared to embrace digital transformation and adapt to the changing demands of the industry.

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Declaration of Competing Interest

The authors declare that they are not aware of any competing financial interests or personal relationships that may have influenced the work described in this document.

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