INDUSTRY 4.0 TECHNOLOGIES AND COMPETITIVENESS OF LARGE MANUFACTURING FIRMS IN NAIROBI, KENYA

BY

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DECLARATION

STUDENT'S DECLARATION

This piece is my authentic work which hasn't been tendered to any learning institution for purposes of the award of any degree.

Signature .... **Date** 19/11/2022

DENNIS KOECH

D67/33514/2019

SUPERVISOR'S DECLARATION

This research has been offered to be examined with my authorisation as the institution's Supervisor.

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DEDICATION

This academic piece is dedicated to my parents Mr. Lawrence Bii and Mrs. Alice Bii and my siblings for the support they have given me in my pursuit of further education

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ABBREVIATION AND ACRONYMS

AI	Artificial Intelligence
AM	Additive Manufacturing
BDA	Big Data Analytics
CC	Cloud Computing
COVID-19	Corona Virus 2019
CPS	Cyber-physical systems
GDP	Gross Domestic Product (GDP)
I4.0	Industry 4.0 Technologies
IoT	Internet of Things
KAM	Kenya Association of Manufacturers
RBV	Resource Based View
TFT	Task Fit Technology

ABSTRACT

The study sought to investigate the influence of Industry 4.0 Technologies and Competitiveness of large manufacturing entities in Nairobi. The objectives were to ascertain the adoption level of Industry 4.0 Technologies by the large manufacturers in Nairobi, to ascertain the relationship between Industry 4.0 Technologies and Competitiveness and to determine the challenges experienced in the implementing Industry 4.0 Technologies by the large manufacturing firms in Nairobi. Descriptive design was the research design embraced. The population was made up of 210 large manufacturing firms whereby simple random sampling was carried out to arrive at 70 large manufacturing firms. Primary data was used which was acquired through the use of questionnaires. Drop and pick later as well as use of electronic mails were the mode of administering the questionnaires. Descriptive statistics was used to analyse objective one and three while regression analysis was used to analyse objective two. On the foremost objective which was to determine the extent of adoption of Industry 4.0 Technologies by the Large Manufacturing entities, it was affirmed that Industry 4.0 Technology were moderately adopted with Additive manufacturing ranking first, followed by Big Data Analytics, 3D Printing, Cloud computing and lastly Internet of Things. Objective two determined that BDA, Additive manufacturing, 3D Printing and Internet of things influences Competitiveness whereas Cloud Computing had no impact on Competitiveness of large large manufacturers as observed by their respective p values. Specifically, Industry 4.0 was established to impact Cost, Speed, Quality and Dependability of large manufacturing firms in Nairobi. High investment related costs, high level of Data insecurity, existence of insecure connectivity, existence of inadequate technological infrastructure and high level of inadequate skilled personnel were among the challenges faced in implementation of Industry 4.0 Technologies. It is recommended that BDA, Additive manufacturing, 3D Printing, Cloud Computing and Internet of things influences to a large extent as they were found to have been moderately adopted by the manufacturing entities in Nairobi. The study was limited in context as it only covered Large manufacturers in Nairobi and left out all the other manufacturing firms. Future studies should focus on Industry 4.0 Technologies in other setting (public entities, Hospitals) apart from the large manufacturing firms in Nairobi. The scope may be widened from large manufacturers in Nairobi to large manufacturers in Kenya.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

In contemporary business surrounding, substantial pressure exists on entities to aid client's contentment and quality levels while also increasing competitiveness by decreasing inefficiency and error rates (Bai, Dallasega, Orzes & Sarkis, 2020). Organizations must acquire and retain customers because they are the driving force behind the economy. There exists numerous concepts and techniques that can be utilized to ensure an elevated level of quality and aid in continuously developing the entity. Contemporary research have indicated growing technological turbulence in production and the risk of job replacement as an outcome of automation in developed nations although not much is known on the factors in developing nations (Frank, Dalenogare & Ayala, 2019). Studies also indicates inadequate information of new technological improvements and its outcome on developing the economy (Kumar, Singh & Dwivedi, 2020). Many businesses must increase their efficiency and agility so as to match the advancing intricate expectations of their clients as well as enhance competitiveness as concluded by Nedjwa, Bertrand and Sassi-Boudemagh (2022). Thus, Industry 4.0 (I4.0) provide substantial prospects for enhancing operational and decision-making processes.

The study was guided by Resource Based View (RBV) and Task-Technology Fit (TTF) Theories. Based on RBV, organizations that own resources that are strategic in nature have important competitive edge over organizations that do not. Strategic resource is a resource that has value, hard to imitate, rare to find and cannot be easily substituted (Barney and Chi, 1994). Based on Goodhue and Thompson (1995), TTF theory is of the view that Information Technology positively impacts the performance of organizations and that the theory can be adopted if the said technology has the ability to match the task that it has been intended to undertake.

Awino (2011) opines that manufacturing is a critical division in the nation and it donates considerably to the development of the nation's economic. Manufacturing entities ought to ensure that the production needs to be undertaken in the most efficient and effective manner (Briens & Williams, 2004). Large Manufacturing entities are mainly involved in large scale production and thus the need to transform raw materials to end product within the shortest possible time and thus the need to implement I4.0 Technologies in their day to day activities (Nedjwa et al., 2022).

1.1.1 Industry 4.0 Technologies

Industry 4.0, also termed as the 4th industrial revolution, was devised in Germany in twenty eleven and is centered on manufacturing entities and optimizes the manufacturing process by combining plants, employees and advanced analytics (Zheng, Ardolino, Bacchetti & Perona, 2021). It consists of a linkage of various devices linked by communications technologies, resulting in systems that can track, gather, interchange, analyze and provide valued insights that enable industrial entities to make smarter and responsive decisions-making.

The most commonly used terms to describe the fourth industrial revolution are Industry 4.0, smart production, the Internet of Things (IoT) and digital transformation (Zheng et al., 2021 & Bai et al., 2020). These concepts embraces the innovation and digitalizing the upstream and downstream of the chain in goods and services and the formation of contemporary corporate structures (Javaid, Haleem, Vaishya, Bahl, Suman & Vaish, 2020). This transformation's key business drivers entails client's experience, increasing speed to market and lowering costs.

Industrial networking, automating knowledge work, big data, robotics cloud based computing, 3D printing, virtual reality, and AI are among the industry's 4.0 technical pillars (Rosin, Forget, Lamouri & Pellerin, 2020). These pillars will produce many business opportunities and entities listings. The IoT, which links numerous systems, devices, sensors, assets and persons via networks is one example of a technology that enables Industry 4.0.

Cloud computing includes solutions for processing and storage of data. Monitoring and controlling the procedures via sensors and processors pegged on the world's digital models is what cyber-physical systems are all about. Big data analytics entails early warning algorithms, predictive models, decision support, workflows, and dashboards, as well as advanced production technologies such as 3D printing as well as robotics and (Rosin et al., 2020 & Nedjwa et al., 2022).

1.1.2 Competitive Advantage

Competitive advantage is at the epitome of an entity's performance in competitive businesses as pointed out by Porter (1995). The organization is deemed to possess a competitive edge when instigates tactics that creates value creating and the competitors are not implementing

(Dagnino, Picone & Ferrigno, 2021). According to Distanont and Khongmalai (2020), an entity is perceived to have a competitive advantage over rivals if sustains a wide wedge between the willingness of buyers to purchase its products and the cost it incurs. A firm must, therefore, identify its position relative to the competition in the market.

Porter (1998) defines competitive advantage as a firm's position relative to its competitors. Gunasekaran, Subramanian and Papadopoulos (2017) agree when they define competitive advantage as an entity's aptitude to generate more economic value than competitors. Competitiveness is the entity's ability to provide services and goods that meet quality criteria of global and native markets at the cost that provide satisfactory returns on the investment used in their production. When a company performs the most critical functions more cheaply or better than its competitors, it gains and maintains a competitive advantage (Koch & Windsperger, 2017).

Slack, Chamber, Johnston (2004) lists the dimensions of competitive advantage as cost, quality, speed, dependability and flexibility. Shakkya (2013), Slack et al. (2004) and Vencataya, Seebaluck and Doorga (2015) further explains that cost is attained by being able to manufacture at a lower cost; quality being the ability to meet specifications with minimal defects; Speed as having shorter lead times by responding quickly to demands; Dependability as the ability of delivering products as and when needed while flexibility as the capacity to swiftly shift operations. The study thus adopted these dimensions

1.1.3 Large Manufacturing Firms in Kenya

Kenya Association of Manufacturers represents manufacturing firms (KAM, 2022). Based on the KAM, the exclusion of price controls, import exchange controls and the introducing investment motivations have not yielded significant changes in the general economy, particularly in manufacturing performance. As a result, in order to build a self-sustaining industrial sector, strategic associations within the local economy must be established. The expansion of the Industrial sector is credited primarily to an increase in the output and maximize on the output. Other key manufacturing segments that perform well include cigarette manufacturing, cement, batteries and assembling vehicle.

Kenyan Manufacturing entities are classified as large with assets exceeding Kshs 100 million), medium with assets ranging from Kshs 40 to Ksh 100M) and small having assets less than Kshs 40M) as categorized by KAM (2022). The entities with high performance in terms of plant requirements, labor requirements (capital and labor intensiveness) and disposition of assets required to come up with the ultimate product. Massive capacity is required for large-scale producing entities to function and it's not a surprise that majority of the manufacturing entities are situated on the peripheries of Nairobi which has room for expanding.

Firms are faced with challenges like stiff competition from cheap imports, inadequate infrastructure, limited access to the market, high cost of labour as well as long lead and cycle time (Nasambu, 2020 & Awino, 2011). There is also longer lead and cycle time, uncertainty in demand and changes in customer preferences. Inventory management, changing consumer trends, globalization, need for S.C visibility, pressure to increase revenue and sales are other challenges encountered by the firms (Krésová, 2019 & Kagechu, 2013). Manufacturing firms are thus challenged to come up with innovative ways that they can use to mitigate this challenges and be able to stay in business.

Nairobi is a commercial and financial sector not just for the country but the East and Central Africa as well. A large number of Industrial entities are situated here and it's perceived to be a preferred destination as attributed to its huge market base. The Kenyan market supplies to the local as well as exports to other nations outside what they produce locally. This industry contributed about 13% considerably to Kenyan GDP in 2017.

1.2 Research Problem

While some of the entities may be in denial on I4.0 and its influence on impacting their daily activities, others have embraced it and incorporated the technologies to enable smart machines in enhancing their operations as noted by Rosin, et al. (2020). Industry 4.0 has been established to enhance competitiveness, increase productivity, enhance revenue and productivity as well as optimize the machines (Kumar et al., 2020). Frank et al. (2019) opine that it enhances seamless record keeping and traceability. It is crucial for any entity to engage in activities that give them a competitive edge so that they can stay ahead of their competitors as well as provide quality services to their clients in a flexible, reliable and cost effective manner (Nedjwa et al., 2022).

Large manufacturing firms in Kenya are confronted with countless challenges for instance perishability of food in the food manufacturing sector, mishandling and conservation of the goods leading to waste through of over-processing beyond demand, penetration of counterfeit commodities in the proper supply channels, the uncertainty of demand, longer lead times and unreliability of labor force. This challenges have hampered the operation process and hindered firms from attaining competitive advantage. Industry 4.0 Technologies is thus needed as it plays a critical part in ensuring that the aforementioned milestones becomes the thing of the past as in enhances efficiency, transparency and effectiveness in the manufacturing process.

Studies on the fourth industrial revolution have been done in the global, regional and local front. Rosin, Forget, Lamouri and Pellerin (2022) studied the part played by Industry 4.0 Technologies on making strategic decision and they affirmed that cloud computing appears enhances the entire decision-making process while IoT had a robust potential for only precise stages within the process of making key decisions. Javaid, Haleem, Vaishya, Bahl, Suman and Vaish (2020) on Industry 4.0 and fighting COVID-19 determined that I4.0 could deliver numerous innovative concepts and answers for fighting medical tragedies.

Locally, Nasambu (2020) investigated the role of Industry 4.0 on performance of on FMCGs by conducting a case study on L'Oréal EA and Unilever. The outcome showed that I4.0 (cloud computing, autonomous robots, augmented reality and big data analytics) aids performance of FMCGs more so in reducing risks and augmenting flexibility for sufficient decision making. Krésová (2019) on the role on Industry 4.0 on enhancing industrialization in Africa; A case of Kenya using qualitative exploratory research methods established that I4.0 characterized by ICT innovation inspires the continent´s share in the universal economy. Using of a digital stage enhanced overall share of the market and the potential for Africa to progress comparatively.

Nganga (2020) on Exploring the Applicability and barrier of adopting I4.0 Technologies in the SMEs in Kenya established that I4.0 increased automation, flexibility and customisation; vertical and horizontal integration of manufacturing units; effective management of supply and distribution chain; manufacture of smart products with high quality; reduced lead times; better interoperability between design and manufacturing as well as effective decision making through artificial intelligence and big data. The study embraced qualitative technique.

Whilst much research on Kenya have been carried out, no known work has been located on how Industry 4.0 Technologies gives competitive edge to large manufacturers in Nairobi. This study endeavors to address this gaps and add insight to the mounting study field of the 4th industrial revolution and competitiveness in the context of manufacturing firms. The research thus pursued to deliver solutions to the subsequent questions which are; what is the extent of

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The segment details the main concepts being studied and the related theories and studies. This chapter covered past studies of other researchers. It reviewed several researches that have been carried by different researchers with respect to I4.0 and competitiveness of different organizations and sectors but more emphasis was on the manufacturing sector since it was the main area of the research study.

2.2 Theoretical Literature Review

The theory backing the study include Task-Technology Fit Theory (TTF) and Resource based view (RBV) theory. The overarching theory was Task-Technology Fit Theory as Industry 4.0 is mainly about embracing new technology and adopting technology which makes production more effective and easier.

2.2.1 Task-Technology Fit Theory

Based on Thompson & Goodhue (1995), this theory opines that Information Technology positively impacts the performance of organizations and that the theory can be adopted if the said technology has the ability to match the task that it has been intended to undertake. The theory can be measured based on eight factors namely; quality, ease of use, reliability of the system, locatability, speed of production, the systems relationship with its user's authorization and how compatible the technology is to the task (Goodhue & Thompson, 1995). The measures, coupled with utilization, were determined to have a substantial impact on job performance and were also effective on the task that they were meant to perform.

Zigurs and Buckland (1998) have a similar model which stresses more on the group as compared to an individual entity. TTF has been applied in different situations ranging from e-commerce systems to Model of Technological Acceptance. Thus, TTF is relatable to the present research as technology is core in implementing Industry 4.0 and hence manufacturing entities should embrace technology in order to attain a competitive edge.

2.2.2 Resource based view

Based on this theory, organizations which own resources that are strategic in nature have important competitive edge over organizations that do not. Strategic resource is a resource that has value, hard to imitate, rare to find and cannot be easily substituted (Barney and Chi, 1994). A valuable resource is that which can influence an entity in coming up with strategies that takes advantage of opportunities to be able to beat stiff competition. Possession of unique products and services, as well as precise and comprehensive work procedures will eliminate competition for the entity's resources and competences as noted by Prahalad and Hamel (1999).

This theory emphasizes the advantages a company gains from having the necessary resources for survival. The resources can take the likeness of financial muscle, strategic locations, skilled workforce, technological innovations and engaging in sustainable practices etcetera. The named resources and competences distinguish a company from competition and contribute to its competitiveness. The ability of an organization to adapt to industrial and marketplace fluctuations may also be viewed as an opportunity to compete globally. A Well managed supply chain which is technology based essentially is gifted with a rear resource thus the advocacy for the adoption of I4.0 by manufacturing entities to enhance competitiveness. .

2.3 Industry 4.0 Technologies

The globe is undergoing a technological revolution known as Industry 4.0. Big Data Analytics (BDA), Additive Manufacturing (AM), IoT and Cloud Computing are some of the technologies that manufacturers can use to adapt to Industry 4.0. (Dubey et al., 2020; Witkowski, 2017; Dagnino, Picone & Ferrigno, 2021). Many businesses are incorporating such technologies into their manufacturing processes in preparation for Industry 4.0 implementation, as discussed below.

Big data is a term used to describe datasets that are too large or complex for traditional databases to capture, manage, and process. Big data enables decisions by tapping into previously inaccessible or unusable data. It is the amassing and analysis of huge amounts of obtainable data by employing a sequence of procedures to sieve, capture and report data, where obtained information is processed in bulk, at higher speeds and in a wider range of formats Horvath and Szab (2019). Data collected can then be analyzed to obtain trends and intelligence as noted by Thakur and Mangla (2019).

Additive manufacturing is the process of bringing togetherr components in sequential layers to create products from 3D model data in order to invent new design and attain high mass-customization potential (Swierczek, 2022; Zheng, Ardolino, Bacchetti & Perona, 2021). Additive manufacturing technologies are those that are utilised to make the production system faster and cheaper (Sony & Naik, 2019). It enables manufacturers to produce a minimal number of customized items while optimizing the design. It can also aid in minimization of distribution distances and inventory held (Kumar, Singh & Dwivedi, 2020). Client's demands change on a daily basis, and additives manufacturing helps to meet those demands by constantly altering the product's design (Krésová, 2019). Numerous manufacturers are currently using additive production systems to meet clients demand rapidly. Companies have only recently begun to use additive manufacturing, primarily to create and prototype components. It is mainly preferred in creating small batched designs of customized products that are complex and lightweight.

Businesses today rely heavily on timely data analysis and data storage facilities. Cloud computing entails collecting components that is grouped and interconnected somewhere so as to carry out numerous functions for a large variety of users simultaneously but in different locations as observed by Dalenogare, Benitez, Ayala and Frank (2018) enabling entities to efficiently vendor computing resources (Dalmarco, Ramalho, Barros & Soares, 2019). Cloud computing facilitates the storage of real-time substantial data obtained from diverse sources for industrial production reasons as observed by Frank, Dalenogare and Ayala (2019). CC provides manufacturers with a new and efficient mechanism for lowering the costs associated with production as compared to the traditional manufacturing (Han & Trimi, 2022). It can be beneficial to connect and share communiqué devices from an entity to the next in order to improve manufacturing. Vaidya et al. (2018) add that cloud computing is involved with the delivery of computer system resources like servers, storage, databases, networking, intelligence etcetera via the internet. It leads to lower operating costs and increased infrastructure efficiency.

3D printing is a complex process that uses components to generate items from a 3D imaging dataset in a layer-by-layer manner rather than subtractive processing technique (Masood & Sonntag, 2020). By sequentially extending materials, 3D printing can transform geometrical representations into physical objects (Han and Jia, 2016). It is used for core manufacturing processes that are faster and less expensive, such as modeling, digitization, converting file data to G-code files, and printing materials using a layer-by-layer technique (Toktaş-Palut, 2022). 3D printing creates three-dimensional objects from digital data. 3D printing can produce complex objects with fewer materials. 3D printers are used in manufacturing for prototyping as well as final production.

IoT represents any device that collects information from its surroundings and transmits it over the Internet, where the information is processed intelligently to offer the necessary services and information as explained by Swierczek (2022). The IoT has made an important input to the manufacturing sector. It is sometimes termed as an industrial internet whereby all internet components such as the Internet of Manufacturing Services (IoMs), the Internet of People (IoP), the Internet of Service (IoS) and ICT are brought together to aid in construction (Sony & Naik, 2019). IoT enables the integration of data from the virtual world for operational purposes that may aid manufacturing processes for continuous improvement (Kumar, Singh & Dwivedi, 2020). As a result, IoT gives collective services that allow machines to perform a variety of activities without needing intervention from human as concluded by Kumar, Singh and Dwivedi (2020).

2.4 Empirical Literature Review

Studies on the fourth industrial insurgency have been done in the global, regional and local front. Rosin, Forget, Lamouri and Pellerin (2022) studied the role of I4.0 Technologies on undertaking Decisions and they affirmed that cloud computing appears enhances the entire decision-making process while Internet of Things has a massive prospective for the specified stages inside the procedures of coming up with strategic decision. Delphi method was used in determining the potential of I4.0 in enhancement of decision-making process.

Javaid et al. (2020) on I4.0 technology and battling COVID-19 determined that I4.0 technologies could offer major innovative notions and solution for combating universal medical pandemics. Systematic literature review was adopted in determining the I4.0 technologies widely adopted by firms, establishing how I4.0 Technologies aids in the fight against Covid-19.

Zheng, Ardolino, Bacchetti and Perona (2021) carried out a review of literature on applying I4.0 technologies in manufacturing context aiming at establishing the applicability of I4.0 technology in the business activities of production entities. It was ascertained that the most applied technologies in manufacturing entails servitization, circular SCM, IoT, CC and BDA.

Moktadir et al. (2018) on challenges faced in Industry 4.0 implementation using literature Review established that absence of technological infrastructure and high investment needed as the key challenges. The objective was determining the challenges of I4.0 implementation of the leather industry in Bangladesh

Locally, Nasambu (2020) investigated Industry 4.0 and performance of FMCGs by focusing on Unilever and L'Oréal EA. The research adopted interview guides and it was established that I4.0 technologies (autonomous robots, BDA, augmented reality, and CC) improves performance of FMCGs more-so in demand prediction, learning clients behavioural patterns, risk reduction and improved flexibility for sufficient decisions. The study aimed at determining the extent that I4.0 were adopted, the type of I4.0 technologies used as well as ascertaining the impact of I4.0 on performance.

Krésová (2019) did the role on I4.0 on enhancing industrialization in Africa; a case of Kenya using qualitative exploratory research methods established that I4.0 characterised by Information Communication and Technology improvement inspires the continent's share in universal economy. Using digital stage boosts the share of the market and enhances the potential for the continent to have a comparative edge. Digital technologies delivers the opening to minimize informal sector and reinforce it via mobile payment. The objectives were to pinpoint the opportunities and challenges related to I4.0 and determining how embracing I4.0 in Africa avails opportunities for moving manufacturing processes from an adversely industrialized economy to less industrialised one.

Nganga (2020) on the application and barriers in I4.0 implementation by the SMEs of Kenya established that I4.0 increased automation, flexibility and customisation; vertical and horizontal integration of manufacturing units; effective management of supply and distribution chain; manufacture of smart products with high quality; reduced lead times; better interoperability between design and manufacturing as well as effective decision making through artificial intelligence and BDA. Qualitative analysis was embraced with the key objectives of determining the applicability and determinants as well as establishing barriers faced in the implementation of I4.0. Ouma (2020) on BDA and operational Agility of public entities used cross-sectional design with the objective of determining the influence of capabilities (people, task and data). It was established that operational agility of Kenyan public entities are positively influenced by Big Data analytics.

2.5 Barriers Faced in Industry 4.0 Implementation

Numerous challenges have been identified by diverse authors in different studies and the barriers identified are among the most popular ones in many articles and studies. Data insecurity (Luthra, & Mangla, 2018; Masood & Sonntag, 2020; Mohamed, 2018) is caused by inadequate systems to provide adequate data guarding for entities during Industry 4.0 implementation.Insecure connectivity impedes timely communication between manufacturers, posing a challenge to I4.0 implementation. Investment of massive resources is a necessity for I4.0 initiatives in the manufacturing sector (Moktadir, Ali, Kusi-Sarpong & Shaikh, 2018).

Financial constraints are viewed as a major challenge by business organizations when it comes to developing their capabilities like upgrading their plants, machines and long-term process innovations (Masood & Sonntag, 2020). There is no technological infrastructure to back the successful enactment of I4.0 by manufacturing companies. Unstable company connectivity (Mohamed, 2018); Job opportunities are dwindling (Swierczek, 2022; Zheng et al., 2021). Because of the swapping of personnel with robots and the extensive adoption of automation in manufacturing, the implementation of I4.0 in the manufacturing industry eliminates some job opportunities. Complexity in assembly pattern reconfiguration (Raj, et al., 2020) in order to effectively implement I4.0 in manufacturing companies. Inadequate management team (Moktadir et al., 2018) as there is an absence of a well-trained team to perform new and innovative tasks as concluded by Müller, Kiel and Voigt (2018).

2.6 Summary of Empirical Literature Review

The subsequent table provides a summary of the key related studies on Industry 4.0. The table is made up of the Author, the studied topic, objectives, methodology used, key findings, the gap and how the gaps were addressed.

Table 2. 1 Summary of Empirical Literature

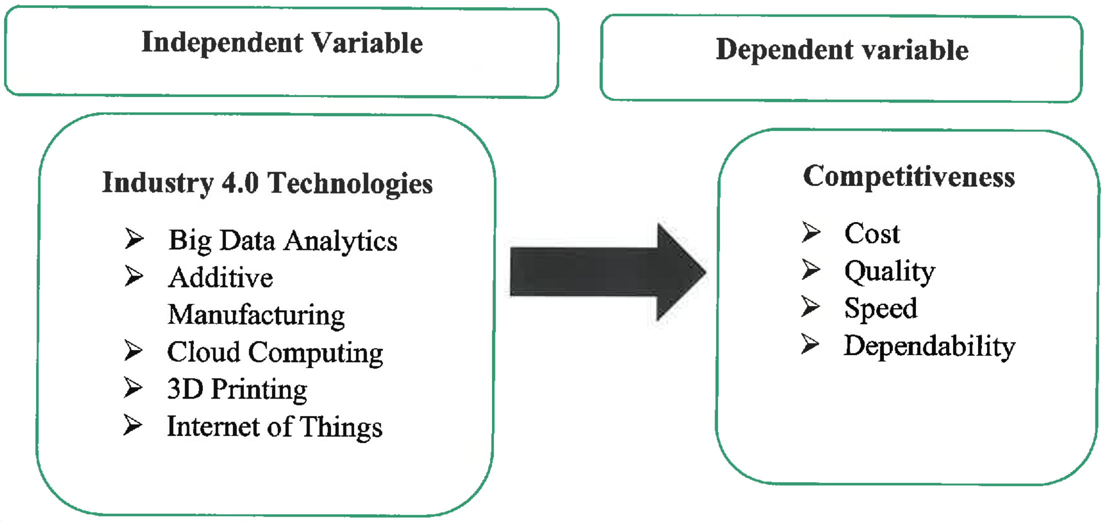
Author(s)	Study Focus	Objectives	Methodology	Results	Gaps	How gaps are addressed in current study
Rosin et al (2022)	Industry 4.0 Technologies and Decision Making	Determining the potential of I4.0 in enhancement of decision-making	Delphi method	Cloud computing enhances the entire decision making process	Left out the connection between I4.0 and Competitiveness	link I4.0 and Competitiveness
Javaid et al (2020)	I4.0 and fighting COVID-19	Determining the I4.0 technologies widely adopted by firms	Systematic Literature Review	I4.0 aids in innovativeness in fighting global pandemics	Linked I4.0 and fighting COVID and not Competitiveness	link I4.0 and Competitiveness
Zheng et al (2021)	Applying Industry 4.0 in Manufacturing Context	Establishing the applications of I4.0 enabling technologies	Literature Review	I4.0 are Cloud computing, BDA and IoT	Use of secondary data	Use of primary data
Moktadir et al (2018)	Assessing barriers in implementing I4.0	Determining the challenges of I4.0 implementation by Bangladeshi leather sector	literature Review	lack of technological infrastructure and high investment needed as the key challenges	Focused on Leather industry only	Focus on and large manufacturing firms
Nasambu (2020)	I4.0 and performance of FMCG	Ascertaining the impact of I4.O on performance	Case study	I4.0 influences performance of FMCG	Case study method was adopted	Cover large manufacturing firms
Krésová (2019)	I4.0 on enhancing industrialization in Africa;	to pinpoint the opportunities and challenges associated with I4.0	Qualitative explorator y	I4.0 stimulates Africa's share in the global economy	Adopted Qualitative exploratory	Adoption of Descriptive design
Nganga (2020)	Applicability and Challenges of I 4.0 in SME	Establishing the Applicability and Challenges of implementing I4.0 in SME	Qualitative design	I4.0 increased automation, flexibility, high quality; reduced lead times	Focused on SMEs and not	Focus on Large Manufacturing firms
Ouma (2020)	Big Data Analytics and operational Agility of public firms	Determining influence of Big Data Analytics on operational Agility	cross-sectional design	Operational agility is influenced by Big Data Analytics	Focus was on Big Data Analytics alone	Focus on entire I4.0 Technologies

Source; Researcher (2022)

2.7 Conceptual Framework

This show the relationship between the variables being studied. The IV is Industry 4.0 Technologies whose dimensions are Big Data Analytics, Additive Manufacturing, Cloud CC, IoT and 3D printing while the DV is Competitiveness operationalized by Cost, Quality, Speed and Dependability. This is exemplified below

Figure 2. 1 Conceptual Model



Source; Researcher (2022)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This part focused on the study techniques that were embraced. Specifically, it covered the adopted design of the paper, the population that the work targeted, the tools that were used to collect and analyze information.

3.2. Research Design

Descriptive design was the methodology used by the paper. Cooper and Schindler (2006) notes that the design helps the researcher in answering questions like when, what, how and who. According to Robson (2002), a descriptive research design depicts a precise profile of events, persons and a specified situation. This design describes a phenomena or characteristics including abilities, opinions, behavior etc. (Schindler & Cooper, 2008). The method aids in affirming and pinpointing the traits of the variables under study (Sekaran, 2006). Descriptive design is appropriate as it entails describing and observing the variable's behavior devoid of influencing it in any way.

3.3 Target Population

The populace consisted of large manufacturing firms in Nairobi. Large manufacturing considered in the study were those firms with employees exceeding thirty. Based on Kenya Association of Manufacturers (KAM, 2022), there are two hundred and thirty large manufacturing entities in Nairobi. The survey chose Nairobi as majority of the large manufacturing firms have their headquarters in Nairobi hence a huge sample could be drawn from it.

3.4 Sampling Design

Stratified random sampling was adopted by the study. This sampling technique was appropriate due to the heterogeneity of the population. The populace was segmented into homogenous strata. The study encompassed 12 strata, each one having a segment in large manufacturing entities in Nairobi. For a sample to be a representative of the populace, at least 10% to 30% of the targeted unit should be sampled as stated by Burns and Grove (2003). Based on Mugenda and Mugenda (2004) and Burns and Grove (2003), a sample of 30% was taken to draw a size of seventy from the populace and is determined sufficient for the study. A sample of 30% from the populace of 230 manufacturing firms is 70 manufacturing firms and is sufficient and can be used as a representative of large manufacturing firms.

Table 3. 1 Sample Population

No	Sector	Target Population	Sample (30%)
1	Building, Construction & Mining	5	2
2	Beverage Food and Tobacco	45	14
3	Chemical and associated Products	29	9
4	Energy and Electrical	18	5
5	Plastics and Rubber	30	9
6	Textile, Apparel	24	7
7	Timber products Furniture and Wood	12	4
8	Pharmaceuticals and Medical Equipment	12	4
9	Hard Metal	20	6
10	Leather Products and Footwear	7	2
11	Motor Vehicles Assembly and	8	2
12	accessories	20	6
	Paper		
Total		**230**	**70**

Source; KAM (2022)

3.5 Data Collection

Primary data was embraced and it was obtained via questionnaires. The questionnaires was deployed via a drop and pick later technique and where not possible, they were administered via electronic mails. The questionnaires gives room for the respondents to assume responsibility for reading and expressing their actual view as per the subject being studied as noted by Zikmund et al (2010). The targeted respondents whom the questionnaires were administered to were the SC managers or their correspondent in each manufacturing firm. The collection instrument was categorized into 4 segment: Section I: Biographic details, Section II: Extent to which I4.0 Technology was implemented, Section III: The Relationship between I4.0 Technology and Competitiveness and Section IV: Barriers of I4.0 Technology implementation by the Large Manufacturers in Kenya.

3.6 Data Analysis

Primary data was gathered and analysis done via descriptive statistics. The questionnaires were scrutinized to make sure that the data is complete and accurate. Zikmund et al (2010) note that information directly gathered from the field may not be in a suitable form as unedited responses consists of errors and thus they must be coded and edited to make meaning out of it. Data was analyzed by descriptive and regression analysis. Objectives (i) and (iii) were analyzed descriptively (means and SD), objective (ii) was measured via regression analysis to determine the correlation between I4.0 Technologies and Competitiveness. SPSS was used as the analysis tool. Regression model that the study was used is; $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + e$

Where;

Y= Competitiveness

X_1= Big Data Analytics, X_2= Additive Manufacturing, X_3=Cloud Computing, X_4= 3D Printing, X_5= Internet of Things

e= error term

$\beta 0$= constant

β_1 to β_5 = coefficients of the independent variables.X_1 to X_5

Table 3. 2 Summary of Data Collection and Analysis

Objectives	**Sections**	**Data collection tool**	**Analysis Technique**
Biographic Statement	SECTION I	Questionnaire	Descriptive Statistics
The extent that I4.0 has been implemented by the Large Manufacturers in Nairobi.	SECTION II	Questionnaire	Descriptive Statistics
The relationship between I4.0 and competitiveness of the Large manufacturers in Kenya	SECTION III	Questionnaire	Regression analysis
Barriers of I4.0 implementation by the Large manufacturing firms in Nairobi	SECTION IV	Questionnaire	Descriptive Statistics

Source; Researcher (2022)

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION OF FINDINGS

4.1 Introduction

The aim of the research was to establish the Industry 4.0 Technologies on the competitiveness of large manufacturing entities in Nairobi, Kenya. This chapter analyses the findings with regards to demographic information, extent of adoption as well as the correlation between I4.0 Technology and Competitiveness.

4.2 Response Rate

The study focused on 70 Nairobi-based Large Manufacturing firms. The researcher was able to collect 59 completed questionnaires, resulting in a response frequency of 84.29%, which was deemed adequate for analysing data as Yin (2017) considers a response frequency exceeding 70% as adequate for interpretation, presentation, and analysis of the results of any research. The outcome is displayed in 4.1.

Table 4. 1 Response Rate

	Frequency	Percent
Obtained questionnaires	59	84.29
Unanswered questionnaires	11	15.71
Total	**70**	**100**

Source: Research Data (2022)

4.3 Biographic information

The biographic data was gathered from Nairobi's Manufacturing firms in order to obtain a perspective on manufacturing firms and the study's participants. This enclosed the position that they held in their corresponding sector as well as the period they operated in the organizations.

Table 4.2 illustrates that 38.98% of the participants were SC managers, 37.29% operations managers and 23.73 were ICT managers. This indicates that all the participants were at a managerial levels and were well suited in responding to the queries under study as per their vast knowledge.

On how long the managers had worked for the large manufacturing firms in Nairobi, 15.25% of the participant's had worked for less than two year, 20.34% had served for periods ranging from three to five years with 35.259% having worked for 6-10 years. The last 28.82% having served for over 10 years. As per the outcome, 64.41% of the participants had served their entities for more than 6 years in the large manufacturing firms and hence were experienced and knowledgeable enough to answer the questionnaires

Table 4. 2 Biographic Information

Position occupied	Frequency	Percentage (%)
Head of Supply chain	23	38.98

Head of Operations	22	37.29
Head of ICT	14	23.73
Length of service(years)		
Below 2	9	15.25
3 -5	12	20.34
6 -10	21	35.59
Over 10	17	28.82
Total	**59**	**100**

Source; Research Data (2022)

4.3.2 Period of Existence

The participants had to answer the period that the large manufacturing firms had existed in Nairobi and for how long they had adopted I4.0 Technologies and table 4.3 tabulates the responses.

Table 4. 3 Period of Existence and Adoption

Existence (years)	Frequency	Percentage (%)
Below 5	11	18.64
5 – 10	23	38.98
Over 10	25	42.38
Period of Adoption	**Frequency**	**Percentage**
Less than 2	18	30.51
2 – 5	28	47.46
Over 5	13	22.03
Total	**59**	**100**

Source: Research Data (2022)

Table 4.3 indicate that 18.64% of large manufacturers had operated in Nairobi for a period of less than 5years whereas 38.98% have been operational for 5 to 10 years with the last 42.38% being in existence for above ten years. This points out that most of the large manufacturing entities represented by 81.36% have been operational for more than 5 years which is a substantial time for them to acquire knowledge on I4.0 Technology and its effect on Competitiveness.

On the period of adoption, 30.51% of the large manufacturing firms had adopted Industry 4.0 Technologies for a period of less than two years while 47.46% had adopted I4.0 Technologies for a period of between two to five yrs and the last 22.03% adopted I4.0 Technologies for over five years. This points out that most of the large manufacturing entities represented by 69.49%

have adopted I4.0 Technologies for more than two years which is a significant period for them to gain insight on Industry 4.0 Technologies and its impact on Competitiveness

4.4 Industry 4.0 Technologies

Objective one of the study sought to determine the extent of adoption of Industry 4.0 Technologies by the Large Manufacturing firms in Nairobi, Kenya. The Industry 4.0 covered include BDA, AM, CC, 3D Printing and Internet of Things and the outcome are presented below.

4.4.1 Big Data Analytics

The research sought to ascertain the extent that Manufacturing entities in Nairobi had adopted Big Data Analytics and the results are tabulated in 4.4

Table 4. 4 Big Data Analytics

Factors	Mean	Std. Deviation
The firm Processes and analyses large volumes of data to enhance productivity	3.3390	1.32105
Delivers the product design needed	3.3559	1.38667
Analyses large data sets to insight about trends and preferences	3.3898	1.31329
Develops algorithms for predicting behavior and error reduction	3.3729	.98082
Aggregate Score	**3.3644**	**1.25046**

Source: Research Data (2022)

From table 4.4, the firm Processing and analysing large volumes of data to enhance productivity (M=3.34, SD=1.32), Delivering the product design needed (M=3.35, SD=1.39) the firm analysing large data sets to gain insight about trends and preferences (M=3.39, SD=1.31) and Development of algorithms for predicting behavior and error reduction (M=3.37, SD=0.98) were all moderately adopted by the by the Large Manufacturing firms in Nairobi.

4.4.2 Additive Manufacturing

The paper aimed at establishing the adoption level of Additive Manufacturing by the Large Manufacturers in Nairobi and the outcome are presented below.

Table 4. 5 Additive Manufacturing

Factors	Mean	Std. Deviation
Produce small batches of customized products	3.4407	1.13367
Production of complex but lightweight designs	3.4237	1.31573
Easily alters the design as needed	3.3898	1.43859
Makes faster and cheaper production systems	3.3559	1.57308
Aggregate Score	**3.40253**	**1.36527**

Source: Research Data (2022)

Table 4.5 exhibits that production of small batches of customized products by the firm had been moderately implemented with the means of 3.44 and SD of 1.13 and production of complex but lightweight designs was adopted to a medium extent as per their mean (3.42) and deviation (1.31). The ability of the entity to easily alter the design as needed (M=3.39, SD=1.43) and having faster and cheaper production systems (M=3.35, SD=1.57) were equally moderately adopted as viewed from their means and deviations.

4.4.3 Cloud Computing

The research wanted to determine the adoption level of Cloud Computing by the Manufacturing entities in Nairobi and the finding are tabulated in 4.6

Table 4. 6 Cloud Computing

Factor	Mean	Std. Deviation
Remotely store relevant and pertinent information	3.3390	1.46934
Makes vital information accessible from virtually anywhere	3.3051	1.52286
Increased data sharing across sites and firms	3.1186	1.32723
Digital production by firms in different geographical locations	3.1017	1.30905
Aggregate Score	**3.2161**	**1.40712**

Source: Research Data (2022)

From table 4.6, storage of relevant and pertinent information remotely (M=3.33. SD=1.46), availing of vital information to be accessible from virtually anywhere (M=3.30. SD=1.52) increased data sharing across sites and firms (M=3.11. SD=1.32) as well as digital production

Table 4.8 portrays that Automatic capture of information by devices (M=3.27, SD=0.96), Intelligent information sharing by the firm (M=3.06, SD=1.12) Real time data transmission between devices (M=3.37, SD=0.69) and employees being able to issue commands to production machines (M=3.13, SD=1.50) were adopted moderately as evidenced by their means and deviations.

4.4.6 Ranking of Industry 4.0 Technologies

Industry 4.0 Technologies were ranked according to their adoption levels and table 4.9 illustrates the results. The standing of Industry 4.0 Technologies were tabulated in a descending order based on the extent of adoption. All the I4.0 Technology were adopted to a moderate extent with Additive manufacturing ranking first, followed by BDA, 3D Printing, CC and lastly IoT.

Table 4. 9 Ranking of Industry 4.0 Technologies

	Mean	**Std. Deviation**	**Ranking**
Additive Manufacturing	3.40253	1.36527	**1**
Big Data Analytics	3.3644	1.25046	**2**
3D Printing	3.2966	1.27648	**3**
Cloud Computing	3.2161	1.40712	**4**
Internet of Things	3.2119	.91523	**5**

Source: Research Data (2022)

Table 4.9 tabulates that Additive Manufacturing was firstly ranked as per its adoption level since it was moderately adopted with the Mean of 3.40 and Standard Deviation of 1.36.

Secondly ranked by the Manufacturers in Nairobi was Big Data Analytics which was moderately adopted as evidenced by the aggregate mean of 3.36 and deviation of 1.25.

The General score indicates that 3D Printing was also moderately adopted by the Large manufacturing entities in Nairobi with the mean of 3.29 and S.D of 1.27 and thus is ranked third based on the extent of adoption.

Cloud computing was ranked fourth as it was moderately adopted (M=3.21. SD=1.40) with the Internet of Things being ranked fifth and was also adopted to a moderate extent (Mean=3.21, SD=0.91) as observed from their individual Means and Deviations

4.5 Industry 4.0 Technologies and Competitiveness

The research sought to establish the relationship between Industry 4.0 Technologies and Competitiveness of large manufacturing entities in Nairobi and the results are subsequently discussed.

4.5.1 Industry 4.0 Technologies and Cost

Data was regressed to determine the relationship between Industry 4.0 Technologies and Cost and the findings are in 4.10

Table 4. 10 Regression Coefficient of Cost

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	2.378	.569		4.182	.000
Big Data Analytics	.462	.141	.463	3.267	.002
Additive Manufacturing	-.104	.126	-.110	-.825	.013
Cloud Computing	.282	.097	.281	2.903	.005
3D Printing	.585	.123	.436	4.771	.000
Internet of Things	.557	.120	.480	4.632	.000

a. Dependent Variable: Cost

Source: Research Data (2022)

$Y_1 = 2.378 +.462X_1 -.104X_2 +.282X_3 +.585X_4 +.557X_5$ ....

(i)

As per table 4.10, the outcome illustrates that the P-values of Big Data Analysis (t=3.267, P<0.05), Additive Manufacturing (t=-0.825, P>0.05), Cloud Computing (t=2.903, P<0.05), 3D Printing (t=4.771, P<0.05) and Internet of Things (t=4.632, P<0.05), are all less than 5% (0.001< 0.05). This is supported by the T value of greater than 1.96 which implies that Big Data Analysis, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of Things have a noteworthy relationship with Cost and thus Industry 4.0 Technologies influences Cost of large manufacturing entities in Nairobi.

Table 4. 11 Model Summary of Cost

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.761[a]	.580	.540	.89249

a. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research data (2022)

As illustrated in 4.11, R Square = 0.580 which interprets to 58%. This infers that 58% of the variations in Cost was attributed to the variations in Industry 4.0 Technology in the model. The variance of 42% which cannot be explained was attributed to other variables not covered by the study.

Table 4. 12 ANOVA of Cost

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	58.191	5	11.638	14.611	.000[b]
Residual	42.216	53	.797		
Total	100.407	58			

a. Dependent Variable: Cost

b. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research Data (2022)

At 0.005 level of significance, Table 4.12 displays the calculated F value of 14.611 with F critical being 11.638 and a P value of 0% which is less as compared to 5% and therefore the model is statistically substantial and sufficient for predicting Cost.

4.5.2 Industry 4.0 Technologies and Quality

The data was regressed to establish the relationship between Industry 4.0 Technologies and Quality. The outcome are displayed in table 4.13.

Table 4. 13 Regression Coefficient of Quality

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.512	.569		.900	.002
Big Data Analytics	.728	.141	.668	5.147	.000
Additive Manufacturing	.355	.120	.280	2.948	.005
Cloud Computing	.212	.097	.193	2.178	.004
3D Printing	.353	.123	.036	2.865	.006
Internet of Things	.193	.126	-.186	-1.525	.133

a. Dependent Variable: Quality
Source: Research Data (2022)

$$Y_2 = .5.12 + .728X_1 + .355X_2 - .212X_3 + .353X_4 + .193X_5 \quad \text{......(ii)}$$

As given by table 4.13, the findings indicate that the P value of Big Data Analytics (t=-5.147, P<0.05), Additive Manufacturing (t=2.948, P<0.05), Cloud Computing (t=.2.178, P<0.05) and 3D Printing (t=-.2.865, P<0.05) do not surpass 5% (0.001< 0.05). The implication is that BDA, Additive Manufacturing, CC and 3D Printing all have a noteworthy relationship with Quality of large manufacturing entities and thus Industry 4.0 Technologies influences Quality. Internet of Things (t=-1.525, P>0.05) on the other hand has a p value that exceeds 5% and thus does not influence quality of the large manufacturing entities in Nairobi.

Table 4. 14 Model Summary of Quality

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.805[a]	.648	.614	.89327

a. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things
Source: Research data (2022)

As specified in Table 4.14, R square is 64.8%. This is an indication that 65% of the variant in Quality is explained by the variations in I4.0 in the model. This is a good model as the variance not explained is 35% which accounts for independent variable not in the model. The ANOVA outcomes are presented in 4.15.

Table 4. 15 ANOVA of Quality

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	77.743	5	15.549	19.486	.000[b]
Residual	42.291	53	.798		
Total	120.034	58			

a. Dependent Variable: Quality

b. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research Data (2022)

At 5% level of significance, Table 4.15 denotes the calculated F value as 19.486 with F critical being 15.549 and the P value of 0% which doesn't exceed 5%. This infers that the study model is appropriate for predicting Quality.

4.5.3 Industry 4.0 Technologies and Speed

Information was regressed to ascertain the relationship between Industry 4.0 Technologies and Speed and the outcome are tabulated in 4.16.

Table 4. 16 Regression Coefficient of Speed

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.981	.607		3.260	.002
Big Data Analytics	.591	.151	.496	3.912	.000
Additive Manufacturing	.012	.135	.011	.091	.928
Cloud Computing	.226	.104	.189	2.183	.033
3D Printing	.411	.131	.256	3.134	.003
Internet of Things	.340	.129	.245	2.645	.011

a. Dependent Variable: Speed

Source: Research Data (2022)

$$Y_3 = 1.981 + .591X_1 + .012X_2 + .226X_3 + .411X_4 + .340X_5 \quad \text{...(iii)}$$

As displayed in table 4.16, the findings reveals that the P value of BDA (t=3.912, P>0.05), Cloud Computing (t=2.183, P<0.05), 3d Printing (t=3.134, P<0.05) and IoT (t=2.645, P<0.05) are less than 5% (0.001< 0.05) and the T values exceed 1.96 which indicates that the I4.0 Technology have a substantial relationship with Speed of large manufacturing firms in Nairobi. However, Additive Manufacturing has a p value greater than 5% and a T value less than 1.96, an indication that Additive Manufacturing does not influence Speed of large manufacturing firms in Nairobi.

Table 4. 17 Model Summary of Speed

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.815[a]	.664	.632	.95368

a. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research data (2022)

As tabulated in Table 4.17, R square is 66.4%. This denotes that 66% of the variation in Speed is explained by the variations in Industry 4.0 Technologies in the model. Based on the thumb's rule, this is a satisfactory model. Variation not explained is 33.6% which is attributed to factors not in the model and pure chance. The ANOVA findings are displayed in Table 4.18.

Table 4. 18 ANOVA of Speed

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	95.321	5	19.064	20.961	.000[b]
Residual	48.204	53	.910		
Total	143.525	58			

a. Dependent Variable: Speed

b. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research Data (2022)

At 5% significance level, Table 4.18 indicates that the calculated F value is 20.961 with F critical being 19.064 and a P value of 0.000 which does not surpass 5%. Thus, the study model is substantial and suitable for predicting Speed.

4.5.2 Industry 4.0 Technologies and Dependability

Information was regressed to establish the relationship between Industry 4.0 Technologies and Dependability and the results are displayed in table 4.19.

Table 4. 19 Regression Coefficient of Dependability

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		

(Constant)	1.620	.653		2.480	.007
Big Data Analytics	.761	.162	.684	4.689	.000
Additive Manufacturing	-.137	.145	-.129	-.947	.008
Cloud Computing	.179	.111	.160	1.603	.005
3D Printing	.302	.141	.201	2.140	.007
Internet of Things	.074	.138	.057	.539	.002

a. Dependent Variable: Dependability

Source: Research Data (2022)

$Y_2 = 1.620 + .761X_1 - .137X_2 - .179X_3 + .302X_4 + .074X_5$ ....(iv)

Based on table 4.19, the outcome showcases the P value of Big Data Analytics (t=4.1689, P<0.05), Additive Manufacturing (t=-.947, P<0.05), Cloud Computing (t=1.603, P<0.05), 3D Printing (t=2.140, P<0.05) and Internet of Things (t=.539, P<0.05) are less than 5% (0.001< 0.05). There is mixed outcomes of the T values as some are greater than 1.96 (Big Data Analytics and 3D Printing) while some are less than 1.96 (Additive Manufacturing Cloud Computing and Internet of things). The p values will thus be used and the implication is that Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of things all have a statistical relationship with Dependability of manufacturing entities in Nairobi and thus Industry 4.0 Technologies influences Dependability.

Table 4. 20 Model Summary of Dependability

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.745[a]	.555	.513	1.02514

a. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research data (2022)

As tabulated in 4.20, the R square value is 55.5%. This implies that 56% of the variations in Dependability is explained by the variations in the Industry 4.0 in the model. The thumb's rule considers this a good model. The variance that the study does not explain is 44% which accounts for variable not in the model and pure chance factors. The ANOVA results are displayed in table 4.21.

Table 4. 21 ANOVA of Dependability

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	69.522	5	12.904	13.231	.000[b]
Residual	55.698	53	1.051		
Total	125.220	58			

a. Dependent Variable: Dependability

b. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research Data (2022)

At 5% significance level, Table 4.21 indicates that the calculated F value is 13.231 with F critical being 12.909 and the P value of 0.000 which is less than 5% hence the model is appropriate for predicting Dependability.

4.5.4 Industry 4.0 Technologies and Competitiveness

The research sought to examine the relationship between Industry 4.0 Technology and Competitiveness of large manufacturing firms in Nairobi. The overall competitiveness is measured as all the dependent sub variables are combined together to see how I4.0 impacts the general competitiveness of Large manufacturing entities in Nairobi, Kenya. This needed to be analysed separately as the study aimed at establishing the impact of Industry 4.0 on Competitiveness in general and not the parameters operationalized under Competitiveness. This therefore summarizes the general finding and the actualization of objective two under the research which aimed at ascertaining the relationship between I4.0 and competitiveness. Thus, a linear regression was fixed to the information and the outcome are as subsequently illustrated. Table 4.22 shows the regression coefficients Competitiveness.

Table 4. 22 Coefficients Analysis of Competitiveness

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.405	.447		5.384	.000
Big Data Analytics	.307	.111	.146	2.760	.003
Additive Manufacturing	.280	.099	.116	2.829	.002
Cloud Computing	.162	.076	.221	2.124	.081
3D Printing	.452	.096	.461	4.688	.000
Internet of Things	.354	.095	.417	3.741	.000

a. Dependent Variable: Competitiveness
Source: Research Data (2022)

The equation for linear regression of the research is:

$Y = 2.405 + .307X_1 - 0.280X_2 + .162X_3 + .452X_4 + .354X_5$

Where

Y = Competitiveness

X_1= Big Data Analytics

X_2= Additive Manufacturing

X_3= Cloud Computing

X_4= 3D Printing

X_5= Internet of Things

From table 4.22, Industry 4.0 Technologies (BDA ($t=2.760$, $P<0.05$), Additive manufacturing ($t=2.829$, $P<0.05$), 3D Printing ($t=4.688$, $P<0.05$) and Internet of Things ($t=3.741$, $P<0.05$) have a substantial relationship with Competitiveness. This is supported by the fact that the P values do not exceed 0.05 and the T values are above 1.96. Cloud Computing ($t=2.124$, $P>0.05$) on the other hand has a p value that exceeds 5% and a clear indication that Cloud Computing does not influence Competitiveness of large manufacturing firms in Nairobi. The model portrays that upon all variables being maintained at constant, the value of Competitiveness becomes 2.405.

Table 4. 23 Regression Model Summary of Competitiveness

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.717[a]	.654	.469	.70122

a. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research data (2022)

From table 4.23, the coefficient of determination (R square) is 0.654 which interprets to 65%. This infers that 65% of the variations in Competitiveness is attributed to Industry 4.0 Technologies. The outcome is considered very good as per the rule of thumb as only 34.6% of the variation in Competitiveness is not accounted for. Analysis of variance is outlined in table 4.24

Based on table 4.24, the model's P value of 0.00 is below (5%). Thus, the study's model is appropriate for prediction of Competitiveness.

Table 4. 24 ANOVA of Competitiveness

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	27.600	5	5.520	11.226	.000b
Residual	26.061	53	.492		
Total	53.661	58			

a. Dependent Variable: Competitiveness
b. Predictors: (Constant), Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing, Internet of Things

Source: Research data (2022)

4.6 Barriers Faced in Implementing Industry 4.0 Technologies

Objective three needed to ascertain the barriers experienced in implementing Industry 4.0 Technology and the results are presented in table 4.25 and it displays the challenges encountered in implementing I4.0 Technology and high investment related costs associated with implementation of I4.0 (M=3.87, SD=1.18), high level of Data insecurity (M=3.81, SD=1.26) and existence of Insecure connectivity (M=3.79, SD=1.36) were determined to be barriers of implementing I4.0 to a large extent. Existence of insufficient technological infrastructure (M=3.61, SD=1.49) and high level of inadequate skilled personnel (M=3.54, SD=1.52) were ascertained, to a huge extent, as barriers faced in implementing I4.0 Technology by the large manufacturers in Nairobi.

Table 4. 25 Challenges of Industry 4.0 Technologies implementation

I4.0 Challenges	Mean	Std. Dev
Industry 4.0 Technologies involves High investment related costs	3.87	1.18
There is a high level of Data insecurity	3.81	1.26
There is Insecure connectivity	3.79	1.36
There exists Inadequate technological infrastructure	3.61	1.49

There is a high level of Inadequate skilled Personnel	3.54	1.52

Source: Research Data (2022)

4.7 Discussion of Research Findings

The study was steered by three specific objectives and the study achieved all.

On objective (i) which was to determine the adoption extent of Industry 4.0 Technology by Large Manufacturing entities in Nairobi, it was ascertained that all the Industry 4.0 Technologies were adopted to a moderate extent. All the I4.0 Technologies were adopted to a moderate extent with Additive manufacturing ranking first, followed by BDA, 3D Printing, CC and lastly IoT.

Additive Manufacturing was the first as per the ranking in accordance with the level of adoption as they were adopted to a medium extent with the Deviation of 1.36 and Mean of 3.40. The finding goes against that of Swierczek (2022) who note that Additive manufacturing is important as it joins components in sequential layers to create products from 3D model data in order to invent new design and attain high mass-customization potential. Sony and Naik (2019) posit that Additive manufacturing technologies are utilised to make the production system faster and cheaper as well as enables manufacturers to produce a minimal number of customized items while optimizing the design. It can also aid in minimization of distribution distances and inventory held

Secondly ranked by the Manufacturing entities in Nairobi was Big Data Analytics which was moderately adopted as evidenced by the aggregate mean of 3.36 and deviation of 1.25. The results opposes that of Horvath and Szab (2019) who asserts that BDA is vita as it enables the entity to employ a sequence of procedures to sieve, capture and report data and the obtained information is processed in bulk, at higher speeds and in a wider range of formats. Thakur and Mangla (2019) add that data collected can then be analyzed to obtain trends and intelligence.

The General score indicates that 3D Printing was moderately adopted by the Large manufacturers with the mean of 3.29 and deviation of 1.27 and thus is ranked third based on the level of adoption. The outcome contradicts that of Han and Jia (2016) who note that 3D Printing is used for core manufacturing processes that are faster and less expensive, such as modeling, digitization, converting file data to G-code files, and printing materials using a layer-by-layer technique. Toktaş-Palut (2022) adds that 3D printing can produce complex objects with fewer materials

Cloud computing was ranked fourth as it was moderately adopted (M=3.21. SD=1.40) by manufacturing entities in Nairobi. The results disagree with that of Zheng, Ardolino, Bacchetti & Perona (2021) who noted that cloud computing is key as it enables timely data analysis and data storage facilities. Frank, Dalenogare and Ayala (2019) adds that Cloud computing facilitates the storage of real-time substantial data obtained from diverse sources for industrial production reasons. Frank, Dalenogare and Ayala (2019) note that it leads to lower operating costs and increased infrastructure efficiency.

Internet of Things was lastly ranked with the mean of 3.21 and deviation of 0.91. This is deduces that it was moderately adopted as well. The finding is opposed to that of Swierczek (2022) who found that IoT is able to process information intelligently to offer the necessary services and information. Sony & Naik, (2019) points out that IoT enables the integration of data from the virtual world for operational purposes that may aid manufacturing processes for continuous improvement. As a result, IoT gives collective services that allow machines to perform a variety of activities without needing intervention from human as concluded by Kumar, Singh and Dwivedi (2020).

The second objective sought to determine the relationship between Industry 4.0 Technologies and Competitiveness of Large manufacturing entities in Kenya. Five regression analysis were carried out and the outcome indicates that Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of Things have a noteworthy relationship with Cost and thus Industry 4.0 Technologies influences Cost of large manufacturers in Nairobi. On Quality, it was established that that BDA, Additive Manufacturing, CC and 3D Printing all have a noteworthy relationship with Quality of large manufacturing entities and thus Industry 4.0 Technologies influences Quality. Internet of Things ($t=-1.525$, $P>0.05$) had a p value that exceeds 5% and thus had no influence on quality of the large manufacturing firms in Nairobi. BDA, Cloud Computing, 3d Printing and IoT all had a substantial relationship with Speed of large manufacturing firms. However, Additive Manufacturing had a p value exceeding 0.005 and a T value of less than 1.96, an indication that Additive Manufacturing does not influence Speed of large manufacturers. On Dependability, it was ascertained that Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of things all had a noteworthy relationship with Dependability of large manufacturing firms and thus Industry 4.0 Technologies influences Dependability.

The general regression analysis aimed at establishing the correlation amongst I4.0 and Competitiveness of Manufacturing entities in Kenya and Industry 4.0 Technologies were noted to statistically and significantly have a relationships with Competitiveness of large manufacturers in Nairobi. These findings are in tangent with that of Rosin, et al. (2020) who affirmed that Industry 4.0 enhance competitiveness, increase productivity, enhance revenue and productivity as well as optimize the machines. Nasambu (2020) established that I4.0 technologies (autonomous robots, BDA, augmented reality, and CC) improves performance of FMCGs more-so in demand prediction, learning clients behavioural patterns, risk reduction and improved flexibility for sufficient decisions. Krésová (2019) established that I4.0 enhances comparative edge.

Objective (iii) aimed to determine the barriers faced in the implementing I4.0 Technologies by Large Manufacturers in Nairobi and high investment related costs associated with implementation of I4.0, high level of Data insecurity, existence of Insecure connectivity, Existence of inadequate technological infrastructure and high level of inadequate skilled personnel were all established, to a large extent, as barriers encoOuntered in implementing I4.0 Technologies by the manufacturing entities in Nairobi. The outcome are in tangent is with the literature as based on Moktadir et al. (2018), the barriers of Industry 4.0 adoption entails absence of technological infrastructure and high investment needed as the key challenges. Data insecurity (Luthra, & Mangla, 2018; Masood & Sonntag, 2020; Mohamed, 2018) caused by inadequate systems to provide adequate data guarding for entities during Industry 4.0 implementation. Insecure connectivity impedes timely communication between manufacturers, posing a challenge to I4.0 implementation. Investment of massive resources is necessity for I4.0 initiatives in the manufacturing sector (Moktadir, Ali, Kusi-Sarpong & Shaikh, 2018). Financial constraints are viewed as a major challenge by business organizations when it comes to developing their capabilities like upgrading their plants, machines and long-term process innovations (Masood & Sonntag, 2020).

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This segment highlights the summarized outcome, draws conclusion, and recommends lessons from the outcome. Limitations as well as suggestions are discussed.

5.2 Summary of Findings

The main goal of the research was ascertaining the impact of Industry 4.0 Technology on Competitiveness of large manufacturing firms in Nairobi. Three objectives guided the research and each one of them was attained. The foremost objective had to establish the adoption level of I4.0 Technology, the second had to ascertain the relationship between I4.0 Technology and Competitiveness with the third being to determine the barriers experienced by the large manufacturers in Nairobi in implementing Industry 4.0 Technology. Descriptive design was used and sampling was carried out to arrive at 70 large manufacturing firms.

On objective one, it was established that only all the Industry 4.0 Technologies (BDA, AM, CC, 3D Printing and IoT were moderately adopted by the large manufacturing entities in Kenya. On Big Data Analytics, the large manufacturing firms the firm processed and analysed large volumes of data to enhance productivity, delivered the product design needed, analysed large data sets to gain insight about trends and preferences and developed algorithms for predicting behavior and error reduction. On Additive Manufacturing, the firms produced small batches of customized products, produced complex but lightweight designs, easily altered the design as needed (as well as have faster and cheaper production systems.

The large manufacturing firms in Nairobi also adopted cloud computing to a moderate extent by storing relevant and pertinent information remotely, availing vital information to be accessible from virtually anywhere, increased data sharing across sites and firms, as well as digital production by firms in different geographical locations. 3D Printing was moderately adopted by large manufacturers by investing in Technologies that they embrace prototype in producing individual components, used optimized design process, scientific modeling for visualizing the operational system and having safety engineering for system security. Internet of Things was adopted to a moderate extent by automatically capturing information by devices, intelligent information sharing by the firm, having real time data transmission between devices and employees being able to issue commands to production machines.

On objective two, I4.0 Technologies were found to Competitiveness of large manufacturing firms in Nairobi. Specifically, BDA, CC, 3D Printing and IoT were found to influence cost while Additive Manufacturing had no impact on cost of manufacturers in Nairobi. BDA, Additive Manufacturing, CC and 3D Printing influenced Quality of large manufacturing firms in Nairobi. Internet of Things on the other hand had no influence on quality. On speed, BDA, Cloud Computing, 3D Printing and IoT were found to influence speed whereas Additive Manufacturing did not impact speed. Dependability of large manufacturers in Nairobi was influenced by Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of Things. The overall Competitiveness was established to contain a statistically significant relationship with Industry 4.0 Technology and BDA, Additive Manufacturing, 3D Printing and IoT were found to have a substantial relationship with Competitiveness. Cloud Computing had no impact on Competitiveness of large manufacturers in Nairobi.

Objective three had to determine the barriers of implementing I4.0 Technologies and high investment costs associated with implementation of I4.0, high level of Data insecurity, existence of insecure connectivity, existence of inadequate technological infrastructure and high level of inadequate skilled personnel were all established as the challenges faced in implementing I4.0 Technologies by the large manufacturers in Nairobi.

5.3 Conclusion

The aim of the study was to ascertain the relationship between Industry 4.0 Technology and Competitiveness of large manufacturing entities in Nairobi. The results has revealed a positive and substantial correlation between Industry 4.0 Technologies and Competitiveness of large manufacturing firms in Nairobi. BDA, Additive manufacturing, 3D Printing and IoT were found to influence Competitiveness while Cloud Computing had no influence on Competitiveness of large manufacturers in Nairobi.

The first objective, which was to ascertain the adoption level of I4.0 Technology was achieved and it was affirmed that Big Data Analytics, Additive manufacturing, Cloud Computing, 3D Printing and Internet of things were all moderately adopted by the large manufacturers in Nairobi and hence it is resolved that the foremost objective was attained

It is concluded that the second objective, which was to determine the relationship between Industry 4.0 Technologies and Competitiveness, was achieved. As per the regression analysis, Industry 4.0 Technologies (BDA, Additive manufacturing, 3D Printing and IoT) influences Competitiveness and whereas Cloud Computing did not impact Competitiveness of large manufacturers in Nairobi.

On objective three, it's concluded that the challenges facing large manufacturing firms in Nairobi in implementation Industry 4.0 Technologies were high investment related costs associated with implementation of I4.0, high level of Data insecurity, existence of insecure connectivity, existence of inadequate technological infrastructure and high level of inadequate skilled personnel

5.4 Recommendations from the Study

As per the results of the study, it is recommended that large manufacturers firms in Nairobi should fully adopt Industry 4.0 Technologies as they have been found to influence Competitiveness. Since Big Data Analytics, Additive Manufacturing, Cloud Computing, 3D Printing and Internet of Things have all been moderately adopted, the paper recommends that the large manufacturers need to adopt them to a large extent in order boost their competitiveness.

Big Data Analytics should be largely adopted as it was noted to be moderately adopted by manufacturing entities in Kenya yet it is beneficial to the firms that adopt it. BDA has been established to be vital as it enables the entity to employ a sequence of procedures to sieve, capture and report data and the obtained information is processed in bulk, at higher speeds and in a wider range of formats.

Additive Manufacturing also ought to be adopted to a huge extent as it has been noted that it is able to join components in sequential layers to create products from 3D model data in order to invent new design and attain high mass-customization potential. It is also able to make the production system faster and cheaper as well as enables manufacturers to produce a minimal number of customized items while optimizing the design. It can also aid in minimization of distribution distances and inventory held

Large manufacturing firms in Nairobi should adopt Cloud Computing since cloud computing is key as it enables timely data analysis and data storage facilities. As well as facilitates the storage of real-time substantial data obtained from diverse sources for industrial production reasons. It has also been found to result to lower operating costs and increased infrastructure efficiency.

3D Printing should also be adopted to a large since 3D Printing is used for core manufacturing processes that are faster and less expensive, such as modeling, digitization, converting file data to G-code files, and printing materials using a layer-by-layer technique. 3D printing can also produce complex objects with fewer materials.

Internet of Things should also be implemented to a huge extent as it has been ascertained that IoT is able to process information intelligently to offer the necessary services and information as well as enable the integration of data from the virtual world for operational purposes that may aid manufacturing processes for continuous improvement. IoT also gives collective services that allow machines to carry out diverse activities without needing intervention from human.

The adoption BDA, Additive Manufacturing, CC, 3D Printing and Internet of Things should all be implemented to a maximum since they have been proven to impact Competitiveness specifically cost, quality, speed and dependability of large manufacturing entities in Nairobi.

5.5 Limitation of the Study

The research was unable to achieve a 100% response rate because not all questionnaires were returned. This could be due to the respondent's unavailability to complete the questionnaires, and others having a policy of not sharing the entity's information. This limitation, however, couldn't prevent the researcher from acquiring the necessary information needed because the returned questionnaire was sufficient to provide a conclusive result on the position of Nairobi's large manufacturing firms.

Contextually, the study is limited to the Large Manufacturers in Nairobi hence the findings may not represent all the manufacturers in the Nairobi and the country. The population however was big enough and can act as a representative of the entire populace and the outcome can present a crystal indication on what other Large manufacturing firms covered by the same scope are engaged in.

Because some questionnaires were dropped-and-picked later, it was difficult to ascertain if the intended participant's filled them or they passed on to other personnel who lacked the necessary knowledge under study.

5.6 Suggestions for Further Research

Further studies may concentrate on the influencers of I4.0 Technologies in manufacturing sector in Nairobi in order to come up with the reasons that thrusts the large Manufacturers in adopting I4.0 Technologies. The study can be carried out in other sectors that is I4.0 Technology and competitiveness of either the public sector, service firms or even SMEs to establish whether the outcome may be the same

Upcoming research may add intervening or moderating variable to observe whether the effect will be conclusive. Other I4.0 Technology which have not been covered in here can be exhausted in other studies to ascertain their impact of either competitiveness or performance.

Lastly, the methodology can be altered in that future studies can adopt a mixture of primary and secondary data to establish whether the outcome may be conclusive.

REFERENCES

Anitah, J. N. (2019). *Industry 4.0 Technologies and Operational Performance of Fast Moving Consumer Goods Manufacturers in Kenya: a Case Study of Unilever Kenya and L'oreal East Africa* (Doctoral dissertation, University of Nairobi).

Anitah, J. N., Nyamwange, S. O., Magutu, P. O., Chirchir, M., & Mose, J. M. (2019). Industry 4.0 technologies and operational performance of Unilever Kenya and L'Oreal East Africa. *Noble International Journal of Business and Management Research*, *3*(10), 125-134.

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International journal of production economics*, *229*, 107776.

Bai, C., Orzes, G., & Sarkis, J. (2022). Exploring the impact of Industry 4.0 technologies on social sustainability through a circular economy approach. *Industrial Marketing Management*, *101*, 176-190.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management*, *17*(1), 99-120.

Culot, G., Fattori, F., Podrecca, M., & Sartor, M. (2019). Addressing industry 4.0 cybersecurity challenges. *IEEE Engineering Management Review*, *47*(3), 79-86.

Dagnino, G. B., Picone, P. M., & Ferrigno, G. (2021). Temporary competitive advantage: a state-of-the-art literature review and research directions. *International Journal of Management Reviews*, *23*(1), 85-115.

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of production economics*, *204*, 383-394.

Dalmarco, G., Ramalho, F. R., Barros, A. C., & Soares, A. L. (2019). Providing industry 4.0 technologies: The case of a production technology cluster. *The journal of high technology management research*, *30*(2), 100355.

Distanont, A., & Khongmalai, O. (2020). The role of innovation in creating a competitive advantage. *Kasetsart Journal of Social Sciences*, *41*(1), 15-21.

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15-26

Gallego-García, S., Groten, M., & Halstrick, J. (2022). Integration of Improvement Strategies and Industry 4.0 Technologies in a Dynamic Evaluation Model for Target-Oriented Optimization. *Applied Sciences*, *12*(3), 1530.

Goodhue, D. L., & Thompson, R. L. (1995). Task-Technology Fit and individual performance. *MIS quarterly*, 213-236.

Gunasekaran, A., Subramanian, N., & Papadopoulos, T. (2017). Information technology for competitive advantage within logistics and supply chains: A review. *Transportation Research Part E: Logistics and Transportation Review*, *99*, 14-33.

Han, H., & Trimi, S. (2022). Towards a data science platform for improving SME collaboration through Industry 4.0 technologies. *Technological Forecasting and Social Change*, *174*, 121242.

Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Gonzalez, E. S. (2022). Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability. *Sustainable Operations and Computers*.

Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R., & Vaish, A. (2020). Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *14*(4), 419-422.

Koch, T., & Windsperger, J. (2017). Seeing through the network: Competitive advantage in the digital economy. *Journal of Organization Design*, *6*(1), 1-30.

Kozlenkova, I. V., Samaha, S. A., & Palmatier, R. W. (2014). Resource-based theory in marketing. *Journal of the academy of marketing science*, *42*(1), 1-21.

Krésová, D (2019). Can the Fourth Industrial Revolution - Industry 4.0 - Hold the Future for Africa´s Industrialisation? Case Study of Kenya. *Master of Science in Global Studies, Lund University*

Kumar, A., Agrawal, R., Wankhede, V. A., Sharma, M., & Mulat-Weldemeskel, E. (2022). A framework for assessing social acceptability of industry 4.0 technologies for the development of digital manufacturing. *Technological Forecasting and Social Change*, *174*, 121217.

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

Laszlo, C., & Zhexembayeva, N. (2017). *Embedded sustainability: The next big competitive advantage*. Routledge.

Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, *117*, 168-179.

Masood, T., & Sonntag, P. (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, *121*, 103261.

Mohamed, M. (2018). Challenges and benefits of Industry 4.0: an overview. *International Journal of Supply and Operations Management*, *5*(3), 256-265.

Moktadir, M. A., Ali, S. M., Kusi-Sarpong, S., & Shaikh, M. A. A. (2018). Assessing challenges for implementing Industry 4.0: Implications for process safety and environmental protection. *Process safety and environmental protection*, *117*, 730-741.

Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability*, *10*(1), 247.

Nedjwa, E., Bertrand, R., & Sassi Boudemagh, S. (2022). Impacts of Industry 4.0 technologies on Lean management tools: a bibliometric analysis. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 1-16.

Nganga, O. B. (2020). Exploring the Applicability and Challenges of implementing Industry 4.0 Technologies in the Small and Medium Sized Industries in Kenya. : *Faculty of Engineering, University Of Auckland*

Raj, A., Dwivedi, G., Sharma, A., de Sousa Jabbour, A. B. L., & Rajak, S. (2020). Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics, 224*, 107546.

Rajput, S., & Singh, S. P. (2019). Industry 4.0– challenges to implement circular economy. *Benchmarking: An International Journal.*

Rosin, F., Forget, P., Lamouri, S., & Pellerin, R. (2020). Impacts of Industry 4.0 technologies on Lean principles. *International Journal of Production Research, 58*(6), 1644-1661

Rosin, F., Forget, P., Lamouri, S., & Pellerin, R. (2022). Enhancing the Decision-Making Process through Industry 4.0 Technologies. *Sustainability, 14*(1), 461

Silvestri, L., Forcina, A., Introna, V., Santolamazza, A., & Cesarotti, V. (2020). Maintenance transformation through Industry 4.0 technologies: A systematic literature review. *Computers in Industry, 123*, 103335.

Slack, N., Chamber, S., Johnston, S.R. (2004), Operations Management. 4th ed. Harlow: Pearson Education

Sony, M., & Naik, S. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An International Journal.*

Swierczek, A. (2022). The effects of industry 4.0 technologies on relational performance: the mediating role of supply chain emergence in the transitive logistics service triads. *Supply Chain Management: An International Journal.*

Toktaş-Palut, P. (2022). Analyzing the effects of Industry 4.0 technologies and coordination on the sustainability of supply chains. *Sustainable Production and Consumption, 30*, 341-358.

Wagner, J. A., & Hollenbeck, J. R. (2020). *Organizational behavior: Securing competitive advantage*. Routledge.

Zheng, T., Ardolino, M., Bacchetti, A., & Perona, M. (2021). The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review. *International Journal of Production Research, 59*(6), 1922-1954.

APPENDIX I; INTRODUCTORY LETTER

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Our Ref: D67/33514/2019

September 2, 2022

TO WHOM IT MAY CONCERN

RE: <u>INTRODUCTION LETTER: DENNIS KOECH</u>

The above named is a registered Master of Science in Supply Chain Management Student at the Faculty of Business and Management Sciences, University of Nairobi. He is conducting research on ***"Industry* 4.0 Technologies and Competitiveness of Manufacturing firms in Nairobi, Kenya."**

The purpose of this letter is to kindly request you to assist and facilitate the student with necessary data which forms an integral part of the Project.

The information and data required is needed for academic purposes only and will be treated in **Strict-Confidence**.

Your co-operation will be highly appreciated.

PHILIP MUKOLA (MR.)
FOR: ASSOCIATE DEAN,
FACULTY OF BUSINESS AND MANAGEMENT SCIENCES

PM/fcl

APPENDIX II; QUESTIONNAIRE

i. This instrument aims to obtain information on Industry 4.0 and Competitiveness of Large Manufacturing firms in Nairobi. The information is for academic reasons only

SECTION I: DEMOGRAPHICS

1. Kindly provide the identity of the firm (Optional).

....

....

2. Kindly choose your role in the entity?

   a) Head of Supply chain [ ]   b) Head of Operations []

   c) Head of ICT[ ]

3. What is the period (Years) of your working at the manufacturing firm?

   a) Below one [ ]   b) Three-Five [ ]

   c) Six-Ten [ ]   d) Over Ten [ ]

4. For what period (Years) has this entity been operational in Nairobi?

   a) Below 5 ( )

   b) 6 – 10 ( )

   c) Above 10 ( )

5. For what period (Years) has this entity adopted Industry 4.0 Technologies?

   a) Less than 2 ( )

   b) 3– 5 ( )

   c) Above 5 ( )

SECTION II: INDUSTRY 4.0 TECHNOLOGIES IMPLEMENTED

6. To what extent have the subsequent Industry 4.0 Technologies been adopted by manufacturing firm? Use a scale ranging from 1 to 5:

BIG DATA ANALYTICS	1	2	3	4	5
The firm Processes and analyses large volumes of data to enhance productivity					
Delivers the product design needed					
Analyses large data sets to insight about trends and preferences					
Develops algorithms for predicting behavior and error reduction					
ADDITIVE MANUFACTURING	**1**	**2**	**3**	**4**	**5**
Produce small batches of customized products					
Production of complex but lightweight designs					
Easily alters the design as needed					
Makes faster and cheaper production systems					
CLOUD COMPUTING	**1**	**2**	**3**	**4**	**5**
Remotely store relevant and pertinent information					
Makes vital information accessible from virtually anywhere					
Increased data sharing across sites and firms					
Digital production by firms in different geographical locations					
3D PRINTING	**1**	**2**	**3**	**4**	**5**
Used to prototype and produce individual components					
Optimized design process					
Scientific modeling for visualizing the operational system					
Safety engineering for system security					
INTERNET OF THINGS	**1**	**2**	**3**	**4**	**5**
Automatic capture of information by devices					
Intelligent information sharing by the firm					
Real time data transmission between devices					
Employees can issue commands to production machines					

SECTION III: IDUSTRY 4.0 TECHNOLOGIES AND COMPETITIVENESS

7. To what extent has implementing Industry 4.0 Technologies influenced competitiveness measures tabulated? Kindly adopt a scale ranging from 1 to 5

COST	1	2	3	4	5
Low production cost					

Minimized labour cost					
Reduced material cost					
QUALITY	**1**	**2**	**3**	**4**	**5**
Enhanced quality products					
Conformance to specifications					
Minimized defects					
SPEED	**1**	**2**	**3**	**4**	**5**
Quick response to clients demands					
Timely delivery of orders					
Shortened lead time					
DEPENDABILITY	**1**	**2**	**3**	**4**	**5**
Reliable delivery schedule					
Reliable and consistent products					
Minimized complaints from clients					
FLEXIBILITY	**1**	**2**	**3**	**4**	**5**
Enhanced ability to alter product volume and services					
Enhances the ability to alter delivery schedules					
Enhanced response to client's demands					

SECTION D: BARRIERS OF INDUSTRY 4.0 TECHNOLOGIES IMPLEMENTATION

8. Please rate the level that you concur with the subsequent challenges in implementing I4.0 Technologies using a scale of 1 to 5

Industry 4.0 Technologies involves High investment related costs					
There is a high level of Data insecurity					
There is Insecure connectivity					
There exists Inadequate technological infrastructure					
There is a high level of Inadequate skilled Personnel					
Industry 4.0 Technologies decreases job opportunities					

Thanks for participating