Engineering, 2023, 15, 533-560
https://www.scirp.org/journal/eng
ISSN Online: 1947-394X
ISSN Print: 1947-3931

The Impact of Internet of Things in Manufacturing Management

Ukazu Noel Chinedu, Eje Brendan

Engineering Management Department, Enugu State University of Science and Technology, Enugu, Nigeria
Email: noel7x@yahoo.com

How to cite this paper: Chinedu, U.N. and Brendan, E. (2023) The Impact of Internet of Things in Manufacturing Management. *Engineering*, **15**, 533-560.
https://doi.org/10.4236/eng.2023.159039

Received: July 25, 2023
Accepted: September 23, 2023
Published: September 26, 2023

Abstract

The study investigated the impact of the Internet of Things in manufacturing management. Specifically, the study examined how IoT implementation and management affect organizational efficiency in Camanov Ltd.; and to what extent IoT implementation contributes to the saving of cost and time of the organization. The research design is a survey. The population of this study consisted of all 141 staff of Camanov Ltd. Port Harcourt. Since the population is not large, the researcher conducted a census of all, and 126 staff completed a structured questionnaire. The two research questions were analyzed using simple percentages and all two hypotheses were tested using sample proportion statistics (Z test) at a 0.05 level of significance. The result showed that the Internet of Things has a significant impact on organizational efficiency in Camanov Ltd. (Z = 4.73); and that the Internet of Things significantly contributes toward saving cost and time of the organization Camanov Ltd (Z = 4.95). It was recommended that organizations should encourage training of personnel in the improved limitless possibility of information gathered from the Internet of Things framework which supports planning, budgeting and monitoring approaches, providing more reliable information to support actions, in particular in the decision-making process, to enhance productivity.

Keywords

IoT, Internet of Things, Automation, Network of Physical Objects

1. Introduction

1.1. Background of the Study

Irrespective of the type of activity and its size, no company can operate without modern technology and be able to compete with its competitors favorably. Stronger demand for customization, increasing customer expectations, the complexity of manufacturing and global supply chain management and many other challenges have continued to encourage manufacturers to find new and more innovative ways to remain competitive. In a bid to gain productivity improvements and uncover new ways of enhancing manufacturing and supply chain operations, businesses resort to digital transformation, hence the need for the Internet of Things.

The Internet of Things (IoT) is the network of physical objects that contain embedded technology to sense and interact with their environment and each other to collect and exchange data to make our lives better. It is another technology worldview. This allows objects to communicate with different objects and with people. This may sound odd. However, it is through embedded electronic hubs that are modified for specific capacities. Basically, this is the indication of fundamentally linking any device with an on-and-off switch to the Internet. Thus, a smart thermostat can speak with its owner and other smart gadgets in the house. For example, a smart vehicle can caution its owner about traffic issues on the way to work. The IoT can also use smart sensors on its industrial floors. This is achieved by planned and prognostic care to avoid big costs [1].

With issues like abrupt outbreaks, disasters, and conflicts, manufacturers are increasing their search towards the Industrial Internet of Things (IIoT). By integrating IIoT, they plan to stay competitive and strategize better for business growth. The importance of IIoT in the manufacturing sector and its benefits are simply. IoT integrated assets provide real-time data information that allows the manufacturers to make informed decisions. The sensor devices provide valuable information regarding machine conditions, which is used for analysis and predicting better outcomes. The use of Industrial Internet of Things technology has the potential to deliver greater gains in efficiency, cost and profitability than its counterparts such as Lean and Six Sigma in the latter part of the 20th Century. Coupled with production floor visibility, conditions-based monitoring and process optimization, manufacturers are already seeing significant benefits. But every producer should be aware that Industrial IoT is still at the beginning. With each passing month, new advances in computing, improvements to algorithms, gains in AI and sensor and device improvement will continue to open the door for even greater improvements to existing services as well as pave the way for new value-added services and capabilities as well.

The theory of the Internet of Thing was initiated by the Auto-ID Labs of MIT in 1993 [2]. The intention of the Auto-ID Lab was to connect all the physical entities to the global network and to provide each entity with a distinctive identification (ID). The concept was approved by the report provided in the World Summit on the Information Society (WSIS) organized in Tunisia in the year 2005 by the International Telecommunication Union (ITU) (ITU Internet Reports 2005). Since then IoT development is becoming the centre of attention of various research groups and scholars. It has been used as a catchphrase by numerous sources.

It provides a unique capability of monitoring and controlling any physical objects having any shape and size anywhere anytime and by anyone via the internet. According to a report presented [3] by 2020, the IoT will help to drive 22 times as much data traffic as exists today. In terms of cost, performance, power consumption, availability, bandwidth, and other key attributes, the IoT will entail a much different variety of hardware, software and networking solutions. According to a survey [4] conducted by Zebra Technologies in June 2012 for various firms about the deployment of IoT Asia 21%, Latin America 12%, North America 12% and Europe 16% already have IoT solutions in place.

The Internet of Things (IoT) envisions a global ecosystem connecting diverse objects to the Internet [5] [6]. The use of engrained technologies, principally sensors, enables these objects to communicate with each other and produce and exchange data with no human intervention, through the internet connection. [7] [8]. The term Internet of Things was coined in 1999 by Ashton, co-founder of the Auto-ID Center at Massachusetts Institute of Technology (MIT), when presenting the idea of using radio-frequency identification (RFID) tags in supply chains to link physical objects with the internet [9]. The concept of a connected devices network, however, has already been discussed before. Weiser addressed a network of connected devices almost a decade earlier [10]. Reports on the development of devices, which could be called IoT devices today, even go back to the early 1980s. For instance, in 1982, a modified Coca-Cola vending machine at Carnegie Mellon University in Pittsburgh was able to report its stock and the temperature of newly loaded drinks via the Internet [11]. In contrast, Jesus *et al.*, consider an internet-connected toaster introduced by John Romkey in 1990 as the first IoT device that could be switched on and off [12]. Today, Tesla is considered a pioneer in helping shape the general idea of the IoT [13]. The IoT is projected to have enormous potential to influence and change society, the economy, and the environment [14]. In this paper, we focus on the economic dimension, and more specifically, the supply chain and manufacturing management perspective on IoT, as the IoT can be seen as a radical innovation [15], which has the potential to innovate many existing business models and generate completely new ones [16]. Ashton and Chambers believe that the IoT has a revolutionary potential, even more than the internet itself has [17].

The McKinsey Global Institute estimates the financial impact of IoT on the general economy to be USD 11.1 trillion by 2025 [18].

Therefore, in light of the importance of the Internet of Things, this study intends to further examine how the adoption of IoT in supply chain and manufacturing processes could influence the efficient delivery of goods and services. Put differently, this study intends to examine the influence of the Internet of Things on organizational performance.

1.2. Statement of the Problem

Through IT advancements, crucial elements have surfaced relating to the gathering and processing of information. IoT represents the latest element in information gathering and data analysis. There is still no standard definition for IoT technology, in fact, it depends directly on the users. Researchers and practitioners provided different definitions of the same technology, as well as entrepreneurs and corporate managers gave descriptions highlighting different features and peculiarities. In general, a possible definition of IoT Technology is: "an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment [19]. The European Commission described IoT, as web-enabled devices that are each coded to acquire specific traits of their own. Allowing for effective and efficient operations in smart environments using the interfaces to connect and communicate within all project variables [20]. The Internet of Thing could support all the different processes during manufacturing and supply chain management. It has the enablement to solve various technical and communication problems, increasing the level of collaboration amongst parties. IoT creates opportunities, and with the continuous development of IT the limits are yet to be set, however with all the possibilities IoT technology has to offer a high consideration should be the ethical manner of information collection and securely storing the data [21]. The Internet of Thing represents a disruptive technology: its structure is revolutionary and the potential limitless. It permits full control of the web-enabled devices connected and is part of the network. IoT technology utilization refers to the degree of IoT diffusion into the organization and the extent to which the organization employs, utilizes or implements the technology in its operations [22]. Despite considerable research into organizational IT technology implementation, it continues to remain an issue for organizations. IT implementation is complex, time-consuming and costly, and every organization is different regarding its respective processes, people and functions [23]. Thus, the extent to which accepted implementation theories can be useful to an organization adopting a technology is limited. Implementation of IoT technologies can even be taken a level further and is not only challenging for the adopting organization but is also very intimidating. It is clear to organizations that IoT technologies are a necessity not only to facilitate increasingly complex supply chains but also to be able to relate to customers. However, IoT implementation is particularly challenging since it is not just one information system implemented, but a thriving and developing pool of smart technologies that are producing an enormous amount of Big Data. The Big Data must be analyzed to contribute value to the firm—a concept referred to as the technology productivity paradox [22]. This study is therefore undertaken in the hope of contributing to knowledge of IOT especially as it is vital for organizations to have clear and focused IoT understandings, strategies and implementation plans when adopting IoT technologies.

1.3. Aim and Objectives

The aim of this study is to investigate the impact of the Internet of Things on supply chain and manufacturing management. The objectives include:

1) To determine how the Internet of Things affects organizational efficiency.

2) To examine how the Internet of Things contributes to saving labour, cost and time for the organization.

1.4. Research Questions

1) How does internet of things affect organizational efficiency?

2) To what extent does the Internet of Things contribute to saving of cost and time of the organization?

1.5. Hypotheses of the Study

Null Hypotheses (H0)

1) the Internet of Things has no significant impact on organizational efficiency.

2) the Internet of Things does not significantly contribute toward saving of cost and time of the organization

Alternate Hypotheses (H1)

1) the Internet of Things has significant impact on organizational efficiency.

2) the Internet of Things significantly contribute toward saving of cost and time of the organization

1.6. Significance of the Study

As already pointed out in the introduction to the study, the Industrial Internet of Things embraces the use of smart sensors and actuators to enhance manufacturing and industrial processes. The Industrial Internet of Things (IIoT) uses the power of smart machines and real-time analytics to take advantage of the data that "dumb machines" have produced in industrial settings for years. The driving philosophy behind IIoT is that smart machines are not only better than humans at capturing and analyzing data in real-time, but they are also better at communicating important information that can be used to drive business decisions faster and more accurately The study provides insights into the contribution of internet of things to organizations manufacturing performance thus, the study would help all managers of firms to learn more about the importance of their duties as it provides answers to some nagging questions about manufacturing data sourcing and utilization as well as helpful strategies in overcoming the shortcomings of delayed and authenticity of data gathering for decision-making system that is in place presently.

1.7. Scope of the Study

This study is not a case study. Therefore, it has a wide scope. It focuses on general issues of the Internet of Things adoption for the competitive performance of organizations. It is also not time-bound but will focus more on the Internet of Things in manufacturing management in the modern technology driven business era.

1.8. Design of the Study

This study is designed to leverage extant content analysis to deepen understanding of the basic factors involved in the phenomenon of interest. In other words, it is a kind of qualitative inquiry into the effects and benefits associated with the adoption of the Internet of Things in manufacturing management in an organization. A survey of extant literature on the subject was conducted to help bring to light the frontline opinions and views of scholars on the subject. The proposed research framework is based on a theoretical implementation process of IoT as a concept or specific IoT applications and/or architectures integrated. The framework represents a theoretical implementation process associated with IoT, based on an input-process-output (IPO) model with three main variables: definition/conceptual design (input), evaluation (process), and implementation/impact (output) [24]. Based on the analysis and oriented by the framework, an overview of the current state of research, as well as potential research gaps and future research directions, will be identified. Due to the complexity and rapid growth of scientific and economic interest in IoT, the research model/framework is proposed to organize the relevant knowledge in a coherent way, serving as a reflection of the current state and guidelines for future research. This will enable the researcher to blend in his observations on the subject with the position of literature and questionnaire outcome based on this model in order to draw conclusions.

2. Review of Related Literature

2.1. Overview of Internet of Things in Manufacturing Management

The Internet of Things (IoT) describes the network of physical objects "things" that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet. Industrial IoT (IIoT) refers to the application of IoT technology in industrial settings, especially with respect to instrumentation and control of sensors and devices that engage cloud technologies. Industries have used machine-to-machine communication (M2M) to achieve wireless automation and control. But with the emergence of cloud and allied technologies (such as analytics and machine learning), industries can achieve a new automation layer and with it create new revenue and business models. IIoT is sometimes called the fourth wave of the industrial revolution, or Industry 4.0. Common uses for IIoT are smart manufacturing, connected assets and preventive and predictive maintenance, smart power grids, smart cities, connected logistics and mart digital supply chains.

These devices range from ordinary household objects to sophisticated industrial tools. The challenges before implementing the IoT Production Monitoring application include limited production visibility and accuracy, low visibility into shop floor operations, causing shipment delays and backlogs, inaccurate inventory details due to human error, and lack of real-time data about the movement of wheels through the conveyors. Because of this, the shipping department could not accurately estimate the completion time for customer pickups. This led to long wait times for trucks, bottlenecks, extra labor costs, and shipping delays, unplanned maintenance, unplanned downtime, disrupted regular maintenance and increased production urgency. Lack of visibility into machine health led to manual maintenance schedules as opposed to automated schedules, and inability to run predictive analysis to predict machine breakdowns. In addition to these challenges, the organization had different software solutions for scheduling, production completion, label printing, and time and attendance management, all of which hindered their ability to optimize production. The business needed the maintenance team to focus on shop floor automation, with the ability to monitor machine health, perform analysis, predict failure, and optimize preventive maintenance schedules. Due to the peculiarity of different industrial sectors, the way that the IoT is leveraged by enterprises varies substantially by industry. Retailers are incorporating RFID tags within their anti-theft tags to help manage inventory and help keep costs down. Within mining, some companies are using IoT to expand on driverless trucks or autonomous haul trucks that can work round the clock, have lower costs, increased output, and reduced maintenance. It is essential for enterprises to understand how the IoT can enable the transformation of their business and industry. Utilities, industrial sectors, connected cars, healthcare and consumers are other verticals at the forefront of IoT investment. Leveraging IoT in vertical industries definitely revolutionizes the traditional way of doing things. These changes will lead to major opportunities for providers too.

2.2. The Origin of IoT Management

The term has its origin at the end of the last century, specifically in 1999, when Kevin Ashton, director of Procter & Gamble, had the initiative to create a group of researchers called the Auto-ID Center at the Massachusetts Institute of Technology (MIT). Their main purpose was to find out information about Radio Frequency Identification Network (RFID) and sensor technologies. Ashton first spoke of the IoT concept when he was trying to solve a problem at the company he worked for, the most popular products were not available in stores. He discovered that this happened because, the more publicity of a product, the faster it sold out. It was an information problem. The solution was to put network-connected sensors on P & G products to know when they were out of stock—a crazy idea in the '90s. At that time, society was experiencing the internet through dial-up modems, it was very slow and the connection was through the telephone line. Ashton had to convince P & G executives, who were much older than him, to put the sensors everywhere. Putting the word "internet" in his proposal managed to attract their attention. The word "things" was used because the idea of being able to embed computers in tables began due to the fact that the devices were getting smaller and cheaper. The whole idea was confusing at first, but it was good enough for him to start doing research at MIT. Subsequently, he made that presentation thousands of times, all over the world. Between 2005 and 2008 people did not talk much more about IoT, until around 2009 when it became a very popular word. In the following years of its birth, the IoT has grown exponentially, to the point that most of society believes that it could not live without it. Technological advances and the IoT have brought great benefits not only to companies but to society as well, improving people's quality of life. The number of connected devices is projected to nearly triple globally over the next few years, according to data provided by Transforma Insights. In this way, it would go from approximately 8740 million in 2020 to more than 25,400 million in 2030. This is an excellent figure to monitor and keep tabs on. According to [25] from the interaction, new information is produced, and things work together to set and reach common goals. It eventually will lead to the birth of contextual, converged, and advanced services. Things are more valuable when networked, and the network becomes more valuable when more things are connected to it [25].

Cost efficiency. Technological researchers suggest cost reduction as a benefit of IoT applications [25]. However, costs associated with a new technology include not only direct costs, but also indirect costs, such as supervision, contractor fees, and legal costs, to name a few [25].

2.3. Application of IoT Today

The IoT technology can, in general, be applied to all areas human beings deal with. In the literature, different classifications of application areas can be found. Guillemin and Friess distinguish society, industry, and environment as three broad and overlapping application domains, with several sub-domains (**Figure 1**). Another classification is suggested by [26]. who identify four application domains for the IoT: 1) in the personal and home domain, where the IoT can help improve daily living issues, such as home and energy management; 2) in the enterprise domain, with an impact on a community level, such as public health or public transportation and infrastructure issues; 3) the utility domain, which represents the surveillance sector; and 4) the mobile domain relating to wireless applications used out and about. [27] provided a comprehensive list of IoT application fields including environmental monitoring, smart cities, smart businesses as well as inventories and product management, smart homes and smart building management, healthcare, and security and surveillance. [28] exemplarily mentioned IoT application fields such as agriculture and livestock or product lifecycle management. Many other fields, such as the electricity or retailing sector, can be added. According to the respective application area, different IoTs can be distinguished. The so-called Internet of Healthcare Things or Internet of Medical Things relates to healthcare issues and is among the areas most rapidly using IoT technologies. Using more medical devices leads to higher volumes of medical data. Moreover, shorter innovation cycles in medical technologies push

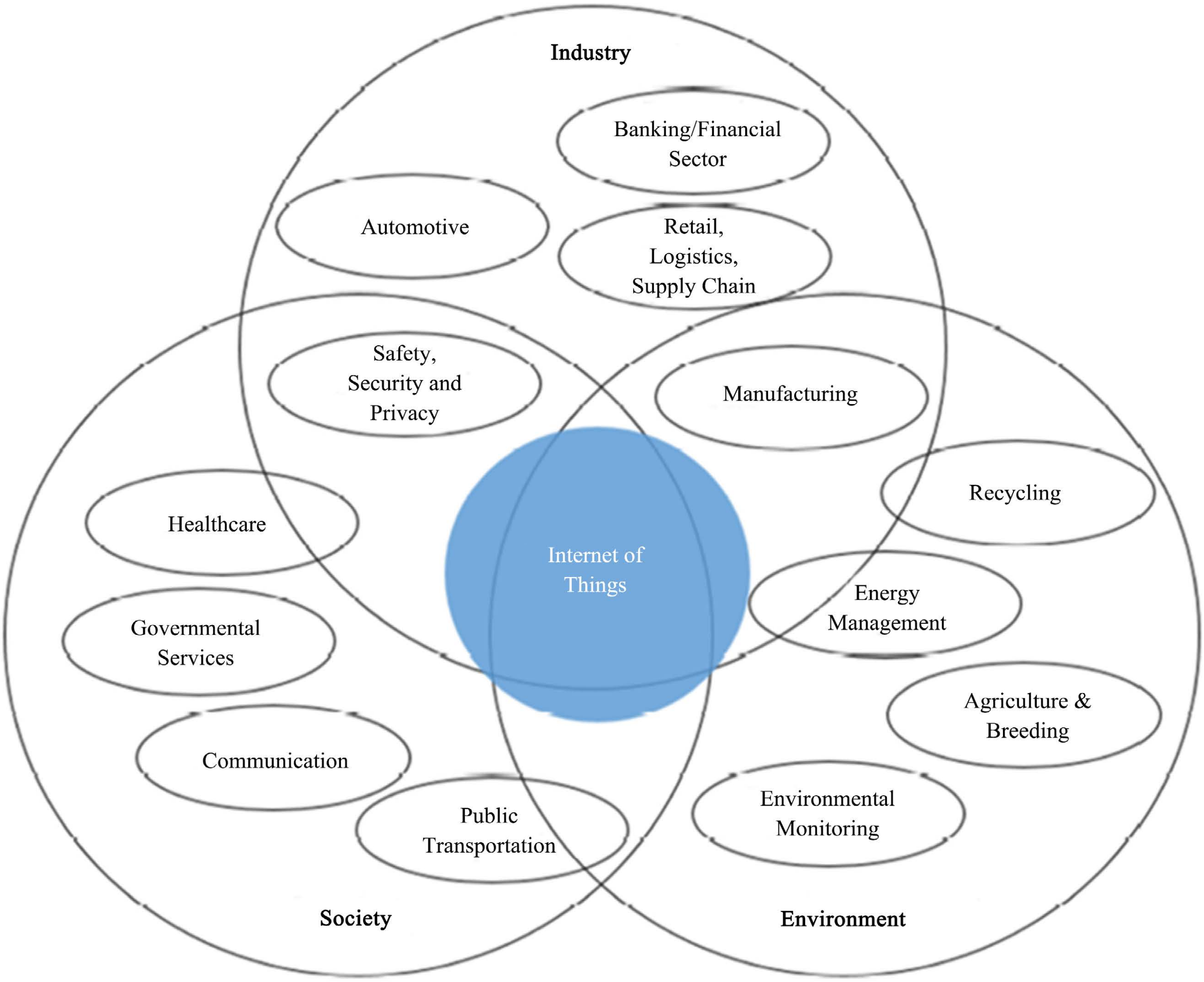

Figure 1. Application domains. Sources: [29].

the need for a digitized and interconnected healthcare system. With IoT technology, the efficiency of medical devices and the health system as a whole can be improved. Recently, IoT technologies have been used to fight the COVID-19 pandemic. The Industrial Internet of Things (IIoT) focuses on manufacturing and production and aims to bring improvements in operational efficiency, production processes, and the development of new business models. Srinivasan *et al.* 2019, explore further IoT extensions, such as the Internet of Everything, or the Internet of Mobile Things, to name a few.

2.4. Principles of IoT Management

1) Big Analog Data

Analog data represents the natural and physical world. It is everywhere. In other words, it is part of everything. It includes the light, sound, temperature, voltage, radio signals, moisture, vibration, velocity, wind, motion, video, acceleration, particulates, magnetism, current, pressure, time, and location. It is the oldest, fastest, and biggest of all big data, but it represents an IT challenge in that it has more than two values that digital data has. Simply put, in many ways analog data needs to be treated differently than digital data. The question is, and will continue to be, how can we efficiently unlock the business value of Big Analog Data?

2) Perpetual Connectivity

The IoT is always connected, always on, and that "Perpetual Connectivity" to products and users affords three key benefits:

- **Monitor**: Continuous monitoring which provides ongoing and real-time knowledge of the condition and usage of a product or user in a market or industrial setting.
- **Maintain**: Due to continual monitoring one can now push upgrades, fixes, patches, and management as needed.
- **Motivate**: Constant and ongoing connection to consumers or workers gives organizations a way to compel or motivate others to take some action, purchase a product, etc.

These are referred to as the Three M's, and the notion that an organization can be perpetually connected to consumers and products is quite profound, with far-reaching implications and opportunities. For example, if your washing machine was connected to the IoT, predictive analytics could sense when the machine would fail and schedule a repair, say, ten days before that unfortunate event occurred. This way you are not standing in front of a defunct washer holding a basket of dirty laundry.

3) Really Real Time

The definition of real-time differs from people who do not understand the IoT than from people who do. Real-time actually begins back at the sensor or the moment the data is acquired. Real-time for the IoT does not begin when the data hits a network switch or computer system—by then it is too old. If you want to know if your house is going to catch on fire, how soon would you like to know that? If and when a crime may occur, mere seconds are crucial. Hence an alarm must go off in very real time, before the data even gets to the cloud or data center, or it does not help. The point is that we are seeking to blend the world of operational technology (OT), sensors, and data measurement with the world of IT. The IoT blends these two worlds for the first time in a major way, and the results will be profound.

4) The Spectrum of Insight

The Spectrum of Insight derived from IoT data relates to its place in a five phase data flow such as real time, in motion, early life, at rest, and archive. Recall real time for the IoT at the sensor or point of acquisition and analytics are needed to determine the immediate response of a control system and adjust accordingly, such as in military applications or precision robotics. At the other end of the spectrum, archived data in the data center or cloud can be retrieved for comparative analysis against newer, in-motion data, to gain insight into the seasonal behavior of an electrical power generating turbine, for example. Hence insight from the big data in the IoT can be extracted across a spectrum of time and location.

5) Immediacy versus Depth

With today's traditional computer and IoT solutions, there is a trade-off between speed and depth. That is, one can get immediate Time-to-Insight on a rudimentary analytic such as a temperature comparison or fast Fourier transform to determine if rotating wheels on a tram will cause a life threating accident. Immediate Time-to-Insight is crucial here.

On the other end of the spectrum is the time required to gain deep insight. The example here is from where they smash subatomic particles together to seek insight into the make-up of such particles. The data collected here takes a long time to analyze, using large, back-end computer farms. Such depth of insight has resulted in the recent discovery of a new subatomic particle called the Higgs Boson.

6) Shift Left

Consider the mutually exclusive objective of deriving both immediate and deep insight, as discussed in Immediacy Versus Depth above. It is really hard to get both today. However, engineers are good at resolving conflicting objectives and getting BOTH. James Collins has referred to this phenomenon as "the genius of the AND" [30].

The drive to get both immediate and deep insight from data will cause sophisticated high-end computing and data analytics that are normally reserved for the cloud or data center (what is called Tier 4 in the IoT solution), to migrate toward the left of the end-to-end IoT solution infrastructure. That is, deep compute will be positioned closer to the source of data, at the point of data acquisition and accumulation in sensors (called Tier 1) and network gateways (Tier 2).

7) The Next "V"

Big data is commonly characterized by the infamous "V's"—Volume, Velocity, Variety, and Value and a fifth "V"—Visibility is proposed. When the data is collected, data scientists around the world should be able to see and work with it, as needed. Visibility refers to the benefit afforded by not having to transfer large amounts of data to remote people or locations [30].

2.5. IoT Management

Companies have been using Internet of Things (IoT) devices for a long time, from agricultural companies monitoring weather and crop conditions to industrial companies tracking the output and safety within manufacturing facilities. In the manufacturing industry, using IoT devices is an easy way for companies to make processes more efficient. Tony Del Sesto, technical fellow at MxD, a Chicago-based public-private innovation center for advanced manufacturing, said IoT allows manufacturing companies to do better continuous improvements, a necessity for staying competitive in the industry [31].

Any manufacturer that is not doing continuous improvement, or that the competitors are doing continuous improvement better than it, the company will not be in business for very long," Del Sesto said [31]. IoT allows you to do things in applications and solve problems that you just cannot do manually, and that is primarily because of speed.

IoT Device Management Basics

- Provision devices using standard provisioning protocols.
- Take extra care when adding legacy technology to the network.
- Take failure into account when planning device orchestration.
- Educate employees on cybersecurity good practices.
- Adopt zero-trust security measures.
- Choose low-maintenance devices.
- Train and upskill employees on IoT device management.

Companies in the logistics industry are dependent on IoT for tracking shipments. For example, a distribution center may have 1500 to 2000 trailers out in the yard somewhere. Their challenge is to be able to identify where those trailers are located at any given point in time. IoT can accelerate processes by giving companies real-time data and visibility but having a lot of devices can be a maintenance and security headache. In those cases, it is even more important to have the right procedures in place for IoT management. The ones who are really into IoT are using thousands of devices and the implication of that is that automation is needed to be able to provision them which is a major problem. Provisioning refers to identifying and connecting devices to a central system. It is the first step of the IoT device management process. This is followed by orchestration, where devices are configured to work together, and finally the ongoing process of updating devices and maintaining their security.

Provisioning Devices: The First Step in IoT Management

Devices need to be activated and incorporated into a company's existing suite of IoT devices before they can be used. Doing that successfully for new devices takes several steps, starting with the IoT system identifying each new device. It has to do with discovery, devices need a shared protocol to join established networks. Companies can use specific standards that are created for the complex communication dance associated with provisioning devices.

Sometimes provisioning is complicated by devices that are not easily compatible with modern protocols. Many companies in the manufacturing industry, for instance, have existing technology that predates the internet and IoT devices. For these companies, provisioning not only involves connecting new devices but sometimes also connecting old devices to a new IoT system.

Most manufacturers are brownfield operations, which means they are established, they have been around for a while. They are using older equipment, legacy systems, and legacy networks. It can be tricky combining new and old systems without breaking either and forcing operations to shut down, but doing so is crucial for older operations that want to take advantage of the opportunities offered by IoT systems. Using resources such as the Industrial Internet of Things Connectivity Framework can help companies navigate old and new protocols, and get them to work together. This is because the organization does not want to redo everything. There is a need to find simple ways in which to connect things to standards and then go from there.

Devices are not necessarily all provisioned together, but rather in an ad hoc manner. Employees in the field sometimes add devices without the knowledge of the IT department, these devices are known as shadow IT. Shadow IT implies that a smart temperature sensor is purchased in order to monitor lab temperatures, but the devices were never properly on boarded. As a result, they were not being managed with the rest of the lab's devices. Companies should try to uncover and incorporate shadow IT into the centrally managed IoT network as early as possible because the best way to get optimal use from devices is by taking them through the correct orchestration and maintenance steps.

Orchestration Needs to Take Failure into Account

The second step of the IoT device management process is orchestration, which makes sure connected devices are able to work together properly and can be controlled centrally. That means configuring more than just the IoT devices. It is not just the devices, it is also the computers and the servers and various other elements that the organization has that make up the system hence the need to find a way to bring all these things together, making them work together as a single whole. The ability to control IoT devices centrally allows companies to save time and money. It can get expensive to send employees to physical locations for standard maintenance issues like checking the health of devices and pushing updates.

The goal of orchestration is to have IoT devices working smoothly together, but part of the process involves planning for when steps do not go as planned. That is especially important for the infrastructure that controls and monitors the devices. You have to find a way to orchestrate all the servers to work together in some way and that must include failure. If that server has died, then you need to find a way to ensure that everything gets shifted.

Managing device failure in IoT systems is a priority for manufacturing companies because normal operations can depend on a company's ability to monitor production by getting real-time feedback from IoT devices.

The benefits gained from IoT are a double-edged sword. It can speed up processes, but failure at critical points can make companies lose even more output than they would have otherwise. For industries like manufacturing where IoT can dramatically increase efficiency, the opportunity cost of having IoT systems go down can be serious. It is much better to do regular maintenance of devices, servers and networks to ensure things run smoothly all the time.

Securing IoT Devices against Attackers

Security is a big concern in the IoT world. Insecure devices can easily let hackers penetrate systems and access sensitive information. And it is not just IT departments that should be aware of these security concerns because of the number and variety of access points, employees also need to work with their companies to keep systems protected. Companies in the manufacturing industry could have thousands of connected devices. Within the factory, you have lots of different systems. There are more and more computers, and more and more servers, more and more microcontrollers.

Employees should practice basic password management and be vigilant against phishing attacks. Companies can take preventative measures that reduce risk by preventing attackers from gaining access to the whole system if one part is compromised. One such method involves building a zero-trust network, where sections of the system are segmented off from one another and only approved communication can go between servers. Because segmentation makes it harder to communicate across a system, it has the potential to interfere with devices' ability to work together. But using zero-trust methods properly reduces the risk, and it is becoming a popular way to manage security. Rather than doing anti-viruses, which is checking for system compromise attacks, there is the need to set up the network, so it only lets through stuff that it knows is good. Most manufacturers know what they need to communicate. When they look at the IoT ecosystem, they know that a particular type of information needs to go from place A to place B, so they structure the systems so only that information can go from place A to place B. IoT device security also extends to the devices themselves and how they were built. The difficulty a manufacturing company might have with securing devices individually if it sources many kinds of devices from different vendors. That factory is going to have all sorts of components bought from all sorts of places. So, what is required or needed is to be able to get evidence that the supplier is trustworthy. Verifying IoT suppliers may sound burdensome, but it is an important part of the IoT procurement process. Companies should ask vendors about their investment in security when shopping around and whether there are built-in checkpoints that ensure security. The kind of thing the company is looking for is evidence of their processes, so they can show you. This is how we developed this. These are the things that we thought about. These are the compliance tests that we have run.

IoT Devices Should Allow for Flexibility in Management

It can be daunting to manage a large fleet of IoT devices, but companies can set up devices so updates do not take as much time. The important thing the organizations need to understand is to try and get as maintenance-free as possible. Simplify that by the use of inactive capacitor tags.

A typical example is the use of RFIDs to track shipments on trucks, which allows the company to make more accurate projections of product delivery times. Companies need to choose between two types of RFIDs: active and passive. Active ones last much longer, but they are more expensive and need to be recharged and maintained. Since passive RFIDs still last many years and only cost a few dollars, most companies decided to use them and also gain the benefit of not having to do regular maintenance on more devices.

It also helps if companies have the flexibility of managing IoT devices however they want instead of being locked into device manufacturers' own proprietary management systems. It is important to be aware of IoT device makers whose products are not compatible with other systems.

A third-party system is needed to be able to give that holistic view as in IoT there is really no standard out there. It is just like when you want to buy an IoT device at home, you want to make sure it is compatible with your central system. It is also important to consider the learning curve associated with IoT management. Companies should invest in training and up skilling employees so they can learn to take care of and make the best use of the company's IoT devices. Conversations tend to be focused on technology, but what many companies tend to forget is the people of the equation. People are extremely important, and they are really the heart of any factory. You have to start asking yourself, "Who is going to install it? Who is going to maintain it? Who's going to use it and operate it? Who's going to fix it when it breaks" [31]?

2.6. IoT and Organizational Efficiency

The Internet of Things and the Industrial Internet of Things are changing the manufacturing process. Improving operational efficiency is the objective of IoT for any company that decides to incorporate it in its processes, so, they address the growing demand for product customization and changing customer expectations. As a result, 86% of manufacturing companies have already chosen IIoT solutions, with 84% reporting they found them extremely effective, according to a 2017 Bsquare IIoT maturity survey. Some of its benefits are improved productivity, supercharged efficiency and driven competitive advantage. The manufacturing industry's spending on IoT solutions far exceeds that of any other industry, reaching $178 billion in 2016, more than double the second-largest market (transportation). In manufacturing IoT is an ecosystem that connects physical objects and other technologies to exchange data to improve operational efficiency towards digitization. One of the big benefits of IoT in the manufacturing process is the combination of minimized machine downtime, optimal asset and inventory management, energy usage optimization, agile operations and supply chain management.

Consequently, this dramatically reduces manufacturing costs and shorten product cycle times. The use of IoT devices in the manufacturing industry results in an additional economic value of between $1.2 and $3.7 trillion before 2025, McKinsey predicts.

Manufacturers will be able to create products that are specifically tailored to their customers' needs using IoT solutions and process optimization tools. The complexity of inventory management will increase due to the changing manufacturing processes required to accommodate mass customization. IoT solutions reduce this complexity by linking previously isolated parts of the production process. This allows for production to be scaled up and down easily, which results in happier customers and lower waste. Companies can use these solutions to track changes in demand and forecast production. Over 76% of early adopters claim IoT solutions are increasing insight into customer preferences. Above all, IoT process optimization tools can be adopted by discrete manufacturers to provide them with data that will enable them to improve operational efficiency, manage complex production cycles, increase profitability and operations, reduce production cycle and incorporate predictive maintenance. Manufacturing is a high-risk industry. Cybersecurity and safety at work are two of the top concerns. The ILO (International Labor Organization) revealed that 151 workers have a work-related accident every minute. Meanwhile, manufacturing was recently ranked the most at-risk industry for cyberattacks. When it comes to the adoption of new IIoT platforms, security is the most important feature. IoT wearable devices improve operational efficiency by monitoring workers' health and tracking high-risk activities in hazardous environments. They can also reduce accidents by collecting vital data, for example Location, Heart rate, Temperature and Gas leaks. IoT solutions addressing safety concerns could save companies $220 billion on injury and illness costs. More than half of supply chain managers regard end-to-end supply chain visibility as a long way off, but IoT technologies will accelerate progress toward this goal. IoT will provide visibility into field operations, the manufacturing supply chain, and remote or outsourced operations, filling the gaps that Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) systems cannot (due to their need for manual data input). The supply chain can be integrated with IoT technology to provide detailed information about products, including their location during transit, properties, and stock levels. IoT applications facilitate better asset management in manufacturing including, for instance, tracking, inventory management, and predictive maintenance. This will increase reliability, prolong equipment life, and give manufacturers a higher return on their investment. Zebra's 2017 Manufacturing Vision Study found that smart asset tracking will overtake old-school approaches by 2022, saving manufacturers between 20% - 50% in inventory carrying costs. According to IoT Analytics, IIoT Platforms for Manufacturing 2019-2024, there are three areas in which manufacturers most rely on IIoT platforms for industry transformation—General process optimization: 43.1%, General dashboards & visualization: 41.1% and Condition monitoring: 32.7%. IBM reported that adopting IIoT insights for process optimization will increase product count by up to 20%. IoT-assisted condition monitors can be used by manufacturers to improve operational efficiency, detect delays in operations and identify malfunctioning or underperforming machinery so that they can address them quickly. IoT devices can quickly identify the problem and fix it before it escalates.

2.7. Framework of IoT Management Architecture

The proposed research framework is based on a theoretical implementation process of IoT as a concept or specific IoT applications and/or architectures integrated. The framework represents a theoretical implementation process associated with IoT, based on an input-process-output (IPO) model with three main variables: definition/conceptual design (input), evaluation (process), and implementation/impact (output). The proposed research framework (**Figure 2**) is aimed to organize the relevant knowledge in a coherent way, serving as a reflection of the current state and guidelines for future research.

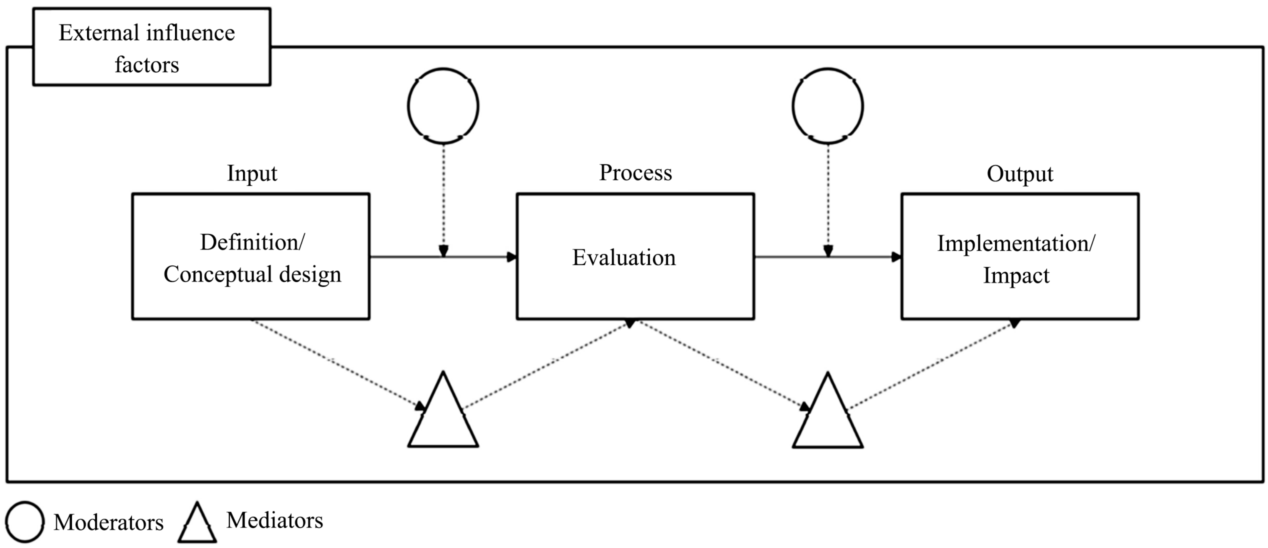

Figure 2. Framework represents a theoretical implementation process associated with IoT source: [24].

2.8. Advantages of IoT Manufacturing Management System

The Internet of Things (IoT) is a network of interconnected, embedded devices that can capture and transmit data without the need for human interaction over a wireless network. IoT applications in everyday life include smart wearables, smart health monitoring, traffic monitoring, IoT in agriculture with many sensors, smart devices, robots in hospitals, smart grid and water supply, and so on.

According to experts, manufacturing is by far the biggest spender on IoT technologies, with a total of nearly $200 billion for discrete manufacturing and process manufacturing combined (https://cygnustechnology.com/blog/the-advantages-and-disadvantages-of-using-iot-in-manufacturing/). In addition, there are many benefits to efficient resource utilization, minimizing human effort, saving time through the IoT platform, enhance data collection that improves security.

The challenges are high-Investment cost, secure data storage and management, connectivity outages, lack of standards. So how does a plant manager decide how to integrate IoT in manufacturing. Let's discuss the advantages and disadvantages of each one.

Advantages of IoT in Manufacturing:

1) Efficient Resource Utilization: Understanding how the machine's functionality and how each device can increase the utilization of the machine to work more productively.

2) Minimize Human Effort: As your machines interact and communicate with each other and do many tasks for us, they minimize the human struggle. This may sound like a disadvantage to losing workers. However, you still need employees to interpret the data, program the machines, and support them.

3) Save Time: Time is the primary factor that can save by using IoT in manufacturing. A job that took many workers now can be done with less time and fewer people. Taking that saved time, you can take on more projects.

4) Enhanced Data Collection: Having data at your fingertips to diagnose an issue with the machine is called predictive maintenance. You know what issues are before the machine breaks down.

5) Improve Security: The machines that are interconnected with the network work more efficiently and securely. All your network operations are connected to use and find data quickly and efficiently.

Disadvantages of IoT in Manufacturing:

1) Security of Data Management: The IoT systems are interconnected and communicate over networks. Various outside attacks can compromise the machine; therefore, having the proper network SSL encryption is a must for any devices that communicate and exchange information.

2) High Implementation Cost: The cost of implementing IoT does cost a considerable amount. The software needed for IoT is expensive to keep updated.

3) Connectivity Outages: In manufacturing, the buildings are massive, which allows for dead spots. This will hamper the productivity of your machine by connections coming in and out.

4) Lack of Standardization: Many embedded developers and designers have their way of doing things, making the hardware industry vastly complex. In other words, each machine speaks a different language.

2.9. Empirical Literature

Considering the critical role of IoT in manufacturing management to organizational performance, several studies have been conducted on the subject of this research.

Miorandi *et al.* 2012, provide a comprehensive list of IoT application fields including environmental monitoring, smart cities, smart businesses as well as inventories and product management, smart homes and smart building management, healthcare, and security and surveillance. Ng *et al.* exemplarily mention IoT application fields such as agriculture and livestock or product lifecycle management. Many other fields, such as the electricity or retailing sector, can be added. According to the respective application area, different IoTs can be distinguished.

[25] from the interaction, new information is produced, and things work together to set and reach common goals. It eventually will lead to the birth of contextual, converged, and advanced services. Things are more valuable when networked, and the network becomes more valuable when more things are connected to it [25].

Cost efficiency. Technological researchers suggest cost reduction as a benefit of IoT applications [25]. However, costs associated with a new technology include not only direct costs, but also indirect costs, such as supervision, contractor fee, and legal costs, to name a few [25].

3. Research Methodology

3.1. Research Design

The research design for this study is a survey research design. In this study, a survey was carried out using the staff and management of Camanov Ltd (Portharcourt Metropolis) to seek understanding on the impact of internet of things in manufacturing management on the organization. The study is executed based on a simple structured questionnaire articulated based on its objectives.

3.2. Sources of Data

The sources of data for this study consist of the responses from the respondents which formed the basis of the analysis and findings of the research. However, secondary data were also very relevant and consisted of already published data in books, journals, magazines, academic thesis, projects and internets which formed the basis for the review of literature on the subject.

3.3. Population of the Study

The population of this study is basically all 141 staff of Camanov Ltd., in Port Harcourt. They number 141 as presented in Table 1 below.

3.4. Determination of Sample Size

Since the population is not large, the researcher conducted a census by surveying the entire population of 141.

3.5. Instrument of the Study and Validation

The instrument of study was a simple and structured questionnaire, which was

Table 1. Distribution of the population.

SN	Department	Number	%
1	Admin/Finance	14	10
2	Production	42	30
3	Quality	12	9
4	Maintenance	14	10
5	Supply chain	14	10
6	Purchasing & Warehousing	10	7
7	Human resources	8	5
8	Commercial	9	6
9	Health/Safety	11	8
10	IT	7	5
	TOTAL	141	100

Source: HR department.

organized in a manner that addresses the key issues in the study objectives and research questions. The document is comprehensive and was made easy to understand by the respondents. The method of questioning used was the Likert's semantic differential such as Totally Agree, Agree, Neutral, Disagree and Totally Disagree.

The instrument was validated at two stages; first, the document was subjected to a small group of respondents called (pilot group) for completion. The responses of this group indicated that some propositions were not clear. Such propositions were dropped in the final questionnaire. Second, the instrument was submitted to an expert in research methods for vetting. More questions were dropped and some added. The final proposition was considered good to capture the purpose and objectives of the study.

3.6. Reliability of the Instrument

The study adopted the Crumbach's Alpha approach to test the reliability of the instrument. Using Statistical Package for Social Sciences (SPSS) version 23, Cronbach's alpha test was conducted to check for the internal consistency of the instrument, that is, how closely related a set of items are as a group. Thus, it measured the reliability of the instrument. This approach yielded an index of 0.82 which implies that the instrument was reliable to the tune of 82%.

3.7. Administration of Questionnaire

The researcher employed the assistance of 2 youth corps members currently serving within Portharcourt city for easy and quick conclusion of the process. The corps members were however well orientated and instructed on the administration modalities before they were considered good for the job. This strategy was in order to ensure we worked within the time framework allocated to the exercise. The administration lasted for two weeks. Reminders, calls, discussions, verbal encouragements, were adopted to motivate respondents to volunteer responses and accept questionnaire administration.

3.8. Method of Data Analysis

Two methods of analysis was adopted for the data analysis. One method consist the use of simple descriptive analytical tools. The second method was the test of hypothesis using the sample proportion test (Z test). The procedure is as follows:

$$Z = \frac{P - Po}{\sqrt{\frac{Po(1 - Po)}{N}}}$$

where P = Proportion of respondents who responded positively to the variable of interest.

Po = probability of rejecting null hypothesis (0.5);

1 = A constant;

N = Total number of respondents.

The computed value of Z is then compared with its critical value at 95% confidence level which is 1.96.

Decision Rule: Accept Ho and reject H1, if the computed Z is less than the critical value and vice versa.

4. Data Presentation and Analysis

4.1. Questionnaire Return Rate

Questionnaire distributed to 141 respondents, out of which 126 were returned, representing a response rate of 89%. The response rate is given in Table 2.

4.2. Analysis of Bio Data

Table 3 showed that 88 respondents (70%) are male, while 38 (30%) are female.

Table 4 showed that 12 respondents (10%) are between the ages of 20 - 25 years, 23 (18%) are between 26 - 29 years, 38 (30%) are between 30 - 35 years, 28 (22%) are between 36 - 39 years, while 25 (20%) are 40 years and above.

Table 5 showed that 11 respondents (9%) have worked between 0 - 2 years, 32 (25%) are between 3 - 5 years, 26 (21%) are between 6 - 8 years, 23 (18%) are between 9 - 11 years, 20 (16%) are between 11 - 13 years while 14 (11%) have worked for 13 years and above.

Table 2. Questionnaire returned rate.

Category	Distributed	Returned	% Returned	Non-return	% Non-return
Total	141	126	89	15	11

Source: Field survey, 2022.

Table 3. Distribution of gender of respondents.

Gender	Response	% Response
Male	88	70
Female	38	30
Total	126	100

Source: Field survey, 2022.

Table 4. Distribution of age bracket of respondents.

Age bracket	Response	% response
20 - 25 years	12	10
26 - 29 years	23	18
30 - 35 years	38	30
36 and 39 years	28	22
40 year and above	25	20
Total	126	100

Source: Field survey, 2022.

Table 5. Distribution of Length of service of respondents.

Length of service	Response	% Response
0 - 2 years	11	9
3 - 5 years	32	25
6 - 8 years	26	21
9 - 11 years	23	18
11 - 13 years	20	16
Above 13 years	14	11
Total	126	100

Source: Field survey, 2022.

4.3. Analyses of Research Questions

Table 6 showed that the average of 40 respondents (31%) strongly agreed that IoT implementation and management affect organizational efficiency in Camanov Ltd., average of 51 (40%) agreed; average of 13 (10%) were undecided; average of 13 (10%) disagreed; while average of 9 (7%) strongly disagreed. Since more than 50 percent agreed, it showed that IoT implementation and management affect organizational efficiency in Camanov Ltd.

Table 7 showed that the average of 42 respondents (33%) strongly agreed that IoT implementation contribute to saving of cost and time of the organization in Camanov Ltd., average of 49 (36%) agreed; average of 9 (11%) were undecided; average of 10 (12%) disagreed; while average of 14 (10%) strongly disagreed. Since more than 50 percent agreed, it showed that IoT implementation contribute to saving of cost and time of the organization.

4.4. Test of Hypotheses

Ho 1: Internet of things has no significant impact on organizational efficiency in Camanov Ltd.

Using Table 6:

$$P = 31\% + 40\% = 71\% = 0.71$$

$$P = 0.71$$

$$N = 126$$

$$Z = \frac{P - Po}{\sqrt{\frac{Po(1 - Po)}{N}}}$$

$$Z = \frac{0.71 - 0.5}{\sqrt{\frac{0.5(1 - 0.5)}{126}}}$$

$$Z = \frac{0.21}{\sqrt{\frac{0.5 \times 0.5}{126}}}$$

Table 6. Analysis of response to research question 1.

How does IoT implementation and management affect organizational efficiency in Camanov Ltd.	
S/N	**Question**
1	Adequate IoT implementation strongly supports the customerism objective
2	Good IoT management is at the root of quick turnaround time and premium goodwill before your customers.
3	Adequate IoT management helps to capture several nitch opportunities, tracking problems and creating solutions for them.
4	It supports the organization's efforts towards creation of interdepartmental synergy which is necessary for optimal performance with a strong positive correlation with profitability.

Options/Questions	Q1	%	Q2	%	Q3	%	Q4	%	Mean response	Mean %
Strongly agree	40	32	44	35	38	30	36	29	40	31
Agree	52	41	57	45	43	34	53	42	51	40
Undecided	15	12	8	7	15	12	14	11	13	10
Disagree	13	10	10	8	18	14	10	8	13	10
Strongly disagree	6	5	6	5	12	10	13	19	9	7
	126	**100**	**126**	**100**	**126**	**100**	**126**	**100**	126	100

Source: Field survey, 2022.

Table 7. Analysis of response to research question 2.

To what extent does IoT implementation contribute to saving of cost and time of the organization?	
S/N	**Question**
5	Good IoT management minimizes time wastage and helps improve overall performance and strengthen the overall market position of the brand through improved goodwill.
6	It is critical to the achievement of the premium manufacturing objectives of the firm by enhancing turnaround time and also helps to minimize cost.
7	By reducing cost, IoT helps to improve profitability, enhances returns on investment and market performance of the organization's stocks.
8	IoT encourages proper allocation of time resources since more tasks are accommodated within a given time frame with good IoT management.

Options/Questions	Q5	%	Q6	%	Q7	%	Q8	%	Mean response	Mean %
Strongly agree	38	30	47	37	47	37	35	28	42	33
Agree	40	32	55	44	60	48	42	33	49	39

Continued

Undecided	10	8	9	7	4	3	11	9	10	8
Disagree	22	17	9	7	9	7	25	20	11	9
Strongly disagree	16	13	6	5	6	5	13	10	14	11
	126	**100**	**126**	**100**	**126**	**100**	**126**	**100**	126	100

Source: Field survey, 2022.

$$Z = \frac{0.21}{\sqrt{\frac{0.25}{126}}}$$

$$Z = \frac{0.21}{\sqrt{0.00198}}$$

$$Z = \frac{0.21}{0.0444}$$

$$Z = 4.73$$

Since the computed value of 4.73 is more than the critical value of 1.96, we reject the null hypothesis (Ho) and accept the alternate hypothesis (H1) indicating that Internet of things has significant impact on organizational efficiency in Camanov Ltd.

Ho 2: Internet of things does not significantly contribute toward saving of cost and time of the organization (Camanov Ltd).

Using Table 7:

$$P = 33\% + 39\% = 72\% = 0.72$$

$$P = 0.72$$

$$N = 126$$

$$Z = \frac{P - Po}{\sqrt{\frac{Po(1 - Po)}{N}}}$$

$$Z = \frac{0.72 - 0.5}{\sqrt{\frac{0.5(1 - 0.5)}{126}}}$$

$$Z = \frac{0.22}{\sqrt{\frac{0.5 \times 0.5}{126}}}$$

$$Z = \frac{0.22}{\sqrt{\frac{0.25}{126}}}$$

$$Z = \frac{0.22}{\sqrt{0.00198}}$$

$$Z = \frac{0.22}{0.0444}$$

$$Z = 4.95$$

Since the computed value of 4.95 is more than the critical value of 1.96, we reject the null hypothesis (Ho) and accept the alternate hypothesis (H1) indicating that Internet of things significantly contribute toward saving of cost and time of the organization (Camanov Ltd).

5. Summary of Findings, Conclusion and Recommendations

5.1. Summary of Findings

From the analyses, the following findings were made:

1) That Internet of things has significant impact on organizational efficiency in Camanov Ltd ($Z = 4.73$ greater than critical value of 1.96).

2) That Internet of things significantly contribute toward saving of cost and time of the organization in Camanov Ltd ($Z = 4.95$ greater than critical value of 1.96).

5.2. Conclusion

From these findings and the studies reviewed, the critical position of the Internet of Things adoption to competitive organizational performance was strongly felt. The tests conducted supported the view that the Internet of Things adoption significantly impacts organizational efficiency. This finding resonates with the views of the studies reviewed under the extant literature analysis. It was found that all the studies pointed to the importance of the Internet of Things to efficient organizational performance. Scholars agree that with proper IoT adoption and management, it is easy to strategize on what to do, how to do it and who to do it as data is made in real-time and decisions are taken based on real-time data availability. Client management is enabled by resorting to critical information resources. Correction of erroneous procedures is enabled by real-time data, financial planning, training and adaptation planning aided by the Internet of Things. Thus, existing literature in the area has argued strongly in support of the utility value of proper internet of things management in the process of job implementation and strategy development for competitive performance.

5.3. Recommendations

From the findings and conclusion, the following findings were made:

1) The findings and conclusion necessitated the following recommendations:

Organizations should encourage the introduction of the Internet of Things as it provides real-time data that aids process monitoring.

2) To improve communication by transmitting data faster and securely between stakeholders.

3) Train personnel in the improved limitless possibility of information gathered from the Internet of Things framework support planning, budgeting and monitoring approaches, providing more reliable information to support decisions and actions.

4) Ensure proper management of change (MOC) is carried out each time

there is any new introduction or change in the organization such as the adoption of the Internet of Things technology.

5) Supervision and control should be exerted in all IoT management processes. There should be proper supervision to ensure IT managers keep effective records of gadgets connected to the smart loop in the organization.

5.4. Contribution to Knowledge

This study has made a positive contribution to the existing body of knowledge on the subject matter. It has revealed the significance of the Internet of Things in manufacturing management to image building, premium goodwill creation, overall profitability and market positioning of firms.

5.5. Suggestion for Further Studies

Based on the scope of this study, the researcher suggests a possible expansion in scope in future studies by including more explanatory variables and possibly covering firms in other industries to see if the outcome would confirm the present findings.

Acknowledgements

This work cannot be fully completed without appreciating those who contributed one way or the other towards the successful completion of this work.

I wish to acknowledge God Almighty for his grace and provisions thus far in this program. I wish to sincerely appreciate the effort of my supervisor Prof. Brendan Eje whose advice, guidance and support resulted in completing the work.

I also appreciate the management and staff of ESUT for providing an academic environment for learning and interaction.

Also, I really appreciate my parents, Late Elder. Cyprian Ukazu and Mrs. Anthonia Ukazu contributed immensely to my educational and moral development. My lovely wife Mrs. Ukazu Victoria Ifeoma and children (Cyprian Blessed Amarachi Chinedu, Cyprian Royalpraise Ugochukwu Chinedu, Cyprian Delight Kaosisochukwu Chinedu and Cyprian Godsordained Chiemelam Chinedu) who have sacrificed a whole lot to ensure that this program is a huge success. I love you all.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Sharma, A. and Sharma, A. (2019) Effect and Impact of IoT (Internet of Thing) on Supply Chain Management. Journal of Emerging Technologies and Innovative Research, **6**, 302-310. https://www.researchgate.net/publication/336251787_Effect_and_Impact_of_IoT_Internet_of_Thing_on_Supply_Chain_Management

[2] Sundmaeker, H., Guillemin, P., Friess, P. and Woelfflé, S. (2010) Vision and Challenges for Realising the Internet of Things. European Commission—Information

Society and Media DG.

[3] Wu, M., Lu, T.L., Ling, F.Y., Sun, L. and Du, H.Y. (2010) Research on the Architecture of Internet of Thing. 2010 3*rd International Conference on Advanced Computer Theory and Engineering* (*ICACTE*), Chengdu, 20-22 August 2010, V5-484-V5-487.

[4] (2012) Forrester Consulting Internet of Things Survey—Key Findings. http://www.zebra.com/content/dam/zebra/product-information/en-us/misc/iot-key-findings-en.pdf

[5] Li, S.C., Tryfonas, T. and Li, H.L. (2016) The Internet of Things: A Security Point of View. *Internet Research*, **26**, 337-359. https://doi.org/10.1108/IntR-07-2014-0173

[6] Whitmore, A., Agarwal, A. and Xu, L.D. (2015) The Internet of Things—A Survey of Topics and Trends. *Information Systems Frontiers*, **17**, 261-274. https://doi.org/10.1007/s10796-014-9489-2

[7] Galinina, O., Andreev, S., Balandin, S.I. and Koucheryavy, Y. (2019) Lecture Notes in Computer Science: Internet of Things, Smart Spaces, and Next Generation Networks and Systems. *Proceedings of the* 19*th International Conference*, *NEW*2*AN* 2019, *and* 12*th Conference*, *ruSMART* 2019, St. Petersburg, 26-28 August 2019.

[8] Rose, K., Elridge, S. and Chapin, L. (2015) The Internet of Things: An Overview: Understanding the Issues and Challenges of a More Connected World. https://www.internetsociety.org/wp-content/uploads/2017/08/ISOC-IoT-Overview-20151221-en.pdf

[9] Ashton, K. (2009) That "Internet of Things" Thing. *RFID Journal*, **22**, 97-114.

[10] Weiser, M. (1991) The Computer for the 21st Century. *Scientific American*, **265**, 94-104. https://doi.org/10.1038/scientificamerican0991-94

[11] MacDonald, K.I. and Dressler, V. (2018) Using Citation Analysis to Identify Research Fronts: A Case Study with the Internet of Things. *Science & Technology Libraries*, **37**, 171-186. https://doi.org/10.1080/0194262X.2017.1415183

[12] Jesus, E.F., Chicarino, V.R.L., De Albuquerque, C.V.N. and Rocha, A.A.D.A. (2018) A Survey of How to Use Blockchain to Secure Internet of Things and the Stalker Attack. *Security and Communication Networks*, **2018**, Article ID: 9675050. https://doi.org/10.1155/2018/9675050

[13] Atzori, L., Iera, A. and Morabito, G. (2017) Understanding the Internet of Things: Definition, Potentials, and Societal Role of a Fast Evolving Paradigm. *Ad Hoc Networks*, **56**, 122-140. https://doi.org/10.1016/j.adhoc.2016.12.004

[14] Vermesan, O., Friess, P., Guillemin, P., Gusmeroli, S., Sundmaeker, H., Bassi, A., Jubert, I.S., Mazura, M., Harrison, M., Eisenhauer, M., *et al*. (2011) Internet of Things Strategic Research Roadmap. In: Vermesan, O. and Friess, P., Eds., *Internet of Things—Global Technological and Societal Trends from Smart Environments and Spaces to Green Ict*, River Publishers, New York, 9-52. https://doi.org/10.1201/9781003338604-2

[15] Tiberius, V., Schwarzer, H. and Roig-Dobón, S. (2021) Radical Innovations: Between Established Knowledge and Future Research Opportunities. *Journal of Innovation & Knowledge*, **6**, 145-153. https://doi.org/10.1016/j.jik.2020.09.001

[16] Del Sarto, N., Cesaroni, F., Di Minin, A. and Piccaluga, A. (2021) One Size Does Not Fit All. Business Models Heterogeneity among Internet of Things Architecture Layers. *Technology Analysis & Strategic Management*, **34**, 787-802. https://doi.org/10.1080/09537325.2021.1921138

[17] Saidu, C., Usman, A. and Ogedebe, P. (2015) Internet of Things: Impact on Econo-

my. *Journal of Advances in Mathematics and Computer Science*, **7**, 241-251. https://doi.org/10.9734/BJMCS/2015/14742

[18] Cisco (2020) Cisco Annual Internet Report (2018–2023) White Paper. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

[19] Madakam, S., Ramaswamy, R. and Tripathi, S. (2015) Internet of Things (IoT): A Literature Review. *Journal of Computer and Communications*, **3**, 164-173. https://doi.org/10.4236/jcc.2015.35021

[20] Botterman, M. (2009) For the European Commission Information Society and Media Directorate General, Networked Enterprise & RFID Unit—D4, Internet of Things: An Early Reality of the Future Internet, Report of the Internet of Things Workshop, Prague, Czech Republic.

[21] Weinberg, B.D., Milne, G.R., Andonova, Y.G. and Hajjat, F.M. (2015) Internet of Things: Convenience vs Privacy and Security. *Business Horizon*, **58**, 615-624. https://doi.org/10.1016/j.bushor.2015.06.005

[22] Liu, Z., Prajogo, D. and Oke, A. (2016) Supply Chain Technologies: Linking Adoption, Utilisation, and Performance. *Journal of Supply Chain Management*, **52**, 22-41. https://doi.org/10.1111/jscm.12117

[23] Motiwalla, F.L. and Thompson, J. (2009) Enterprise Systems for Management. Upper Saddle River. Prentice Hall, Hoboken.

[24] Korte, A., Tiberius, V. and Brem, A. (2021) Internet of Things (IoT) Technology Research in Business and Management Literature: Results from a Co-Citation Analysis. *Journal of Theoretical and Applied Electronic Commerce Research*, **16**, 2073-2090. https://www.mdpi.com/journal/jtaer https://doi.org/10.3390/jtaer16060116

[25] Lee, G.M., Park, J., Kong, N. and Crespi, N. (2011) The Internet of Things: Concept and Problem Statement: 03. https://www.researchgate.net/publication/278777402_The_internet_of_things_concept_and_problem_statement_03

[26] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M. (2013) Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. *Future Generation Computer Systems*, **29**, 1645-1660. https://doi.org/10.1016/j.future.2013.01.010

[27] De Pellegrini, F., Moiso, C., Miorandi, D. and Chlamtac, I. (2008) R-P2P: A Data Centric Dtn Middleware with Interconnected Throwboxes. 2*nd International ICST Conference on Autonomic Computing and Communication Systems*, Turin, 23-25 September 2008, page. https://doi.org/10.4108/ICST.AUTONOMICS2008.4598

[28] Ng, C.K., Wu, C.H., Yung, K.L., Ip, W.H. and Cheung, T. (2018) A Semantic Similarity Analysis of Internet of Things. *Enterprise Information Systems*, **12**, 820-855. https://doi.org/10.1080/17517575.2018.1464666

[29] Guillemin, P. and Friess, P. (2009) Internet of Things Strategic Research Roadmap. https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2430372/SINTEF%2BS13363.pdf

[30] Bradicich, T. (2015) The 7 Principles of the Internet of Things (IOT). https://www.iiconsortium.org/2015/07/the-7-principles-of-the-internet-of-things-iot/

[31] Xu, T. (2021) How Companies Oversee IoT Device Management. https://builtin.com/iot-internet-things/iot-management