

EXPLORING ADOPTION OF INTERNET OF THINGS IN THE SUPPLY CHAIN PROCESS IN FRUIT PROCESSING FIRMS IN THIKA SUBCOUNTY, KENYA

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Abstract: The research entails an in-depth analysis of IoT adoption in enhancing supply chain performance in fruit processing firms. The major problem faced by the organizations of study was the minimal degree of integration of devices, machine and people within the organization therefore affecting the supply chain process. The research paper, therefore, sought to bridge the existing research gap on IoT adoption in the supply chain process in fruit processing firm in Thika Sub- County. The specific objectives sought to identify the level of adoption of internet on supply chain performance, the extent of hardware systems used, the software applications adopted and cloud computing to enhance supply chain performance in Fruit Processing firms in Thika Sub County. The study employed use of secondary research technique and single method approach to existing literature; whereby the data was collected from websites, scientific journals, and other resources. The collected data was analyzed using content analysis method which depicted that IoT adoption in improving the supply chain process was vital due to minimizing delays in the supply chain process, inventory management and meeting customer requirements. Early detection of suitable temperatures and humidity levels of varied fruits was reported and minimization of data loss due to cloud back up was observed. Based on the findings, it is worthwhile to recommend robust quantitative research on IoT adoption in other processing firms.

Keywords: Computer network, Protocol, Objects and devices, Internet of things.

1. INTRODUCTION

The research is a desk research on adoption of IoT technology in Fruit Processing Plants and the firm's supply chain performance. Supply chain performance is considered a significant aspect in every manufacturing and production entity. The Internet of Things (IoT) in this case is one of the technological advancements that facilitates an increased supply chain performance. In an enterprise setting, IoT is explained as a technological innovation that integrates together people, things, and objects (Lee, 2015). Over the last five years, IoT has gained popularity due to the numerous benefits associated with its adoption in varied organizations.

Some of the fundamental benefits of effective supply chain performance include: Just in Time (JIT) delivery, improved inventory management, activity transparency, and enhanced competitive advantage among many other merits (Ray, 2017)).

In well-established organizations, application of IoT in supply chain guarantees an effective identification, location, tracking, sensing, and control of all organizational activities. The use of internet networking in digital upgrading of machines creates enhanced capabilities to the object functionalities. The progression of ICT applications in organizations improves the process of capturing and sharing data. IoT adoption in organization can be deemed to play a pivotal role in managing supply chain networks in response to the consumer requirements. In managing the network, IoT is considered to bridge the physical and the digital platforms through the internet networking facilitating information symmetry within all the organizational levels (Li, 2017).

Globally, IoT technology has been applied by numerous firms in support of effective supply chain performance. For instance, the Intellicup Firm uses IoT in providing viable solution to the extensive wait durations and thus ensuring lean production. The consumers synchronize their cell devices to the cup by scanning QR code using a companion application (Rivera, & Goasduff, 2014). Thereafter, a customer loads credit to purchase the drink. Another notable organization that has successfully adopted IoT is the Culinary Science Industry. The CSI has created a set of goods and services that improve and target particular pallets. Amazon has in a similar manner utilized IoT in the management of its operations. Machines, objects and people in the organization have been well integrated whereby a manager can assign a duty to an employee through the internet (Saarikoo, Westergren, & Blomquist, 2017).

BronPro Processors (Pty) Ltd is utilizing internet networking in streamlining the supply chain operations through initiating successful supplier-customer relationship (Westerlund, Leminen, & Rajahonka, 2014). The management of this organization can effectively conduct periodic reviews on the employees' activities and guarantee better performance through online monitoring of the activities. In a similar manner, the organization ensures highest order of transparency by tracking and monitoring machines and products amid the production and delivery process.

Organizations in Kenya have embraced technology in their supply chain process. Del Monte Company for instance, has applied ICT capability in its production processes. Through IoT, the company has adopted the use of CropTrack which allows the management to monitor various data. Other companies such as Centrofood and Kevian Fruit Processing have ensured traceability, customer audit, and sustainability through IoT. The companies can also trace disparate elements like the nitrogen per the crops produced, the rates of irrigation, and the engagement with the local communities. The use of this technological tool aids the organizations to enhance high crop projections as well as increased harvest and streamlines the entire grading system (Zhang, & Hou, 2013).

There are at least four Fruit processing located in Thika Sub County. They are: Kevian Fruit Processing Firm, Biofarms, Kenya Fruit Processors and Centrofoods. The industries focus on backward integration which entails using locally grown fruits as the raw materials. The firms compete on several fronts such as: fruit concentration and packaging. The companies have also deployed the current technology in enhancing the production, distribution, and customer satisfaction. However, the organizations face a main challenge in integrating the main activities in the supply chain process. Thus, the application of ICT capability is deemed to offer a transformation and solution to the problem (Zhou, Chong, & Ngai, 2015).

1.1 Problem Statement

IoT as a current trend in technology has expanded immensely. Its adoption facilitates organizations in attaining increased production and performance. Specifically, the application of IoT in supply chain process guarantees increased asset management through monitoring and tracking organizational activities (McFarlane, & Sheffi, 2013). In the production and supply chain environment, the application of advanced technology offers a critical opportunity in improving organizational performance and efficiency.

Lee (2015), argues that, lack of integration and interconnection of people, machines, and objects remains the primary problem encountered by numerous fruit processing industries. The challenge of poor linkage within the supply chain processes contributes to poor asset management, poor production, delayed delivery, poor communication, and information asymmetry. The major problem faced by the Fruit Industries is the poor integration of activities in the supply chain process. Sourcing raw materials, processing the obtained materials, and delivering the produced products to the customers constitute the entire supply chain process. In the organization of study, these activities are not well planned and organized. This problem has significantly resulted in the overall decline of the supply chain performance and efficiency.

Theoretically, adoption and application of innovation cannot be ignored but has to be useful to the recipient as identified by Misango (2018) in research on safety and security factors affecting adoption of innovation. Despite this observation, uses of IoT in enhancing supply chain performance have not been significantly explored (Fleisch, 2010). In numerous organizations, minimal efforts have been deployed in evaluating the impacts of IoT in improving supply chain performance. Therefore, there exists a significant knowledge gap in the technology domain and especially IoT as applied in promoting supply chain performance.

2. THEORETICAL REVIEW

2.1 Adaptive Structuration Theory

Adaptive structuration theory is concerned with the implementation and use of information and communication technologies in groups and organizations to enhance communication. The theory was proposed by Marshall Scott Poole based on the work of Giddens, Robert Mc Phee and David Seibold. The theory tends to show the impacts of ICTs on group as well as group process (Luhmann, Baecker, & Gilgen, (2013). The outcomes depend on the structures incorporated in the technology and on the structures that emerge as users attempt to adapt new technologies. AST aids in studying the role of advanced information in organizational change. Moreover, the theory tends to understand the type of structures that are in existence in an organization and the structures that actually emerge in human action as people interact with the technologies. Studying the structures of an organization simplifies the decision making of the top management of that organization.

2.2 Systems Theory

Systems theory is one of the dominant organizational theory used in management. The theory treats organizations as either an open or closed system. The theory consists of both open and closed systems whereby the closed system is not impacted by the external environment. On the other hand, an open system is significantly influenced by the operational environment. According to Gopal, Bostrom, & Chin, (2012) changing part of the system may impact the other parts of the entire system. It may be possible to predict these changes in patterns of behavior. The essence of this theory to the research is to show that systems should be integrated together to bring out better results. Also, the use of the theory will enable the achievement of the designed organizational goal.

3. EMPIRICAL REVIEW

3.1 Supply Chain Process and Performance

A study by Chopra, & Meindl, (2017), reveals that, supply chain management concept has been popular for an extensive period due to several reasons. Specifically, current trends in global sourcing, consideration of time, and quality-based competition are the main drivers to these reasons. Supply globalization has forced organizations to coordinate the movement of materials in and out of the company in an effective manner resulting in close supplier relationships. Thus, many organizations compete today on the time basis and quality of production. Manufacturing and delivering a top-notch quality product to a customer in a timely manner provides an organization with a competitive hedge in the market. To ensure these factors, a close relationship and flexibility between all the participants in the supply chain is highly required. Despite the popularity of supply chain performance, there exists a confusion of what the concept means. The below section offers an in-depth explanation of Supply Chain Process and Performance and the key players in the entire supply chain.

According to the Council of Supply Chain Management Professionals (CSCMP, 2013) supply chain management entails coordination as well collaboration with all chain participants. The supply chain performance incorporates sourcing, making, and delivering products and services to the customers. The sourcing majorly focuses on acquiring raw materials while making involves the process of transforming these raw materials into finished products. Bozarth, & Handfield, (2018), argue that, to achieve increased chain performance, metrics as well performance measures are highly required. These metrics combined with the current technology can effectively result in an increased firm performance.

Some studies reveal that, most of the leading industries have invested a lot in enhancing their supply chain process. A study by Gangwar, Date, & Raoot (2014), show that the application of ICT in supply chain transforms the traditional supply chain into a digital one. The transformation therefore helps organizations to break down the chain challenges and create an integrated system that operates smoothly. As per Haller, Karnouskos, & Schroth, (2016), the digitization is mainly concerned with establishing a flexible digital supply chain. Büyüközkan, & Gocer, (2018) explain that digital supply chain

as a well-integrated and operative exchange of varied forms of information such as production and financial data among the chain members to enhance the organizational communication process. Concerning the entire preference in chain digitization, IoT is deemed as a current technology and its adoption contributes critical impacts on the entire supply chain performance.

3.2 The Internet of Things (IoT) in Supply Chain Performance

The ever-growing technological advancements can be witnessed in numerous sectors in the whole world. Today, the use of internet is significantly increasing as billions of individuals surf the web to obtain and access services and content. According to Ashton (2011) in their study on accessibility of communication, individuals in varied sectors are able to send and receive tons of emails. Through the development in technology, global machine and object platforms have been developed for enhancing communication, computation, and to coordination of these objects. In an enterprise setting, ICT capability creates an effective connection between the devices, objects, and even the humans present in the company (Wagenaar, 2017).

3.3 The use of Internet in enhancing Supply Chain Performance

Ashton (2011), explains internet as a system of interconnected computer networks that deploy protocols in linking devices in the entire world. A protocol on the other hand is defined as a standard set of rules as well as policies that allow electronic devices to communicate with each other. The rules contain the type of data to be transmitted and the commands used to send and receive information. In an IoT system, the protocols used vary depending on the varied layers in the system.

The protocols include wireless networking, wired networking, and internet communication protocols. The internet plays a critical role of enhancing supply chain performance in three main ways. Firstly, internet reduces the operational and production costs by minimizing human interaction and providing online market for the produced commodities. Secondly, internet improves supply chain performance by facilitating effective order management and tracking. Finally, the internet allows information symmetry which in turn provides just in time production and delivery of products.

3.4 Adoption of Hardware Systems in enhancing Supply Chain Performance

Ashton (2011), explains IoT hardware systems as the external, visible, and tangible devices and objects. The hardware system incorporates a vast range of devices which when integrated together with the internet guarantee smart service provision. A research by Ericsson (2016) on use of hardware components, has revealed that bridges, routing, sensors, and the basic computing objects are the main components that make up the hardware system. When integrated together through networking, these devices play a pivotal role and tasks in an organization. Braun, (2015), argues that, a good device integration in an enterprise setting provides significant benefits like security, proper communication, product detection, and timely system activation.

A study by (Xu, Wendt, & Potkonjak, 2014) on supply Chain processes and connectivity, shows that hardware systems have a significant positive impact on the supply chain performance. For instance, setting up smart connection within the organizational assets like refrigerators and vehicles makes these products monitor and control themselves. In another perspective, sensor devices contain numerous modules like RFID modules, NFC sensing modules, and power management modules. An integration of these sensing devices ensures timely control of operations and an effective organizational activity tracking.

3.5 The use of Software Systems in enhancing Supply Chain Performance

The software system encompasses different programs and applications installed in computers as well other hardware devices to facilitate proper service provision. IoT software applications are deemed as a set of instructions coded by use of a programming language to work in a particular manner and to meet a set objective. A study by Alnaeli (2016), explains a software as the intangible part in a computer system. The programs and applications in software systems play critical roles in an organization.

In the supply chain aspect, software programs facilitate data filtering, security, and measurement. Applications installed in computers have the ability to collect and distribute supply chain data to devices in the entire connection since the data is entirely controlled from a single server. Moreover, device integration is deemed to be facilitated by software applications.

These programs ensure that objects bind and link to the networks which in turn facilitate communication symmetry and proper information sharing. The products in an organization and those in transit to consumers can be tracked all the way to ensure security and timely delivery to clients (Patel, & Patel, 2016).

Alnaeli (2016), further states that applications and programs installed facilitate real-time data analysis and process extension. The programs interlink devices for particular purposes such as allowing devices like smart watches and mobile devices to communicate with other devices. The integration of the devices and application thus contributes improved production and accurate data storage and processing. These benefits combined together result in improved supply chain.

3.6 Use of Cloud Computing in enhancing Supply Chain Performance

In an enterprise setting, cloud computing can be viewed in two broad perspectives: outsourcing and data security through back-up systems. Truong, & Dustdar (2015), defines the outsourcing process as the action of hiring storage, platform, and infrastructure services from outside company. Numerous studies show that outsourcing is a cost-cutting measure undertaken by organizations to minimize the operational as well production costs.

A study by Borgia, (2014), explains data security as standards and technologies deployed to secure data from destruction, disclosure, and modification. The security of data can be ensured through provision of data back-up services. A data backup involves archiving and copying files to guarantee restoration in the situation of data loss. Cloud computing is considered as a collection of services accessible by organizations from anywhere by the use of mobile devices with an internet based connection.

Surveys conducted in 2019 by Gartner reveal that cloud computing is majorly deployed in businesses to reduce costs and increase data security. Supply chain expenses can be minimized by hiring software application and program services. Generally, obtaining as well installing software and platform packages involves high costs. The outsourcing process therefore streamlines the supply chain performance by ensuring affordable secure storage and software services (Haddud, et al., 2017).

4. RESEARCH METHODOLOGY

The research employed descriptive research design whereby literature review on how Internet of Things has impacted the supply chain performance was covered. By using descriptive study techniques to assess the previous research, the research used appropriate information and contents that are deemed important in responding to the research questions (Saunders, Lewic, & Thornhill, 2013). The study involved secondary research with focus on the Kevian Fruit Processing Industry, Delmonte, Biofarms, Kenya Fruit Processors and Centrofoods. The data for the study was collected from websites, peer reviewed journals, the internet and other previous study materials (Sutton, & Austin, 2015). The research employed a content analysis which was considered the best approach since it gives a proper insight of the information provided in text on websites, journals, and over the internet (Sutton, & Austin, 2015). The content analysis technique aimed at analyzing how Internet of things technology created value and performance in the supply chain. The critical performance indicators like the Just in Time (JIT) delivery, reduced organizational costs, and efficient order management were considered in the entire data analysis. The researchers selected the contents to analyze and then defined the analysis categories. In this case, the categories identified were the hardware, software, internet, and cloud computing.

5. RESEARCH FINDINGS

5.1 Study Analysis and Presentation

A solid content analysis of the journals, peer reviewed articles, and other study materials from websites and internet has contributed significantly in obtaining data for this study. Sensors and devices like RFIDs have been identified as the primary devices that constitute the hardware domain of the IoT. These devices manage effective communication as well as inventory management through their sensing capability and fast signal processing. The connectivity of devices in most companies rely on the wireless networks; WiFi, and the wired network which is guided by numerous internet protocols. Internet connectivity and linkages has helped a significant number of organizations in ensuring just in time delivery, reduction of cost and inventory management (Sutton, & Austin, 2015).

5.2 Extend of IoT System Adoption

The study revealed that only 33% of fruit organizations use IoT software. The rest 67% of companies rely on the traditional methods like Excel or paper work. On average, these organizations lost 18 hours each month doing paper work. The paper work process constitutes 88% of organizational supply chain errors.

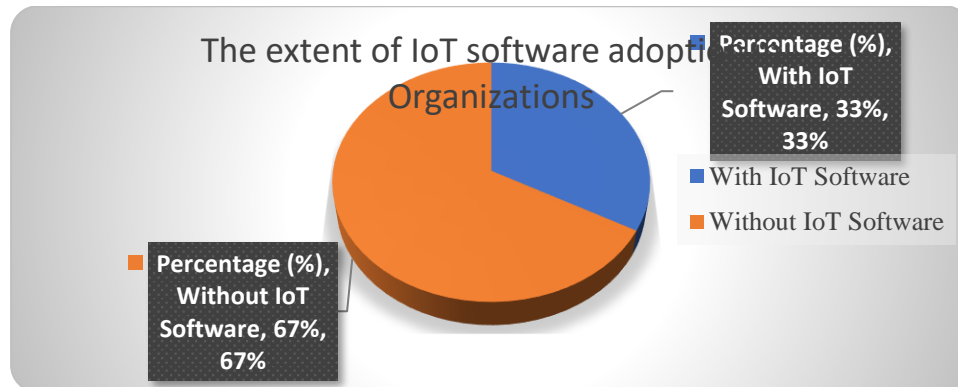


Figure 1: Extend of IoT Software adoption in organizations

Companies reaping from the use of IoT have been using applications and programmed software components that constitute the software domain. Firms have developed the need for new systems considering the benefits of the programs in their supply chain process. These platforms have proven to be effective in monitoring the transportation of production from the organization to the customers. Service outsourcing and security through back up as well as recovery systems have been observed as the main components constituting the cloud computing aspect of the IoT (Patel, & Patel, 2016). Having servers and other critical platforms has turned out to be expensive and that's the need for outsourcing.

Table 1: Main IoT components

No.	IoT Domain	Key Components and Devices
1	Internet	Networks -Wireless Network: WiFi -Wired Network -LAN Protocols
2	Hardware System	Sensors -RFIDs -Sensing modules Objects and devices -Radio transceivers -Power management modules
3	Software System	Applications and Programs -New system software -Platforms and websites
4	Cloud Computing	Service Outsourcing Security -Back up Systems -Data recovery systems

5.3 Use of Internet in Supply Chain Performance

An in-depth research and analysis of data from different journals has revealed the importance of having internet in the supply chain. Networking was observed to primarily introduce new opportunities for client value and enhancing integrative operations in the supply chain process. The application of internet linkages in cost reduction brings about the effectiveness within the supply chain operations. Through the internet, organizations have stood a better position to understand their

market and hence serve the customers better. Fruit industries can effectively track the movement of the products to the customers and this creates effectiveness in inventory management and JIT delivery. A proper WiFi installation in the industries would result in real time communication and packet switching from one component to the other (Rivera, & Goasduff, 2014). The integration of the hardware and software systems through the network would suggest a development in the supply chain process.

5.4 Adoption of Hardware Systems in Supply Chain Performance

In IoT, the hardware systems consist of mainly sensors and other computing devices. These devices have been observed to enhance supply chain value and effectiveness if well integrated with other components in an organization. The creation of value and productivity in this case is undertaken by focusing on the key main performance indicators. These are; JIT delivery, cost minimization, and inventory management. The RFID system is considered to feature three major components, RFID tags, RFID readers, and RFID antennas. The devices deploy radio frequency waves to collect and distribute information to the relevant target device. Objects to be integrated in the industry are identified with different ID carrying particular information about the product. The antennas catch different waves originating from the readers and relay signals to the readers. The hardware components are applied in the industry to monitor and test the temperatures as well the humidity of fresh fruits. An example of Kevian Industry is shown below.

5.5 Adoption of Software System in Supply Chain Performance

Organizations have formulated and implemented new application softwares which facilitate effectiveness in supply chain. Systems like E2open and Enterprise Resource Planning (ERP) have proven the significance of IoT in business. The softwares have interesting features that aid in inventory processing management, order delivery monitoring, and client collaboration. A combination of all these benefits reduce the overall cost of production. Another software, SPA has proven to work well in other organizations. Implementation of the SPA IoT software in the in particular would provide an advanced analytics and visibility as used in these firms. The software helps the organization in planning, sourcing as well manufacturing, and delivering the right products to the customers. In cost reduction, IoT creates a perfect commerce platform providing the organization the chance of serving a large number of customers (Zhang, & Hou, 2013). One benefit of IoT is the temperature detections levels and humidity of fruits as shown below.

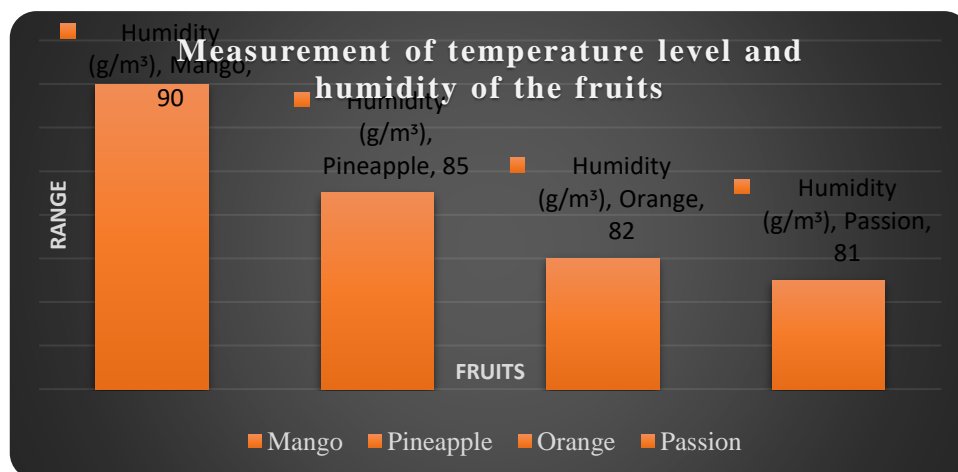


Figure 2: Temperatures and humidity detection of different fruits in Kevian Fruit Processing Industry.

If the temperature of the fruits exceeds the fresh fruit temperature, the fruits can be detected as bad and be separated from the fresh ones before storage. The information concerning the quality of the fruits would allow the organization in planning effectively the fruits to process first.

5.6 Application of Cloud Computing in Supply Chain Performance

Cloud computing is analyzed considering the two main components: outsourcing and security. In numerous organizations, the outsourcing is conducted under three processes: Software as a service (SaaS), platform as a service (PaaS), and Infrastructure as a service (IaaS). The application of these concepts in Kevian Industry would offer the organization the

opportunity of hiring storage, and other critical supply chain services. In this manner the organization minimizes the production, storage, and distribution costs. Moreover, studies show that organizations have shifted from the traditional methods of data storage to the modern systems. The movement is brought about by the increased demand for data security. Data back-up and recovery systems have helped many organizations in reducing the instances of data loss (Rivera, & Goasduff, 2014). In Kevian Industry, these services promise the continuous synchronization of organizational and customer information. It makes it simplified to contact different clients with limited complications.

5.7 The Relationship between IoT in Supply Chain Performance

In regards to the obtained results, IoT is considered to play a critical role in the supply chain performance. The research has achieved varied ways on how to attain the critical three key performance indicators: Inventory management, product delivery, and cost minimization. IoT is seen to play a pivotal role in inventory management by turning the information fetched from the systems into helpful organizational insights. Additionally, through software, an organization is able to cut cost of operation due to the simplified span of control and management (Ray, 2017). The organization gains the capability of tracking its products in transit and ensure just in time delivery.

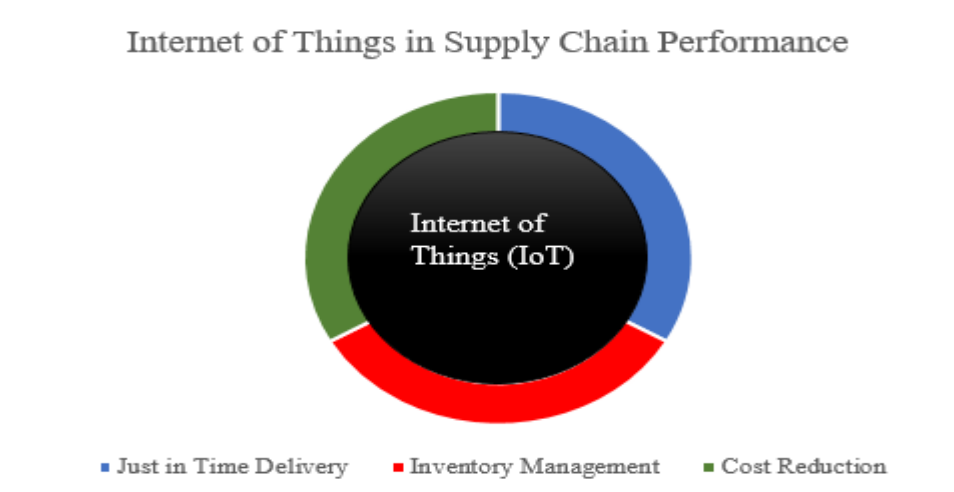


Figure 3: The relationship between IoT and Supply Chain Performance

6. DISCUSSIONS

6.1 Use of Internet in Supply Chain Performance

The research has revealed a positive influence of internet on the performance of supply chain. Advancements in internet technology have been observed to integrate varied organizational activities. Through networking, organizations have improved the process of information sharing. Supply chain information entails the inventory management and customer requirements. In this case, the organization is observed to get real time demand information from the customers and respond in an effective manner. Additionally, internet has been identified as a critical factor in monitoring and tracking activities (McFarlane, & Sheffi, 2013).

6.2 Adoption of Hardware Systems in Supply Chain Performance

A fundamental analysis of the research data shows that hardware systems positively influence the effectiveness of supply chain performance. Installation of sensing and computing devices have been found to contribute significantly in incrementing the performance of organization. Use of radio frequency waves in communication among many devices promises the constant monitoring of the organization inventory. The RFIDs have promoted the performance by detecting temperatures and humidity levels of varied fruits. In this case, inventory waste is highly minimized and thus reduced the costs in acquiring fresh products (Haller, Karnouskos, & Schroth, 2016).

6.3 Adoption of Software Systems in Supply Chain Performance

The implementation of application and program software has positively influenced the performance and effectiveness of supply chains. The software programs have been observed to promote a single working location where different requests

are handled. Software like the ERP and E2open are seen to possess paramount features that monitor customer requests, inventory management, and the entire production procedures. Moreover, the softwares have been considered in reducing the costs of operation since some activities have been shifted online and increased performance (Gangwar, Date, & Raoot, 2014).

6.4 Application of Cloud Computing in Supply Chain Performance

The research has found a positive influence of cloud computing on the supply chain performance. Outsourcing has been observed to meet several demands of the organization which would have resulted in extortionate costs if acquired directly. Through the three main outsourcing strategies: Software as a service (SaaS), platform as a service (PaaS), and Infrastructure as a service (IaaS), companies have significantly cut down the costs of storage and the expenses involved in acquiring expensive facilities like servers (Xu, Wendt, & Potkonjak, 2014). Additionally, data back-up and recovery systems have been identified tenets in minimizing data losses which can bring about huge losses. Through cloud security, important information is encrypted and stored in a secure format. Security being a key concept in the cloud computing, it has notably facilitated the effectiveness of chain operations.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The purpose of the research was to explore the effect of IoT adoption in enhancing supply chain performance. Through the research findings and the exploration of resourceful tools, it has been depicted that IoT adoption in supplementing supply chain is vital. Fundamentally, the components of IoT substantially have a positive impact towards the profitability of fruit Firms. For instance, the software programs have been observed to promote a single working location where different requests are handled. Consequently, via the cloud element, industry activities and information is highly secured since security is a critical factor.

The research results have revealed how a fruit processing organization can employ IoT technology in enhancing supply chain process. Secondly, an effective network integration of the hardware, software and cloud computing components was deemed to result in achieving organizational excellence. Devices like RFIDs are said to perform excellently in detecting the freshness of fruits. The Kevian Industry is therefore seen in a better position to manage inventory and minimize wastage upon implementing the IoT system.

In view of improvised software and cloud services, the Industries experience a reduction in operation cost. IoT is considered to flatten the organization by providing efficient distribution of information among different departments. The software systems have also proven the ability to monitor and control delivery activities (Researchers, 2020).

7.2 Recommendations

Based on the findings, it's worthwhile to recommend more robust research on quantitative research technique. A quantitative approach will allow researchers to gather responses that are more specific to the organization. The study could focus on getting a proper understanding of how the organization has strived in the hedge of technology to meet various customer need. Since IoT is a developing technology, it's recommendable for further studies to be conducted focusing on varied organization sectors like the logistics, distribution, and production sector.

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