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Developing a Framework for Future Warehousing Using the Internet of Things

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Abstract

The Internet of things (IoT) is the next generation of Internet-connected embedded IT frameworks. However, IoT is still in its initial stages in the manufacturing industry and respective supply chain environment, leaving uncertainty about possible application areas and impacts. This paper explores the role of Internet of Things (IoT) and its impact on supply chain management (SCM) for warehousing through an extensive literature review. The purpose of this study is therefore to study the role of IoT technology in enabling the supply chain visibility and connectivity, and impact on supply chain performance. In addition, most studies have focused on the framework for warehousing.

Keywords: Internet of Thing, Warehouse, Supply Chain Management, Conceptual

Introduction

Individual businesses cannot compete as independent entities in modern business management (Muhamed et al., 2020), but rather as active members of a larger supply chain comprised of a network of multiple businesses and relationships (Ben-Daya et al., 2019). The warehouse's fundamental processes continue to be receiving, storing, processing, and dispatching inventory based on customer orders, as well as some value added services. The warehouse is critical to supply chain management because it ensures that customer orders are fulfilled correctly (Yerpude et al., 2018). Every organisation requires inventory to manage supply chain and logistics lead times, among other things. Inventory de-stresses the supply chain by instilling predictability, managing demand fluctuations, mitigating the risk of supply chain unreliability, and, in some cases, providing price protection (Yerpude, 2018).

The Internet of Things (IoT) is the primary actor in Industry 4.0, enabling increased connectivity and the development of Cyber Physical Systems (CPS) (de Vass et al., 2021). The fundamental tenet of the Internet of Things is that "everyday objects can be equipped with identifying, sensing, networking, and processing capabilities that enable them to communicate with one another and with other devices and services over the Internet in order to accomplish some useful task" (Lao et al., 2020). Numerous Internet of Things (IoT) devices such as RFID tags, sensors, handheld devices, wearables, GPS telematics, medical devices, actuators, vehicles, drones, machines, and smartphones coexist in order to interact with their environment and with one another (de Vass et al., 2021).

The supply chain is frequently defined as "all parties involved, directly or indirectly, in fulfilling a customer request." Not only the manufacturer and suppliers are included in the supply chain, but also transporters, warehouses, retailers, and even the customers themselves" (Mostafa et al., 2019). It is a term that refers to the collection of processes and resources required to create and deliver a product or service to a customer from start to finish. The Internet of Things is already being used in a variety of industries, including manufacturing, healthcare, building automation, transportation, and environmental monitoring (Caro & Sadr, 2019). The application of IoT and CPS concepts to the manufacturing environment resulted in the definition of Industry 4.0, which enables the development of smart manufacturing, smart products, and smart services.

For warehousing, IoT can be beneficial in terms of optimising the overall supply chain's performance and transforming it into a smart one; for example, it can be used for monitoring, tracking products, developing an intelligent transportation system, and forecasting demand. Inventory management is a significant area of cost reduction in a supply chain (Mostafa et al., 2019). Specifically, IoT has the potential to reduce inventory costs and the bullwhip effect throughout the supply chain. Industry 4.0 implementation and integration focuses on critical functions such as procurement, logistics and transportation, warehousing, and order fulfilment. The internet is almost ubiquitous in this digital era. It not only eliminates the space constraint for people who live in separate locations, but also transforms human lives (Shah et al., 2020).

The primary objective of this research is to examine the economic and social consequences of implementing Industry 4.0 and IoT technology in warehouses, to demonstrate how they can help save money for any industrial organisation and to demonstrate how they can improve performance by developing a detailed theoretical framework for IoT implementation in warehouses. A sub objective is to apply IOT to SCM in order to connect supply chain entities and processes, automatically identify products and goods, track product flow at each stage, provide complete information about products throughout their life cycle, and achieve supply chain transparency in order to overcome the challenges associated with traditional SC. This study is significant as a guide for industry practitioners and academics in developing a warehousing system that leverages the internet of things to increase warehouse efficiency.

Result and Discussion

While the concepts of IoT blocks and layers remain undefined, various perspectives have been addressed in the literature. These various perspectives are discussed in this section.

Building Block of IoT

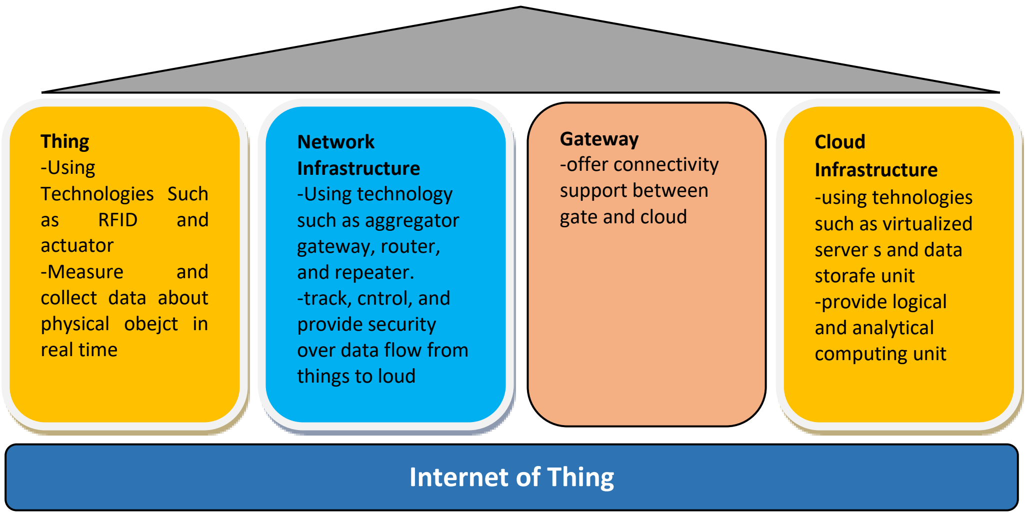

Figure 1: Internet of Thing Building Block

The architecture of the Internet of Things can be explained using the concept of building blocks, as it varies according to the application to which it is adapted. The four fundamental building blocks of IoT implementation are depicted in Figure 1: things, gateways, network infrastructure, and cloud infrastructure (Hamdy et al., 2018).

Architecture of Layer
The architecture layers used in IoT applications vary. The four-layer architecture of IoT is frequently used in conjunction with recommended security mechanisms:

Perception Layer
It is referred to as a sensor layer. It functions similarly to a person's eyes, ears, and nose. It is responsible for identifying objects and collecting data from them. Numerous types of sensors are attached to objects to collect data, including RFID, 2-D barcodes, and sensors. The sensors are selected based on the application requirements. These sensors can collect data on location, changes in the air, environment, motion, and vibration, among other things. They are, however, the primary target of attackers who wish to use them to substitute their own sensor for the original. As a result, the majority of threats are sensor-related (Burhan et al., 2018).

Network Layer
Network layer is referred to as the transmission layer. It serves as a link between the perception and application layers. It stores and transmits data collected from physical objects via sensors. The transmission medium can be wireless or wired. Additionally, it is responsible for connecting smart things, network devices, and networks. As a result, it is extremely vulnerable to attackers' attacks. It has significant security concerns regarding the integrity and authentication of data being transported over the network (Burhan et al., 2018).

Support Layer
The reason for adding a fourth layer is to ensure the security of the IoT architecture. In a three-layer architecture, data is transmitted directly to the network layer. Due to the fact that

information is sent directly to the network layer, the likelihood of encountering threats increases. A new layer is proposed to address flaws in the three-layer architecture. In a four-layer architecture, data is transmitted to a support layer from a perception layer. The support layer is responsible for two functions. It verifies that data is sent by genuine users and is protected from threats. There are numerous methods for verifying users and information. Authentication is the most frequently used method. It is carried out through the use of pre-shared secrets, keys, and passwords. The support layer's second responsibility is to communicate with the network layer. The medium used to transmit data from the support layer to the network layer can be either wireless or wired. This layer is susceptible to a variety of attacks, including denial of service attacks, malicious insider attacks, and unauthorized access (Burhan et al., 2018).

Application Layer

The application layer encompasses all applications that make use of or incorporate IoT technology. The Internet of Things has a variety of applications, including smart homes, smart cities, smart health, and animal tracking. It is accountable for providing services to applications. Services may vary depending on the information collected by sensors for each application. There are numerous issues at the application layer, with security being the primary concern. When IoT is used to create a smart home, it introduces a plethora of threats and vulnerabilities from both the inside and outside. To implement strong security in an IoT-based smart home, one of the primary challenges is that the devices used in smart homes, such as ZigBee, have limited computational power and storage (Burhan et al., 2018).

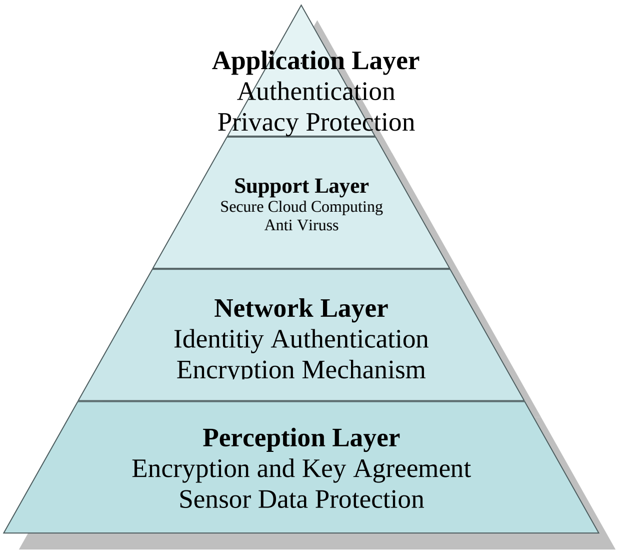

Figure 2: The Layer of Internet of Thing

Implementation of Internet of Thing in Warehousing

SCM encompasses a variety of functions, including procurement, production, inventory management, distribution, routing, location, and marketing (Mostafa & Eltawil, 2016). According to the literature, IoT has the potential to significantly improve the various functions of SCM. Figure 3 summarises several of the implementation's potential benefits. Warehouses play a critical role in meeting customer expectations in today's business world. Warehouses can hold thousands of products, which is why they should be utilised optimally to ensure accurate and timely performance across all functions in order to meet customer demands.

Applying IoT to warehousing has the potential to have a significant impact because it can be used to monitor multiple processes in real time and eliminate manual intervention. It can connect everything and thus enable the analysis of the massive amounts of data captured through these connections, transforming them into insights to aid in decision-making and overall performance improvement (Mostafa et al., 2019).

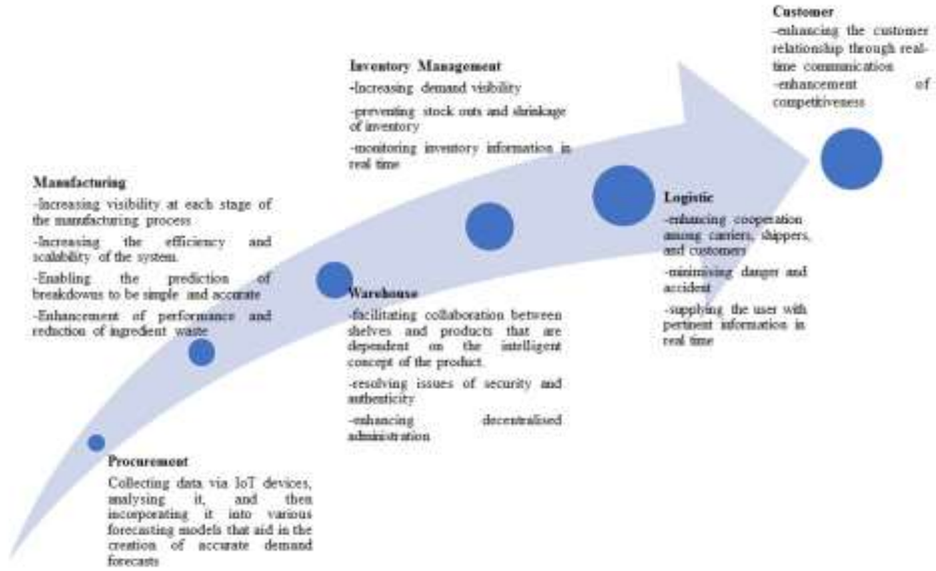

Figure 3: The advantages of the Internet of Things in supply chain management

Warehouses play a critical role in meeting customer expectations in today's business world. It is a critical source of competitiveness, as it determines who can deliver products more quickly and with greater cost efficiency and flexibility. In that regard, managers must have a thorough understanding of all aspects of warehousing and how they affect the entire supply chain (Richards, 2014). According to Trappey et al (2017), warehouse improvement can be quantified in terms of the accuracy and speed with which demands are met, the reduction of non-value-added functions, and effective management.

Another area of concern is data integration, which encompasses critical functions such as inventory status updates, order management, and product tracking. The purpose of this study is to propose a framework for implementing IoT in warehouse operations. Figure 4 illustrates the framework's flowchart. When products with attached tags pass through the gateway, the reader attached to the gate reads the data from the tags, preventing stock-outs by providing real-time visibility of inventory levels. When products are loaded onto the forklift, readers attached to the forklift read data about the product's type, location, and expiration date and communicate this information to the driver via an attached screen. Once the products are placed on the shelves, the driver receives confirmation via the screen.

Additionally, sensors can be used to monitor the Heating, Ventilation, and Air Conditioning (HVAC) system in order to optimise energy consumption and ensure the warehouse's safety and product quality. The same functions apply to order picking; when an order arrives, the driver proceeds to the location of the product displayed on the attached screen and confirms that it is indeed the correct order using the forklift's readers. When an order leaves the warehouse, the inventory level is automatically updated. This improves the efficiency, simplicity, and accuracy of order fulfilment, while also preventing counterfeiting. All of this data is transmitted via the internet to the WMS, which processes it and converts it to useful information and actions.

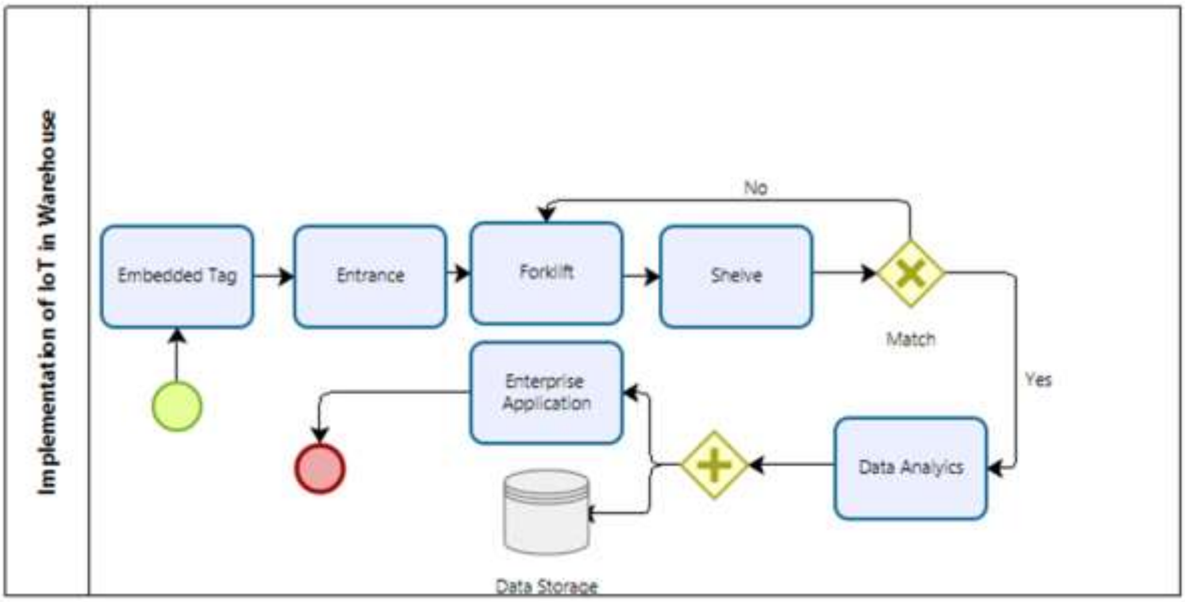

Figure 4: Internet of Thing Implementation in Warehouse

The proposed framework can be viewed as a guide for businesses looking to improve the performance of warehouses that have a significant impact on the supply chain's overall performance. This framework can help improve the order fulfilment process's performance by providing the location of any product when it is required, allowing employees to locate a given product more quickly. Additionally, it can enhance the storage process's performance because data about the product is captured upon arrival at the warehouse, reducing the time required to inspect the product.

This also improves order accuracy, as the sensor on the forklift verifies that the order is correct, thereby streamlining the pick-up process. Additionally, the proposed system improves inventory accuracy because it eliminates manual operation in favour of readers attached to the entrance and exit, significantly reducing the risk of errors, theft, and forgery. However, according to IoT reviews, businesses may encounter numerous challenges when implementing IoT; with a large number of connected devices and a large amount of data generated, the enterprise should prioritise privacy, security, and security, as the network is susceptible to hacking.

Conclusion and Future Research Recommendation

The Internet of Things is a critical component of the Industry 4.0 industrial revolution. IoT is regarded as one of the most promising technologies for controlling and improving supply chain performance; warehouses are a critical component of the supply chain, contributing to the success of industrial organisations, and thus new technologies are attracting considerable attention from various enterprises in order to boost performance, reputation, and thus gain more customers and profits. The purpose of this paper is to provide an overview of Industrial Technology 4.0 (IoT), as well as information sharing in the supply chain and previous research on IoT implementation in the supply chain.

The Internet of Things intelligently connects the physical warehouse world to the digital world. Today's Internet is pervasive, enabling the evolution, implementation, and spread of the Internet of Things (Yerpude & Singhal, 2020). The components of the IoT infrastructure are classified into four layers: perception, network, support, and application. Additionally, the potential consequences of IoT use on various supply chain functions have been discussed. Additionally, the framework for implementing IoT in warehousing operations is proposed, along with an explanation of how it will benefit the warehouse and improve overall performance. The economic and social consequences have been discussed. Additionally, it is discussed how the proposed framework can help improve warehouse performance, efficiency, prevent inventory shortages and counterfeiting, and expedite and simplify order delivery, thereby increasing profits.

Future research should apply this framework to the actual warehouse and compare the benefits expected from this proposal to the actual results; simulation models can be developed to demonstrate the benefits of this framework's application.

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