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A STUDY ON INTERNET OF THINGS IN FOOD SUPPLY CHAIN'S

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ABSTRACT

This essay analyses the Food Supply Chain's (FSC) use of the Internet of Things (IoT) and outlines the system's advantages and disadvantages. Following a review of the literature, six fundamental uses for this kind of network were identified, including those for transportation procurement, food production, resource/waste management, improving food safety, maintaining food quality, and FSC transparency. To accomplish these, clustering is used. According to cluster analysis, researchers should focus more on IoT applications for improving product quality and supply chain transparency, and take into account how IT-based systems can operate seamlessly at every stage of the supply chain.

Keywords: Internet of things, food supply chain, IoT-based supply chain processes, virtualization.

I. INTRODUCTION

Organizations have been forced to optimize their supply chains in order to survive in the market and increase their share of product sales in international markets. This has enabled them to quickly respond to customer needs in the shortest amount of time with products that are both affordable and of the highest quality. Therefore, it is essential to properly monitor, manage, and regulate every stage of the supply chain, from raw material suppliers to product delivery to customers. Supply Chain Management (SCM) is a process that includes the planning, implementation, and management of all activities linked to the manufacturing, distribution, and storage of goods for customers. In order to obtain a sustained competitive advantage, SCM concentrates on the integration of activities and flows of financial information and materials between levels of the chain. Many supply chains today are distributed across significant portions of the globe and are subject to very high global hazards.

Therefore, modern consumers desire many goods at various price points and with various levels of customization. Because product complexity is rising so quickly, technology is changing at a breakneck pace. At various times and locations, numerous economic, political, social, environmental, and ecological factors have an impact on consumer demand for various goods. Therefore, in order to be able to predict a wide range of consumer needs and wants in the shortest amount of time, businesses in such a complicated competitive market must have a high degree of flexibility and be very nimble. The entire supply chain, from the supplier level to the distributor level, must be flexible and move quickly enough to satisfy customer

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demands in order to maintain supply chain balance. Information technology, which supports each supply chain in the direction of agility and rapid adaptability, is one of the crucial aspects in SCM in difficult competitive conditions for the company.

Customers can now immediately address their demands thanks to information technology (IT), and businesses can now manage their supply chains more quickly to satisfy client demand. The Internet of Things (IoT) is one of the most significant and recent innovations in the field of IT. IoT in the supply chain can enhance human-to-human connection and object coordination while raising the bar for supply chain communication. By gathering and analysing data, this new technology may quickly improve supply chain agility and enable swift decisions at every stage of the chain, from a supplier to a distributor. IoT can perform the ability to collect, evaluate, and deliver suitable solutions in the lowest amount of time as gathering and analysing large data in the traditional supply chain is not a simple task. The existing literature on IoT and its use in the Food Supply Chain (FSC) is examined in this paper as part of a review research. Therefore, the IoT in the field of the FSC has been investigated and its impact on various food supply, production, and distribution organizations has been assessed by studying articles, books, and documents published from 2010 to 2021. Definitions of the FSC, IoT, and its use in various FSC components are described in the sections that follow. The next step is to analyse the data gathered from the literature review in order to illustrate where the IoT fits into the FSC and identify any remaining research gaps.

II. IoT APPLICATIONS IN THE SUPPLY NETWORK FOR FOODS LITERATURE REVIEW

There is a lot of demand on the Food Supply Chain (FSC) to increase profitability as well as sustainability and supply chain effectiveness overall [8]. Additionally, the FSC aims to keep expenses low, which is a challenging challenge if you need to invest in order to increase performance and sustainability. But the development of digitalization and related technology is assisting firms in handling this challenging task. Thanks to advancements and synergies between the relevant regions that have given rise to the IoT, FSCs in particular have seen a combination of information technology and operations. The MIT Auto-ID Lab first used the phrase "IoT" in 1999, specifically mentioning Kevin Ashton. The definition of the Internet of Things (IoT) given by the IoT-GSI is "global infrastructure for the information society that enables advanced services through the connection of physical and virtual objects based on existing and evolving information and communication technologies". According to Jagtap et al. [11], the Internet of Things (IoT) is a complex physical cyber system made up of several tools and methods for measuring, recognizing, communicating, networking, and informatics that are based on both people and things. It links interests so that anyone may more easily obtain information on any object and service through devices and media, wherever they are, at any time.

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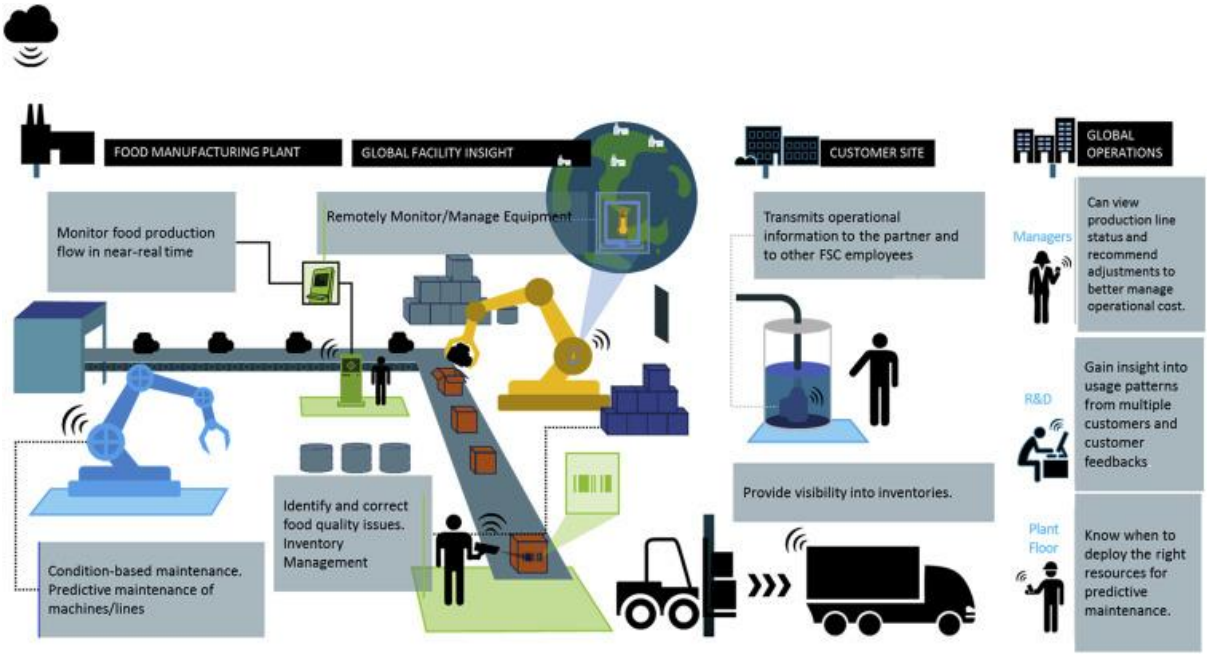

Fig. 1. Application of the IoT in the food supply chain

III. IoT ARCHITECTURE IN THE SUPPLY NETWORK FOR FOODS

The FSC's IoT is made to make it simple to link machines, pieces of equipment, and other objects through the network. Therefore, an IoT infrastructure is required to seamlessly collect data and transport it for additional analysis. Three network layers and three application layers make up the most fundamental IoT architecture, which is explained below:

Observation layer: A physical layer made up of sensors and actuators that measures and gathers information about physical parameters and identifies other intelligent objects nearby.

Network layer: In charge of data transmission and processing, as well as communication with other intelligent objects, network hardware, and servers.

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Application layer: This layer establishes a number of IoT applications (such as smart health, smart homes, and smart cities) and simultaneously offers services to customers for certain applications.

The ideal IoT design for FSCs, however, has four layers: measurement, network, service, and application. The IoT architecture in the FSC is depicted in Figure (2) .

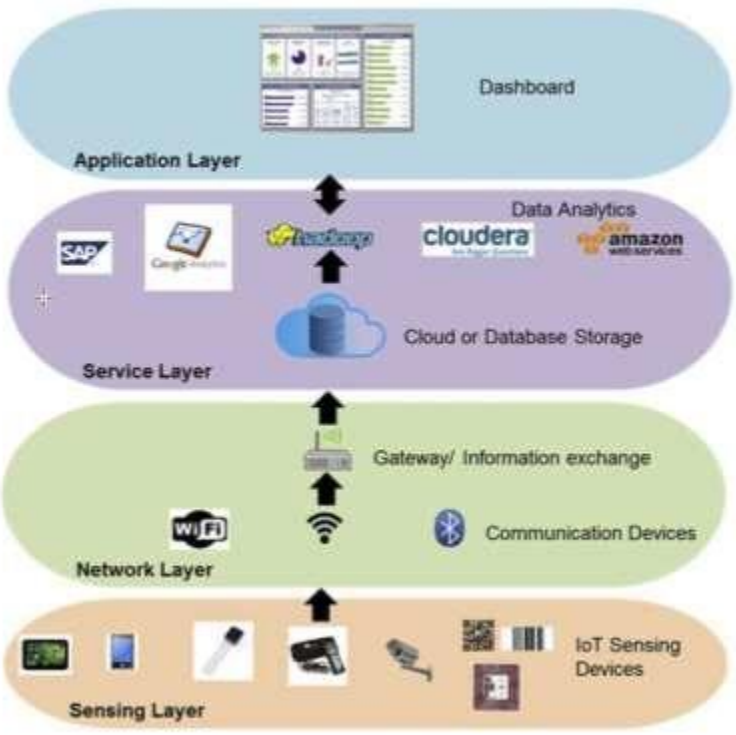

Fig. 2. IoT architecture in the food supply chain

The measurement layer comprises information about the machine, location, time, temperature, and so forth. Typically, sensors, Radio Frequency Identification (RFID), cameras, and other devices are used in the FSC to collect data. In this layer, all data collected from the origin of the raw material through the end of the product life is pre-processed.

The network layer uses a variety of network technologies, such as Wireless Sensor Networks (WSN), Bluetooth, and WiFi routers, to send the data gathered at the sensor layer to the service layer.The service layer consists of several different analytics engines and services where data is stored or evaluated.

The supply chain actors can examine the information in real time and use the various programs and modules (such as tracking, production efficiency, and food quality) on the application layer to take the necessary actions.

IV. APPLICATIONS OF THE IoT AND ITS USE IN THE FOOD SUPPLY CHAIN

Many IoT applications nowadays are dependent on the industry they are used in. Their availability, coverage, scalability, heterogeneity, repeatability, user involvement, and impact

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may all be categorized. Unique FSCs offer insights into food quality, operational effectiveness, and food safety and have broad geographic coverage, complicated operational processes, and numerous stakeholders along the chain. For everyone, access to wholesome food is more crucial than any advancement in the economy, society, or environment. By 2050, there will be nine billion people on the planet, which will drastically alter the planet and place a lot of strain on FSCs. But as IoT technology advances, hopeful answers may be on the horizon. Every aspect of the FSC, including farming, food production, processing, storage, distribution, and consumption, can benefit from the IoT. The tracking, visibility, transparency, and controllability problems can be solved through the IoT. Among the qualities needed in the FSC are stability, efficiency, transparency, and safety.

When it comes to temperature control, hygiene and pest control, traceability, product management (i.e., movement of goods, damage, rejection, and safety), preventive maintenance of the vehicle/container, and staff management (i.e., handling, personal hygiene, safety, policies, and training), the product that is being transported may encounter a variety of challenges. All activities involving food can be tracked with the help of the Internet of Things. One of the most efficient and affordable IoT methods for tracking food products is RFID technology. RFID tags can readily connect over a wireless network and store precise and significant information about the food products being sent. Alerts are instantly transmitted throughout the supply chain in the case of a food recall or food safety issue, and the contaminated product is quarantined right away.

The wireless remote system's low price makes it possible to set up a wireless network in food transport vehicles and keep an eye on food safety while it is being transported. For instance, FSC actors can control temperature and other conditions in real time, effectively manage the cold chain, ensure global compliance, and monitor and document compliance with the use of IoT technology linked into risk analysis methods, Hazard Analysis Critical Control Points (HACCP). Simple and sophisticated wireless systems are available for use in food transport vehicles, enabling constant connectivity and real-time information access.

Without requiring human interaction, procedures and processes can be utilized to optimize food production systems using data gathered from various plant units (such as equipment, personnel, vehicles, and materials). The control software is built to handle real-time data, algorithms, and actuators so that it can make the optimal choice and lessen the stimulation from any deviation from the plot. The current FSCs are lengthy and complicated, with rising safety hazards and on-going customer pressure to deliver high-quality and secure food products. All participants in FSCs contribute to the knowledge of food safety, which can result in unforeseen dangers from improper data exchange or delays. IoT development can spot any flaws and offer food safety warnings before manufacturing, in addition to effectively collecting, sharing, and giving you the chance to study data. results in the creation of a system that can foresee potential threats to food safety and alert users when standards for food safety and quality are being breached. Therefore, any FSC participant can contribute to reducing resource waste and deviation in quality, which will assist to avoid any accidents with food safety. The main factor in achieving sustainability in the FSC is maintaining and producing high-quality food while providing consumers with advance notice on food safety.

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Food safety is a topic that is receiving a lot of attention right now, and there has been a lot of work done to solve this issue. One of these is the pre-warning system, which can find actors and alert them to problems with food safety before they develop into serious crises. The HACCP-based tracking systems are used in conjunction with the alarm system. Since there are currently multiple actors involved in FSCs, it is challenging to track, monitor, and manage the food trade. Because most food safety accidents are the result of insufficient monitoring, it is obvious that a prior warning system is required to effectively and totally automate the food trade.

The quality and specifications of raw materials and finished products can be maintained with the use of various image processing technologies and sensors. Sensors can track the product's quality throughout time, allowing any deviation from the established criteria to be quickly identified and fixed. Product tracking, employee tracking, and real-time production analysis for efficiency are some other advantages of these sensors.

The improvement of FSC activities results from this. To fully understand how their food is created and processed, end users and buyers require transparency. Gaining the trust and loyalty of customers helps food producers expand their business. Full tracking and visibility throughout the supply chain. Despite the length and complexity of many current FSCs, IoT technology can make tracking simple for all FSC actors.

Additionally, transparency can be advantageous for food producers because it results in improved labour, stock, and cost management as well as shorter lead times. By solving supply chain inefficiencies, exceeding the bare minimal standards for food safety, and giving customers a complete picture, these advantages can be realized. Transparency in the FSC can be summed up as the information that each actor in a supply chain network has access to. A product's capacity to be traced from farm to fork, for instance, where the raw materials are prepared, how they are processed, and how they are given to customers, can be shown by the FSC. The FSC could benefit from more transparency thanks to block chain technology.

V. RESEARCH APPROACH

This section outlines the research methodology used to review the literature on IoT applications in the FSC. Consequently, a summary of descriptive statistics is given first. Then, items in various clusters are grouped and examined using cluster analysis. In other words, the primary goal of this paper is to offer a roadmap for assessing the current status and the usage of the IoT in the FSC, as well as to recommend potential areas for future research. In order to do this, first examine all articles on the use of IoT in the FSC that have been published, including those from Elsevier (www.sciencedirect.com), Springer (www.springerlink.com), Taylor and Francis (www.tandf.co.uk), Emerald (www.emeraldinsight), and papers of various sizes presented at international conferences between 2014 and June 2021. 93 articles that directly relate to the food safety chain and the use of the IoT have been extensively examined and evaluated in relation to this topic. The clustering method and six categories—transportation procurement, food production, resource/waste management, food safety enhancement, food quality maintenance, and

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transparency in the FSC—are utilized to categorize the papers for this evaluation. Investigated is how each IoT application affects each cluster.

VI. RESEARCH CONCLUSIONS

This section discusses the present state of documents and articles that have been published in the area of IoT applications in the food safety chain as well as how they have been divided into several areas. Descriptive data will now be supplied, such as the quantity of papers published in various years and journals. Then, the K-means clustering approach is used to examine the descriptive statistics for each of the clusters.

Table 1. Application of the IoT in food transportation procurement in the food supply chain

Process	Role Of The IoT	Impact
Food Transportation Logistics	Capacity sensing	The present study focuses on the development of systems capable of detecting and effectively communicating the presence of vacant spaces inside various environments such as warehouses, ports, and parking lots.
	Planning and reporting	The ability to identify and evaluate events, such as traffic jams, within a delivery network would greatly improve the timeliness of deliveries.
	Route optimization	Tools (such as delivery vans) that can find the shortest or most fuel-efficient route
	Energy management	Monitoring and decision-making tools for fuel, lighting, and heating/cooling usage in vehicle fleets and buildings
	Fault detection and resolution	systems that may keep track of a fleet's malfunctions and maintenance requirements, increasing the fleet's uptime

VII. CONCLUDING AND FUTURE SUGGESTIONS

The FSC can employ dynamic permutation in its operations management procedures thanks to internet technology. This assistance helps food businesses deal better with perishable goods, erratic fluctuations in supply and food safety, and the need for sustainability. Supply chain agents can now remotely plan and improve business operations using virtual objects over the internet rather than at a controlled location. FSCs can develop into a self-adapting system on the IoT where smart objects can be installed, make choices, and pick up knowledge on their own. This article examines many papers from several sources and discusses the usage of the IoT in the FSC. The FSC's current IoT applications are shown, and the benefits and drawbacks of the IoT are discussed. It is advised that the majority of supply chain actors embrace IoT technologies because studies demonstrate that there are more benefits than drawbacks. A examination of the literature revealed that a lack of knowledge of or access to reliable real-time data causes various issues for supply chain activities. To

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achieve efficiency and transparency, it is crucial to track and examine each actor's activities. For the many FSC activities to alter, reliable information must be available. Real-time data collection and analysis allow for the simultaneous decision-making of economic and environmental challenges, improving the FSC. The cluster analysis of the journal data reveals that researchers should focus more on IoT consumers in terms of product quality and supply chain transparency, and seamlessly integrate IT-based solutions at every stage of the supply chain.

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