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APPLICATIONS OF INTERNET OF THINGS IN FOOD AND BEVERAGE INDUSTRIES

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Abstract

The food industry is no exception to the widespread benefits provided by information and communication technologies. On the other side, we live in a society where people are always struggling to put food on the table. More advanced technology may boost productivity, quality, and profitability. In many countries, IoT devices and apps are used by the food industry to ensure that food is safe to eat, transport, package, monitor temperature, analyse nutrition, and detect spoiled items in real time. The primary concerns of this research were related to the Internet of Things (IoT) in food technology, namely food production, security concerns, and potential remedies. This was achieved by a qualitatively performed comprehensive literature review. The results showed that Internet of Things (IoT) and associated technologies positively offer their full support to raise both the demand for and the quality of food production. In the meanwhile, the most pressing technological challenges facing the security of IoT devices and applications are related to concerns about personal data privacy. It discusses the benefits and drawbacks of using IoT solutions in FSCs, as well as emerging technologies like Industry 4.0, blockchain, intelligent packaging, and artificial intelligence.

Keywords: Food Industries, Safety, Transportation, Sensor, Industry 4.0 and Smart phones.

1. Introduction

There is a lot of demand on FSCs to boost their profits, but also their sustainability and supply chain efficiency. However, companies are also trying to keep costs down, which may be challenging if expenditures are required to boost sustainability performance and efficiency. The introduction of digitalization and associated technology, however, is allowing firms to accomplish

this arduous job. In particular, the IoT has led to the convergence of information and operational technology in FSCs as a consequence of innovations and synergies across relevant fields [1]. The Internet of Things (IoT) is a word that was first used in 1999 by the MIT Auto-ID Lab, with credit going to Kevin Ashton. IoT is "a worldwide infrastructure for the information society, allowing improved services by linking (physical and virtual) objects based on current and emerging interoperable information and communication technologies," as described by the IoT Global Standards Initiative (IoT-GSI). According to Lee, the Internet of Things is a sophisticated cyber-physical system that flawlessly links people and things on the basis of shared interests, allowing for convenient, anytime, everywhere access to data about any item or service through electronic means. Identification, sensing, computing, and intelligence are only some of the aspects of the Internet of Things [2]. The Internet of Things (IoT) may therefore be seen as a solution that helps collect and organise the massive volumes of data created by supply chains. Internet of Things (IoT) platforms support applications that gather, analyse, and make data-driven decisions more quickly and accurately, which in turn improves operational efficiency. The Internet of Things (IoT) is a relatively new technological development that has the potential to progress the ICT industry in significant ways in the near and far future. Using sensors, actuators, and digital devices, IoT brings networking and online technology into the real world to improve automated services. Everything from transportation to healthcare to agriculture to retail to tourism to food production to education and engineering all makes use of IoT-enabled devices. All of this could happen automatically as the number of things with wireless connections grows, and the data provided by those things could improve the quality and reliability of the results obtained from the collected data. The information gathered by the networked devices is uploaded to a remote server [3]. Donkey years' worth of storage space on demand, provided by cloud computing (CC). Together, IoT and CC pave the way for seamless, hands-free integration of ICT across all industries. This conceptual IoT diagram is shown in Figure 1.

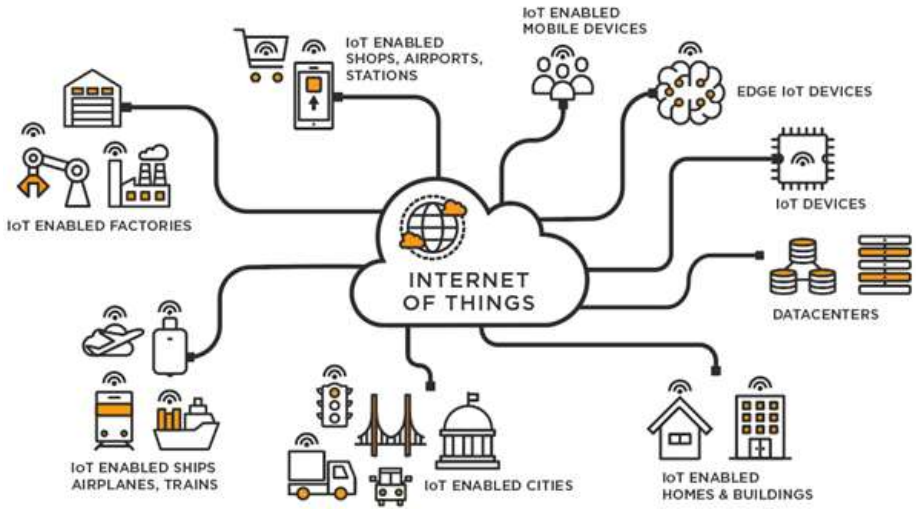

Figure 1: Theoretical diagram of IoT

Internet of Things is abbreviated as IoT. IoT, or the Internet of Things, is the process of adding AI to real-world gadgets like computers and mobile phones. Without a shadow of a doubt, IoT is the ultimate winner [4]. The Internet of Things (IoT) has shown its worth in every industry, from transportation and aviation to manufacturing and healthcare to mining and even military in recent decades. The importance of the Internet of Things (IoT) in the food and drink sector is almost unparalleled. The Internet of Things has brought new and innovative tools to the food industry [5]. Both the by-products and the final goods are of higher quality, and the overall cost of producing food items has decreased because to technological advancements.

Modern food and drink producers use IoT-based solutions to keep tabs on product quality. Food and beverage firms may improve the quality of their goods for customers, as well as their operational efficiency and compliance with government standards, with the aid of IoT. Proper precautions must be taken to ensure that all foods and drinks sold to the public are free of harmful contaminants. Transport and storage security may be monitored via sensors. Staff are prompted to conduct and double-check inspections thanks to automated warnings [6]. Just-in-time logistics relies on IoT-powered inventory management systems to keep supplies at the right levels at all times. By eliminating both shortages and surpluses, these methods reduce stress on consumers and the risk of perishable food going bad. The use of sensors and analytic software has resulted in reliable documentation of the food supply chain. In order to create a more cost-effective food and drink distribution chain, this data is crucial at all stages of the product life cycle [7]. The food and beverage industry's green movement focuses on ensuring sustainable practices. IoT-enabled food management systems support these initiatives by: **Providing insight into the supply chain** to improve raw material and packaged goods tracking. **Reducing waste** through ongoing food and beverage quality and supply monitoring. **Increasing energy efficiency** by environmental monitoring and adjustments and distribution practice improvement

2. Food Industries

In this context, "food sector" refers to the collection of businesses that deal with food in some way, either as suppliers or as final processors. Every step in the chain from farm to fork, from processing to packaging, from preparation to storing, is part of the food industry. Standard food production facilities provide two sorts of goods: by-products and final goods [8]. A wheat flour business, for instance, would not exist without the agricultural sector, since wheat is the primary raw material for the final product. During this procedure, wheat bran is created as a by-product. However, they both carry some monetary worth.

Food industries are classified into following types:

Primary food industry: Primary food industry involves in converting agriculture produce into consumable items. It involves the cleaning, washing and processing of food items.

Secondary food industry: Secondary industry converts the consumable food items into proper edible food items.

Tertiary food industry: Tertiary food industry is also known as frozen food industry. It consists of preserved food items. For example, packed snacks and frozen food items. Let us consider all types of food industries by taking a common example :

Kashmir's principal industries harvest apples from the region's many orchards. There, they get various levels of cleaning, washing, and packaging [9]. The secondary industry then collects the finished product from the main industry, in this case apples, and turns them into pickles and other food products.

In addition to acquiring primary industry's output, tertiary industries process it into long-lasting products like chips and juices. As such, the food business may be broken down into three distinct categories.

3. Applications of IoT in the Food Industry

IoT has a huge impact in the food industry. Following are the applications of the IoT in the food sector.

Management of the industry equipments: Useful Internet of Things devices may prevent a major breakdown of kitchen appliances. This would reduce the need for frequent maintenance, which would save both time and money [10]. The IoT's built-in signalling and reform capabilities will alert the device's owner if it's ready to fail. Considering the negative effects that a bottleneck in the service delivery chain may have on a company's market standing and customer happiness, this is an important aspect of IoT's involvement in the hotel industry. When it happens, there is usually a corresponding drop or shift in earnings.

Smart Refrigerators: Because so much food is kept in refrigerators, it is crucial that they remain in good working order, and here is where IoT comes in. The temperature rises thanks to IoT. There's a wide range of storage temperatures needed for food [11]. It's important that the flavour and aroma of perishable goods be preserved and don't fade with time, so the fridge is put to good use. When it comes to food, the Internet of Things not only makes it more palatable, but it also helps keep its nutrients intact. It is possible to store ice cream, fresh fruits, meat, and other foods at the same temperature, or to utilise separate refrigerators and freezers for each kind of food.

Reduce the energy consumption: The Internet of Things speeds up processes while simultaneously cutting down on energy consumption. When the oven's food is removed, the sensors turn the oven off automatically. Primarily, this is done to keep tabs on costs and keep the owner informed.

Stock management: The kitchen's stock can be monitored more efficiently thanks to the internet of things. The app is downloaded onto smartphones and tablets and is used in restaurants and other food service establishments to keep track of their kitchen inventory [12]. It could send alerts to connected devices in the food service industry or restaurant whenever stock levels or replenishment needs changed.

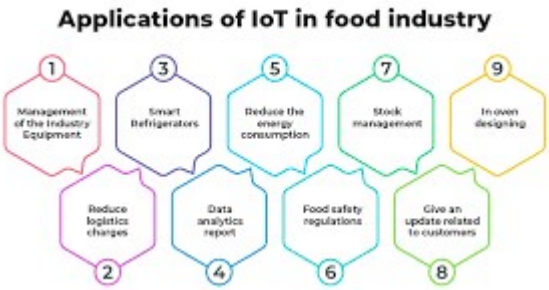

Figure.2. Applications of IoT in Food Industy

In oven designing: The Internet of things controls the temperature of the oven. IoT in the oven prevents the overcooking and damage of food in the oven. The sensors are fitted in the oven which notify the person in charge about the condition of preparatory food in the oven ad it's temperature condition, is it optimum or not. If the response is zero, then the oven will switch off automatically.

Reduce logistics charges: IoT technologies and instruments reduce the transportation and logistics costs. The technologies provide the owner insights related to the real time supply chain.

Data analytics report: The Internet of things tracks the data and records of the restaurant. This gives priority to the person in charge about the information and feedback. This in turn, tells industries how they should improve.

Food safety regulations: IoT enabled sensors and the recorders help in ensuring the premium quality of the food. Thus, helps in achieving quality regulations set up by different organizations and institutes.

Give an update related to customers: IoT technologies update the users regarding the customers behavior and demands.

Limitations of the IoT in the food industry

Though, the internet of things has many advantages in different sectors. Still following are the limitations of the IoT in the food industry:

Security: Internet of things systems are interrelated and communicate with the network. It gives control despite any type of security messages and it leads to various types of security attacks.

Privacy : The participation of users is very less, but the internet of things provides the personal data of users in maximum detail. So it provides less privacy to the users.

Complexity: The IoT system is very complicated. Its designing, developing and maintaining is very complex. It needs a well knowledgeable person to handle such a complex system.

4. Food Technology

While the world as a whole moves inexorably toward hunger and poverty, the FT principles that form the backbone of the food production process (FPP)—including production, preservation, quality control, and R&D—are actively working to slow this trend. Best manufacturing practises in the food sectors include nutritional analysis, quality control, and regular maintenance [13]. The success or failure of a country's economy depends on the success of its food production industry. As a result, food quality is crucial to the success of these businesses. However, improving worker output is essential to achieving a profit. As we've established, those four criteria are essential to

achieving high-quality results while preparing meals. People are increasingly prioritising eating meals that are good for them above consuming items that just taste good. Human intervention and certain forms of digitalized technology are driving the evolution of these quality determinants. Manual food development processes mean that food production might be negatively impacted [14]. As a result, the food industry is looking to automated technology to do more with less, speed up the process, and allow for more variety in output without compromising quality for the sake of a larger consumer base. The use of ICT-enabled traceability systems may improve food safety. When it comes to the FPP, the role that ICT plays in user friendliness, ease of access, cost-effectiveness, and security is crucial. The Internet of Things (IoT), cloud computing (CC), drones (drones), and artificial intelligence (AI) are only a few of the technologies introduced by the development of ICT applications with the (AI). Nutrition analysis, quality control, packaging, supply chain management, and food safety are just few of the areas that these technologies improve throughout the FPP. Food distribution systems enabled by the Internet of Things may aid in automating the food supply chain. Meanwhile, a mobile-based IoT application can keep tabs on the freshness and quality of food in real time. And there's an Internet of Things app that utilises sensors to determine how nutritious a certain item is. As with AI-based packaging, sensor technologies are used [15]. Computerized systems used in the food industry to monitor product weight and detect any product leaks. However, advancements in food safety and supply chain management are needed across all food industry technology. Additionally, the bulk of the studies done so far on the Internet of Things and food science have not provided the necessary development stages for food technology. In addition, the agricultural sector is a prime candidate for Internet of Things implementation. With the further use of IoT methods in agriculture, precision agriculture, which is recognised as one sustainable, ecological, and profitable strategy to advance agricultural yields and quality, will finally come true. As an added bonus, the quality and longevity of smart agriculture may be ensured by combining cloud computing with IoT. Numerous studies and experiments were undertaken, and researchers are currently tallying the total. This research builds on previous efforts to identify the most effective method for enhancing FT using IoT. This research examined a wide range of promising new agricultural and food technologies that are ushering in a "smart" agricultural and food business, with a focus on IoT. The problems of cyber security and privacy in the IoT have also been explored. For this reason, we gathered all the information we needed by doing a comprehensive literature search. Different indexing databases were scoured for recently published articles on food technology and agriculture from a variety of angles, including the technologies employed, the IoT applications created, and security issues.

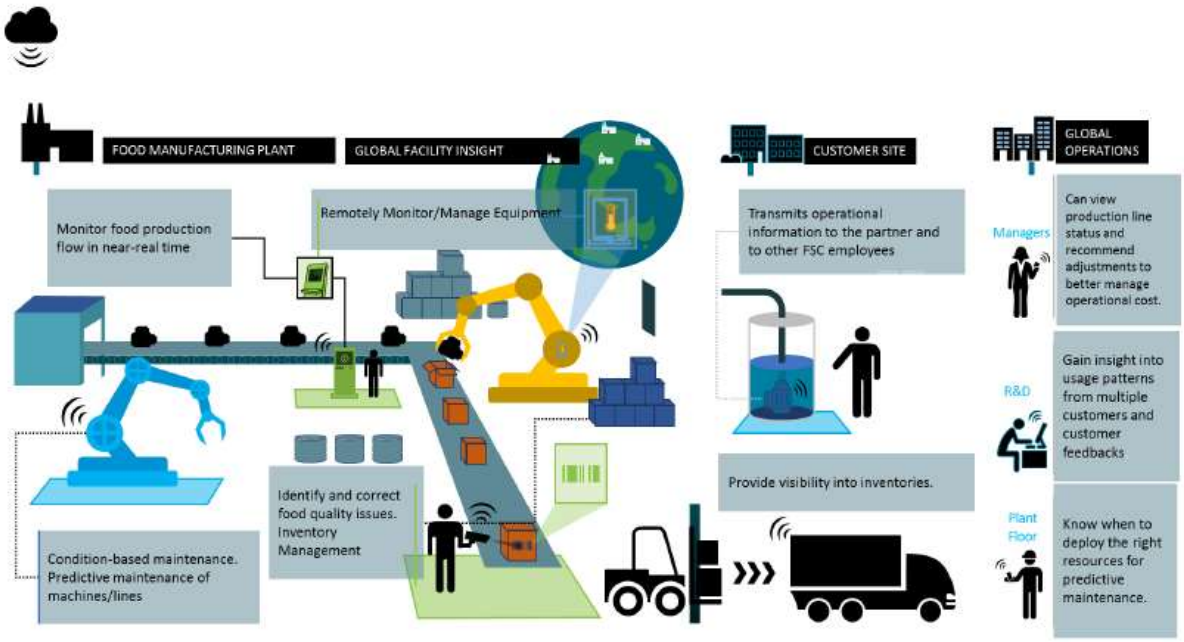

Figure.3. Applications of IoT in food manufacturing

The Internet of Things (IoT)-enabled food processing facility is shown in Figure 3. This diagram demonstrates how the Internet of Things may benefit stakeholders and factory management by enabling them to keep tabs on the status of the food production flow in real time and to keep track of the linked devices. Moreover, it provides greater visibility and transparency in inventory management and the potential for predictive maintenance so that quality concerns may be identified and resolved quickly. Figure.3 shows how managers, R&D specialists, and production line workers may all benefit from using IoT. The Internet of Things may be put to greater use if these challenges could be overcome. The manufacturing sector is a common user of IIoT because of the technology's emphasis on industrial applications. It symbolises the IoT's industrial subset, which is already bringing about a fourth industrial revolution dubbed "Industry 4.0" in the manufacturing sector. The goal of Industry 4.0 is to create smart factories that use the Internet of Things (IoT), cyber-physical systems (CPSs), and cloud computing to enhance and change industrial technology. Using the Internet of Things (IoT) and other cutting-edge manufacturing methods, Industry 4.0 creates linked, intelligent production systems. According to Accenture's technology vision for 2014, "every company is a digital business," and the merger of the digital and physical is transforming traditionally manufacturing firms into service providers. These companies understand the importance of IIoT and how it can help their company expand by incorporating digital services and product innovations. It is projected that by 2030, companies would have invested $500 billion, up from the $20 billion they spent in 2012. Implementing automation and agile production strategies like predictive maintenance to reduce downtime and plant and facility shutdowns is one way that IIoT improves operational efficiency. A growing number of businesses are opening their eyes to the immense potential of the Industrial Internet of Things (IIoT) — the global network of intelligent industrial products, processes, and services that communicate with one another and with humans everywhere, opening up new avenues for

expansion through the incorporation of digital services and technological advancement. Numerous FSC operations, including food tracking, warehouse management, transportation, and logistics, have already incorporated IoT. It was predicted by Dunbrack that 33% of all market leaders will be overthrown by companies with digital capabilities. In addition, they claimed that 24% of businesses saw IoT as a game-changer, and that the youthful population will speed up IoT adoption. Therefore, it is safe to anticipate that IoT, which will drive and alter most FSCs, will be a vital enabler to boost productivity and development in the near future.

5. Architecture of IoT in the food supply chain

The Internet of Things (IoT) is tailored to make it simple to establish network connections amongst various items used in FSCs. That's why having an IoT architecture in place is crucial for a smooth data collection process and a safe data transfer for further analysis. The three levels of the simplest IoT architecture are as follows: perception; network; and application.

- Perception layer – is a physical layer consisting of sensors and actuators for sensing and collecting data on physical parameters as well as identifying other smart objects from its surroundings.
- Network layer – is responsible for communicating with other smart objects, networking devices, and servers and also transfers and processes the sensor data.
- Application layer – This layer delivers specific application services to the users and, at The same time, defines several applications in which IoT can be installed such as smart health, smart home and smart city.

However, for FSCs, the most suitable IoT architecture consists of four layers: the sensing layer, the network layer, the service layer and the application layer (see Figure.4.), as described below:

The sensing layer – The data such as time, temperature, location, machine, etc. in the whole FSC are collected using sensors, RFID, camera etc. All of the collected data, i.e. from the point of raw material sourcing until the end of life, is then pre-processed in this layer.

The network layer – This layer transports the data collected in the sensing layer to the service layer via various networking technologies such as Wireless Sensor Network (WSN), Bluetooth, WiFi router, etc.

The Service layer – This layer consists of a wide range of analytic engines and services where data can be analyzed or stored.

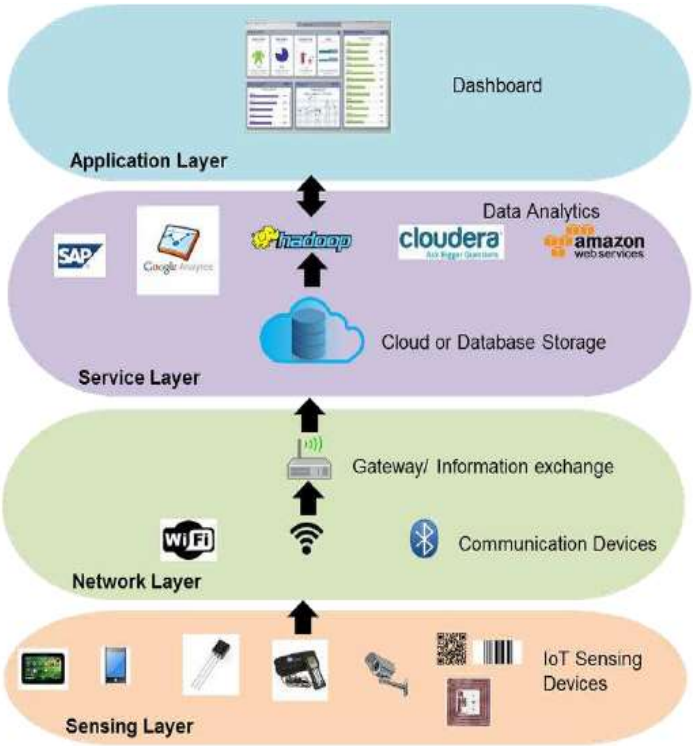

Figure.4. IoT architecture for FSC

6. IoT application in food production

Without the need for human intervention, the data acquired from factory floors (machines, employees, vehicle, materials, etc.) may be utilised to automate work procedures and processes to enhance food production systems. The custom control software may make autonomous judgments and trigger actuators with the help of real-time data, algorithms, and hardware, therefore reducing the likelihood of unintended consequences. By allowing people to monitor and adjust their own food production, it promotes optimum decision-making and gives them more freedom. Embedding sensors at numerous energy hotspots also allows the IoT to continually monitor and compare energy use and FSC actions in realtime. With the use of IoT, FSC actors may become energy-aware and optimise energy use across several domains (e.g., machines, people, materials, vehicles, etc.) to boost FSC's overall energy efficiency. Some companies in the food industry have realised the value of predictive/proactive maintenance, which allows for prompt diagnosis and repairs depending on the condition and performance of the machinery to lessen the effect of unscheduled downtime and undesirable failures. Data about machine performance may be gathered and analysed with the use of low-cost, wirelessly connected sensors, all driven by big data technologies. Modeling, comparing, analysing, and displaying machine-collected data in real time and over time may help in predicting machine deterioration. By connecting to the Internet of Things, FSCs may share real-time data about production, logistics, maintenance, resources, inventory, sales, and more with all the relevant parties. Because of the visibility into dependencies, material flow, and problem detection that

results from this operation, lean implementation is strengthened. By allowing all parties to access the same data in real time, we can solve the problem of a lagging data stream.

Therefore, sensors and networked devices may be linked in food production to gather data such as temperature, quality, machine maintenance, sales, orders, and information on transportation, storage, and environment round-the-clock during the product's whole lifespan. All of the consumers or stakeholders in question may benefit from the processed information derived from the massive data set.

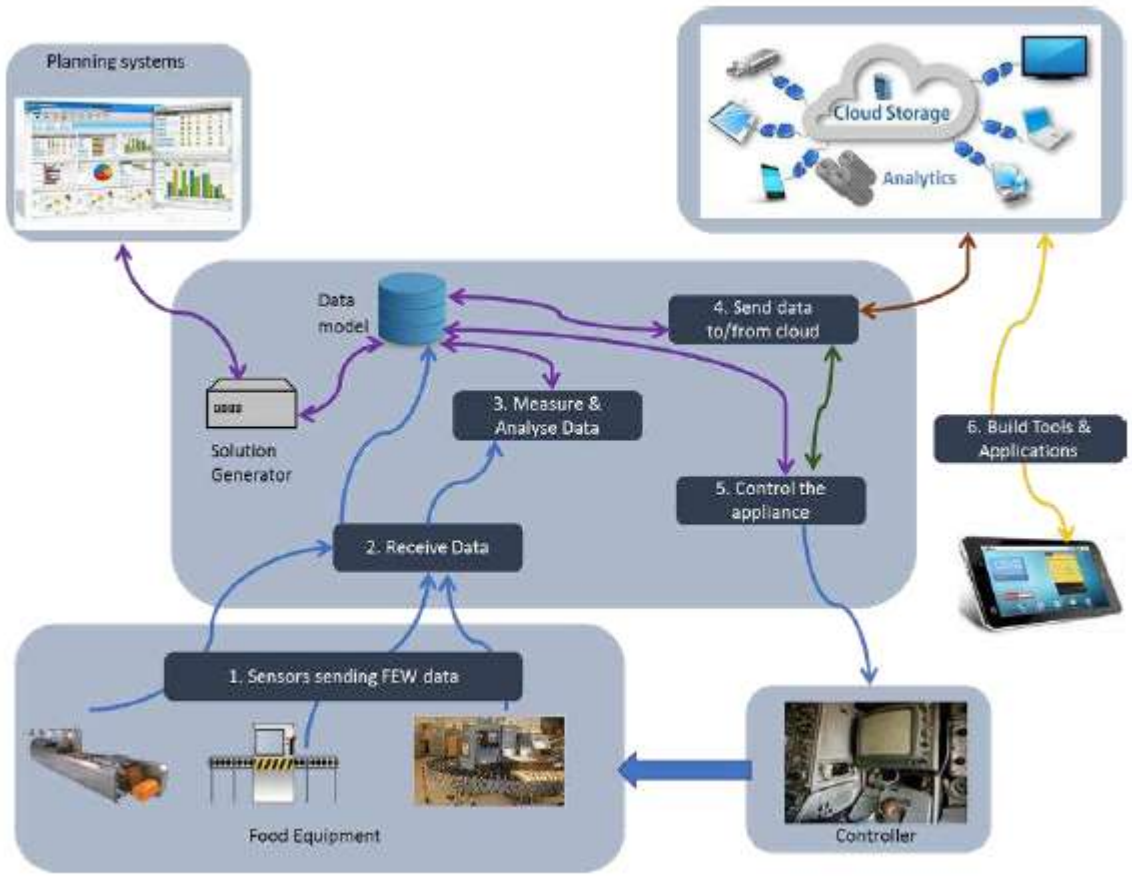

Figure.5. Resource efficiency monitoring in a food factory

To implement a resource-efficient production system and to make efficiency a priority in production management, it is necessary to have in-depth knowledge of how people typically use resources. Therefore, in order to accomplish these goals, customers want more up-to-date information on the costs of producing and using resources. emphasised that ICT enable resource-efficient production by merging real-time information from the shop floor to planning systems by concentrating on idle hours on the shop floor, which can be scheduled as per the order requirement. As demonstrated in Figure 5, IoT can efficiently handle this scenario by enabling the optimization of product manufacture via the use of fewer resources. Accordingly, having access to accurate, useful, and real-time data is crucial for minimising resource usage and waste. Consequently, in

this drive to enhance FSCs' resource efficiency, IoT-based apps that can tackle the aforementioned problems are essential.

7. Future trends

The Internet of Things has enormous potential for adoption and integration throughout FSCs' many mundane processes. Because of the exponential rate at which the IoT is developing, however, its ultimate impact is difficult to foresee. People are being offered or promised a wide variety of future possibilities and opportunities based on IoT technology. Industry 4.0, blockchain technology, and smart packaging are just a few areas where it might be useful. The idea behind Industry 4.0 is to digitally transform manufacturing by integrating product, processes, and people inside a factory setting to improve factory-wide transparency and the ability to make autonomous choices. It encourages the development of "smart factories," in which advanced technologies allow for better inter-machine communication and the analysis of sensor data on the machine level, allowing for greater adaptability to changing production requirements. Improving operational efficiency also necessitates the integration of information technology and the dissemination of critical data across the whole supply chain. As low-cost sensors and data storage become more widely available, FSC actors now have a greater potential to place their faith in IoT-powered apps. Actors who have access to the internet are more efficient, creative, quick, and intelligent than their peers who do not. Having fewer product recalls, more efficiency, and the ability to meet a wider range of consumer needs are all positive outcomes for the food and beverage industry's supply chains. Because of the time, money, and crucial resources it saves, the overall sustainability of FSC will increase as supply chain participants become more proactive as a result of Industry 4.0. Another benefit of Industry 4.0 is its predictive maintenance function, which uses data collected from sensors put on machinery and vehicles to foresee when those machines or cars will need repairs. Predictive maintenance's ability to reduce waste and unexpected downtime would greatly benefit FSC actors and their supply chain operations. The advent of the Industry 4.0 paradigm has made this feasible, and it will provide a significant competitive edge for supply chain participants in the current era of intense rivalry.

Robotics, simulation, system integration, Internet of Things, cybersecurity, cloud computing, additive printing, augmented reality, and big data are only some of the nine components of Industry 4.0 shown in Figure.6. Significant possibilities and novel services or products might emerge when all of these elements come together.

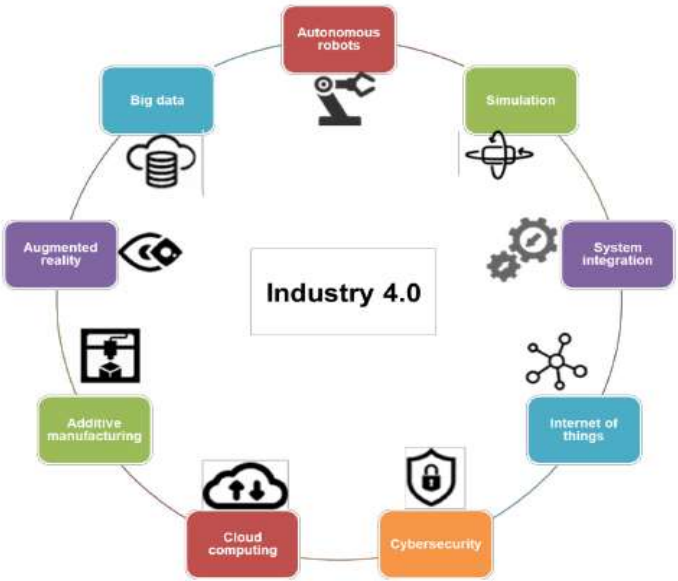

Figure.6. Nine components of Industry 4.0

8. Conclusion

The Internet of Things (IoT) is a mature technology that has been around for a while. We conclude that the advantages of introducing the IoT in the FSC much exceed the drawbacks. As IoT technologies have advanced, the prices associated with digitising supply chains have decreased, making them more accessible to the food industry. Being first to implement this technology will allow you to enjoy the advantages for the long run and capture a large portion of the market. Incorporating Internet of Things (IoT) technology into all facets of FSCs would improve the whole supply chain's efficiency and longevity. IoT has the potential to improve production, detect and avert developing difficulties, and automate a variety of processes inside FSCs thanks to its benefits, such as greater transparency, monitoring, and control over numerous food operational activities. More participants in the supply chain are encouraged to use IoT technologies due to the technology's many advantages.

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